

A Comparative Study on Renewable Energy Sources

Shipra Gupta¹,

¹School of Management,
Graphic Era Hill University,
Dehradun, Uttarakhand, India.

Sweta Bagdwal²

²School of Management,
Graphic Era Hill University,
Dehradun, Uttarakhand, India.

Veni. J³

³AP, J.J. College of Engineering and Technology,
Tiruchirappalli, Tamilnadu, India.

ABSTRACT

The green energy sources especially solar, wind, biomass and geothermal has become predominant systems which push the whole world towards more technology added to its installing phase every day. Since the time their recognition as an indispensable part in global sustainable steps that is moving toward new era of modernized usages. As the world struggles to balance energy security and climate change, greener generation solutions have become a financially friendly way of reducing greenhouse gas emissions, while also decreasing dependence on fossil fuels. This manuscript sought at the technological advancement and economic benefits, policy initiative that is driving faster growth of renewable based power supply globally. This will be followed by the challenge of how to integrate these energy sources in existing electricity grid systems, job creation potential and use for achieving national commitments on sustainable development goals. The larger demand for renewable energy solutions is becoming globally and there comes a need to know the positive and negative sides of the source. Solar and onshore wind boasts have the greatest potential because of their scalability and ever-cheaper costs. But it is hampered by intermittency barriers. Geothermal is another type of base load power that reliability provides constant energy but only available in certain geographical location. While hydro leaves great scar on ecological system. Bioenergy, if produced sustainably causing minimal emissions and without competing for land use. The research is meant to analyse and illustrate that while none of the single renewable energy resources could satisfy dedicated segment in terms of energy demand. A sophisticated set up for these can be developed which together with technological advancements and strong policies may substantially contribute towards achieving stable as well as safe future vision on the use of sustainable energies.

Keywords- Sustainable, Renewable Energy, Economic Benefit, Geothermal, Solar.

I. INTRODUCTION

With a smart world on the horizon, all are more and more in need of saving energy. Today the whole globe should be walking down to save the environment. The one movement is getting smarter then sustainability needs another look. Now the humans have realized that the comfort zone must be made. This is done where the need arise. A global blueprint should be developed for sustainability and renewable resources. Energy source is categorised into two forms in the world, renewable energy and non- renewable energy. They vary based on accessibility, ecological footprint and resources. Renewable energy refers to a source of power that comes from and availability nature- which is replaced by natural processes. At least it is sustainable over time whereas non-renewables come out finite stock within nature sanctuary, and then someday will run-out there [1]. The world is going towards sustainability so its main aim here is using a renewable energy. The unicorn of the energy sector renewable sustainable or eco-friendly, these represent the solution for many demanding consumers globally. As all are aware by now, the acceleration to cleaner electricity for many reasons such as climate change and pollution of environment or depletion of own resources due fossil power plants that only use coal, gas or atomic relies on renewable. Renewable energy includes options like solar, wind, hydropower, biomass and geothermal as well as oceanic power that are clean, guarantee reliable source of sustainable production. While each of these poses its own particular benefits, such as low greenhouse gas emissions and increased energy independence. They all share challenges ranging from high initial expenses to environmental detriment. Every renewable energy has its strengths, limitations and best use cases it is only by understanding these that the potential of each can be realised to contribute towards a more sustainable future. This manuscript addresses the benefits, barriers and impacts of several renewable energy technologies to meet global energy demands with respect also for climate protection [2].

II. LITERATURE REVIEW

In this study the author is introducing the various advantages of the renewable source of energy. According to the author the greener energy is a clean energy and sustainable source to be used for sustainable development [3].

This study focuses on the advantages and the disadvantages of the renewable energy source. In this study the author is focusing on the benefit of the renewable source of energy, and providing us the insights, the renewable source of energy is a clean and sustainable source of energy [4].

In this study the author has highlighted the growing need of renewable energy, particularly solar and wind, in addressing carbon emissions and mitigating global warming. While these sources offer pollution-free electricity, their variable nature introduces system challenges, especially at higher grid penetrations. Research indicates that managing these challenges, such as grid stability and integration costs, is possible but requires significant investment. Studies also explore the financial implications of high renewable penetration on energy poverty, emphasizing the need for equitable energy access. Overall, the transition to renewable requires careful planning and technological advancements to balance costs and benefits [5].

The research demonstrates how renewable-energy micro grids can provide economic and environmental benefits over fossil-fuel systems. The study also concluded that integrating renewable energy into micro grids leads to a substantial decrease of Net Present Cost (NPC) in the range from 7% up to 44%, as well saving CO₂ emissions. Simulation results at different places of interest reflect that renewable micro grids are economically feasible, but those works concentrate on sizing. In the end shore, renewable micro grids are identified as a better solution to improve power reliability and sustainability [6].

This paper concentrates renewable energy. RE forecasting illustrates a difficulty of such problems: the sample size is particularly small and those kind of big data methods are inappropriate. The application of grey prediction models GM, NGBM and the Grey Verhulst model for such scenarios has been highlighted by several studies. Although, GM model is known to the general field; however, it has to be adjusted properly in new fields such as renewables for improved result. Empirical results indicate that the NGBM and grey Verhulst models are better than GM in both point forecast accuracy and interval estimation for small samples. The uses of those models are getting closer to the global futures including beyond China energy demand projections [7].

The paper here is about the essential significance of renewable energy for fueling worldwide increase in power use and production, while lessening or decreasing carbon pollution from current forms of conventional fuels. Renewable energy is regarded as a safe alternative because it has little effect on ecosystems and can work in different weather conditions. Research points to the positive impact of solar on economic growth, job creation and energy security. Challenges remain however in terms of issues relating to storage as well public resistance towards installations. Research is also proving that public awareness and government strategies play a key role in driving renewable energy diffusion. Substantial growth in renewable energy usage is likely owing to consistent innovation across technology and policy realms [8].

This study has undergone cyclical developments in its evolution and transition from reliance on fossil fuels to the rise of renewable energy technologies as the principal means by which contemporary energy security are ensured. Studies demonstrate that as renewable technologies bring about energy security, the disorganized character of the sector results in fiscal costs compared to fossil fuels which no longer do enhance energy security. Transitioning away from fossil fuels requires broad, unwavering political support and public awareness. This could lead to the dominance in future CO₂ reduction efforts not of feasible grid-compatible options such as nuclear power or fossil fuel technologies with carbon capture but zero-CO₂-on-the-grid local generation. This study analyzes the types of renewable energy resources and their usage across various countries, focusing on both developed and developing nations. It highlights the challenges faced by developing countries and their preference for renewable solutions, while discussing the economic, educational, and environmental impacts of these resources. The research also explores emerging business opportunities and employment mechanisms associated with renewable energy. Overall, it advocates for sustainable policies to optimize the benefits of renewable energy resources [9].

The novel looks into the Turkish energy sector, having a prosperous 9-year period starting from to onwards while struggling with unsatisfied customer needs because of high urbanization and growth in number of cars alongside country's growing economy that will add up approximately 580 billion kWh consumption by year. Studies highlight the high cost of imported energy resources in Turkey, which burden the economy and increase air pollution. In the answer of researchers, we can have another resolution by renewable energy to get clean and sustainable energy development. Turkey has strong potential in the area of renewable energy sources as its location is perfect on a map to take advantage of all forms. In general, the literature emphasizes that an immediate shift in policy towards a renewable energy strategy should be pursued at once on both economic as well as environmental grounds [10].

In this manuscript, an attempt has been made to bring focus on Renewable Energy Sources (RES) as a solution for sustained economic, social and environmental advancement. In short RES help in accessing energy, reduce greenhouse gas emissions and other pollutants besides establishing local developed chances. Furthermore, energy is a crucial factor in economic development and contributes to sustainable growth as well poverty reduction. This paper systematically reviews the economic pros and cons of different form RES, including its potential benefits to global warming mitigation while offering an approach for a more sustainable utilization [11].

It brings to the fore, for instance, how heavily dependent Ghana is on wood fuel which contributes 72% of the country's primary energy supply and it is associated environmental and health hazards. The increasing popularity of biogas technology provides an alternative for clean energy; it is produced by the anaerobic digestion of organic waste. More studies have showed that Ghana is well endowed with various biomass resources for the provision of biogas which will salvage Ghanaians from reliance on wood fuel and fossil fuels, thus reducing greenhouse gas emission. Despite its potentials, a tiny piece of the technical biogas plant potential was established so far and it faced numerous challenges in terms of implementation as well as taking over scale [12].

Renewable energy is seen by the author as a bubbling alternative to non-renewable sources, but the current implementation only compensates for part of our global needs. Numerous reviews have investigated technical, economic and social or public constraints for renewable energy investments. It however requires multi-dimensional analyses in order to understand the interactions and root causes of these barriers. Evidence from the case of wind energy in Saskatchewan, Canada suggests that knowledge gaps and stakeholder discord account for a substantial portion of barriers to investment. A holistic approach is needed to find solutions that really work in addressing these challenges [5-7].

It is as an example that due both to the growing pressures of the environment and gradually stronger competitive economic ones, rational energy planning will be explored in this study. In many studies, various alternative sources of renewable energy such as wind, solar, biomass and geothermal features have been proposed to support the use of an MCDA approach in planning for new sustainable energies as Small Hydro. Prior researches prove the need for qualitative and quantitative assessment criteria to provide an efficient energy mix at regional scale. The case of Thasos Island, Greece proofs that renewable energies are able to cover the increasing energy needs and in a sustainable way by adopting integrated wind/biomass/photovoltaic (PV) systems. The objective of this approach is ultimately the optimum production and use of energy at regional level [8-9].

The challenge of integrating renewable energy (RES) into existing autonomous Greek island grids, with annual penetrations never above 10%, despite ample sunshine and windmr0060ipient potential, is addressed in this prospective study. The seasonal nature of power usage driven by climatic variance compounds the problem with diesel generators which have technical challenges serving demand in these conditions. Wind Energy Studies Hybrid systems (Wind-Hydro Plants) contributes to removing the stochastic nature of wind energy and enables 90-100% RES penetration. Efficiency analysis for higher RES integration shows both RESS and super grids are efficient ways to accomplish this, which will decrease fuel costs [10-11].

This study also provides conclusive evidence for renewable energy has a beneficial but statistically significant influence on sustainable development compared to non-renewable energies. Recurrent studies show that renewable energy enables sustainable development, in both developed and developing countries having higher impacts as renewable energy penetration increases. The need for all the states to focus on renewable energy has been emphasized if they are going to meet their SDGs come 2030 [12].

III. OBSERVATION

TABLE I Emphasizes the versatility of renewable energy sources

Rene wable Ener gy Sourc e	Advantages	Challenge s	Best Use Case	Sustainability Contribution

Solar Energy	Abundant, widely available. Low operational costs. Reduces carbon footprint.	Intermittent (depends on sunlight). High initial costs. Requires large space for utility-scale projects.	Residential solar panels. Solar farms in sunny regions. Rural electrification.	Zero emissions during operation. Helps reduce dependence on fossil fuels. Promotes energy independence.
Wind Energy	Low operational costs. No emissions during operation. Scalable for both small and large installations.	Intermittent (depends on wind speed). Requires large, open areas. Potential noise and visual impact.	Wind farms in windy regions (onshore and offshore). Rural and coastal power generation.	Carbon-neutral power source. Can supply large-scale electricity needs. Reduces global reliance on fossil fuels.
Hydro power	Continuous, reliable energy. Can be combined with water storage and flood control. Highly efficient (90% energy conversion).	Environmental disruption (ecosystem, fish habitats). Expensive to build dams. Limited by geographic location.	Large-scale electricity generation. Energy storage via pumped hydro. Regions with abundant water resources.	- Provides consistent, renewable power. - Reduces need for coal and natural gas plants. - Can help in climate resilience (flood control).
Biomass Energy	Utilizes organic waste. Can be carbon-neutral if managed sustainably. Reduces waste in landfills.	Produces some emissions. Requires large land areas. Competes with food	Power plants using agricultural/industrial waste. Rural energy generation.	Converts waste into energy. Helps reduce landfill use. Can be a sustainable alternative to fossil

		production if not managed well.	Transportation fuels (bioethanol, biodiesel).	fuels when managed responsibly.
Geothermal Energy	Reliable and continuous. Low emissions. Small land footprint.	Limited to geologically active regions. High upfront costs for drilling. Potential for induced seismicity.	Power generation in volcanic or tectonically active regions. District heating systems.	Constant, renewable power source. Minimal environmental impact compared to fossil fuels. Contributes to local energy security.
Ocean Energy (Wave, Tidal)	Predictable energy generation (tidal). Abundant in coastal areas. No emissions during operation.	Expensive technology. Potential environmental impact on marine ecosystems. Limited to coastal areas.	Coastal regions. Supplementary power generation for island nations or coastal cities.	Harnesses the ocean's vast, untapped energy potential. Provides a renewable power source for coastal communities. Reduces reliance on fossil fuels.

TABLE II The cost comparison of various renewable energy sources in Indian Rupees (₹/MWh) (by using a conversion rate of ₹83 per USD)

Renewable Energy Source	Average LCOE (₹/MWh)	Initial Investment Costs	Operational & Maintenance Costs	Remarks
Solar Energy (Utility-scale)	₹2,490 - ₹4,980	High (solar panels, installation)	Low (minimal maintenance)	Costs have decreased significantly due to advancements in technology

				y.
Wind Energy (Onshore)	₹2,490 - ₹4,980	Moderate (turbines, land)	Low (minor maintenance, location-dependent)	Competitive with fossil fuels, especially in high-wind regions.
Wind Energy (Offshore)	₹5,810 - ₹9,960	Very High (offshore turbines, installation)	Moderate (higher due to sea exposure)	More consistent wind resources, but higher setup and maintenance costs.
Hydropower	₹3,320 - ₹7,470	Very High (dam construction)	Low (long-term maintenance)	High upfront cost but highly efficient with a long lifespan.
Biomass Energy	₹4,565 - ₹9,130	Moderate (plant construction)	Moderate (fuel sourcing, maintenance)	Biomass emissions depend on the type used but can be carbon-neutral.
Geothermal Energy	₹3,320 - ₹8,300	High (drilling, exploration)	Low (minimal operational costs)	Viable in geologically active regions, providing continuous power.
Ocean Energy (Tidal/Wave)	₹9,960 - ₹20,750	Very High (technology, infrastructure)	Moderate to High (maintenance due to harsh marine conditions)	Emerging technology with great potential for coastal areas, but high costs currently.

TABLE III Best renewable energy sources based on different key factors

Renewable Energy Source	Best for	Cost-effectiveness	Scalability	Reliability	Sustainability Contribution

Solar Energy	Residential and urban power generation	High	High (rooftop and utility-scale)	Moderate (intermittent)	Significant reduction in carbon emissions; widely available.
Wind Energy (Onshore)	Large-scale rural and coastal power	High	High (wind farms)	Moderate (intermittent)	Carbon-neutral, no emissions during operation.
Hydro power	Continuous, large-scale electricity	Moderate	Low (site-dependent)	High (consistent power)	Reduces need for fossil fuels, supports flood control.
Biomass Energy	Waste-to-energy and rural power	Moderate	Moderate	Moderate (depends on fuel availability)	Converts organic waste into energy, reduces landfill use.
Geothermal Energy	Continuous power in active regions	Moderate	Low (location-limited)	High (24/7 availability)	Low emissions, minimal environmental impact.
Ocean Energy (Tidal/Wave)	Coastal and island power generation	Low (high costs)	Low (technology still emerging)	High (predictable in tidal regions)	High potential for coastal communities, no emissions during operation.

IV. RESULT AND DISCUSSION

Table 1, shows the solutions abound in form of renewables as they are carbon free, decrease crypto-relation with oil but most importantly can be scaled. Solar and wind energy are widespread but intermittent, at the same time because

hydropower constructions enormous undependable of power along with a few ecological dislocation. Using organic waste, where there is no competition with food for a production resource, geothermal energy reliable, but geographically constrained. Ocean energy: once proven too expensive with limited promising frontiers. While achieving sustainability, all contribute to a reduction in carbon emissions and energy independence; however they also face issues of cost, space and environmental burden respectively. Together, they help lay the groundwork for a cleaner energy future.

The cost comparison shows in table 2 that solar and onshore wind energy are the most affordable renewable sources in India, with LCOE ranging between ₹2,490 and ₹4,980 per MWh. Offshore wind and ocean energy are significantly more expensive, with costs up to ₹20,750 per MWh due to high infrastructure and maintenance demands. Hydropower offers efficient, reliable energy but requires a high initial investment. Biomass and geothermal energy also have moderate to high costs, with geothermal being location-specific. While the initial setup costs for most renewables are high, their operational costs tend to be low, making them economically viable in the long run, particularly for solar and wind energy.

Table 3 shows the best renewable energy sources and their key factors. Solar and wind are currently the most viable and widely adopted renewable sources globally, due to their affordability and ability to scale in diverse environments. Solar Energy and on shore wind energy offer the highest scalability and cost-effectiveness, making them ideal for widespread use. Hydropower and geothermal energy provide continuous, reliable energy but are geographically limited and require high initial investments. Biomass Energy is moderate in cost and scalability, using organic waste for energy, while ocean energy shows promise but is still in early stages of development due to high costs.

V. CONCLUSION

A renewable energy analysis identifies onshore wind and solar as the most cost-effective assets, both of which are used to significantly curb carbon emissions and mitigate increasing consumption in fossil fuels. Ocean and wind energy include higher infrastructure costs, biomass hydropower and geothermal all exhibit moderate infrastructural overhead but are limited by geography or the environment. Solar and wind are universal in application, for both residential as well as utility-scale applications while hydropower & others limited to specific locations offer renewable energy with high reliability. Waste-to-energy technologies are assessed HERE for both agricultural and CSOSSF type residues as well; while all forms of future ocean energy from absorbing heat, dislocation tides and waves show good potential there is still a high cost regarding the deployment of this clean technology overcoming technological challenging (IES(2020) onshore). Ultimately solar and onshore wind energy was found to be the two best candidates for future replication of greener households, while hydropower as well as geothermal and ocean technologies offer promise in a more equitable market. The series of technological break-through on the development, supporting functionalities such as energy storage solutions and system integration will ensure an increased scalability that will reward ably pave the ways for a more sustainable future. Renewable energy looks promising in future and contributed to a large extent by the technological enhancements and growing worldwide concern about global warming. Major advancements pertain to solar and wind technologies, intended for more efficient outputs at lower costs. And energy storage options have the potential to be an important complementing element in balancing some of these needs as battery tech and grid scale solutions continue improvements. Real time monitoring with efficient energy distribution will be made possible by the introduction of smart grids that could allow better integration and larger penetration of greener sources for generation. In addition, decentralized energy systems like micro grids will enable local communities to take control of their own power. Government support and investment will continue to boost the sector. Technologies like ocean energy and hydrogen fuel production will further contribute to the growth of green energies. Lithium-Ion Batteries for EVs: What is Li-ion Battery and How it Works in an Electric Vehicle as the negative effects of climate changes across the globe become more apparent, renewable energy will become critical to improve not only our global carbon footprint but also enhance national security by making us less dependent on fossil fuels. In sum, renewable energy is poised to be a critical aspect of the sustainable, low-carbon economy.

REFERENCES

- [1] S. Abu-Elzait, and R. Parkin, "Economic and environmental advantages of renewable-based microgrids over conventional microgrids," In 2019 IEEE Green Technologies Conference (GreenTech) pp. 1-4, 2019.
- [2] S. B. Tsai, Y. Xue, J. Zhang, Q. Chen, Y. Liu, J. Zhou, and W. Dong, "Models for forecasting growth trends in renewable energy. Renewable and Sustainable Energy Reviews, 77, 1169-1178, 2017.
- [3] U. kumar Nath, and R. Sen, "A comparative review on renewable energy application, difficulties and future prospect," Innovations in Energy Management and Renewable Resources, vol. 52042, pp. 1-5, 2021.
- [4] T. Güney, "Renewable energy, non-renewable energy and sustainable development," International Journal of Sustainable Development & World Ecology, vol. 26(5), pp.389-397, 2019.

- [5] B. R. Lingampalli, S. R. Kotamraju, M. K. Kumar, Ch. R. Reddy, M. Pushkarna, M. Bajaj, H. Kotb, S. Alphonse, "Integrated Microgrid Islanding Detection with Phase Angle Difference for Reduced Nondetection Zone," *INTERNATIONAL JOURNAL OF ENERGY RESEARCH*, vol. (1), pp. 2275191, 2023.
- [6] M.M. Mahmoud, H. S. Salama, M. Bajaj, M. M. Aly, I. Vokony, S. S. H. Bukhari, and A. M. M. Abdel-Rahim, "Integration of wind systems with SVC and STATCOM during various events to achieve FRT capability and voltage stability: Towards the reliability of modern power systems," *International Journal of Energy Research*, vol. 1, pp. 8738460, 2023.
- [7] M. V. Kumar, A. V. Babu, C. R. Reddy, A. Pandian, M. Bajaj, H. M. Zawbaa, and S. Kamel, "Investigation of the combustion of exhaust gas recirculation in diesel engines with a particulate filter and selective catalytic reactor technologies for environmental gas reduction," *Case Studies in Thermal Engineering*, vol. 40, pp. 102557, 2022.
- [8] K. Kakouche, T. Rekioua, S. Mezani, A. Oubelaid, D. Rekioua, V. Blazek, and S. S. Ghoneim, "Model predictive direct torque control and fuzzy logic energy management for multi power source electric vehicles," *Sensors*, vol. 22(15), pp. 5669, 2022.
- [9] S. B. Hamed, M. B., Hamed, L. Sbita, M. Bajaj, V. Blazek, L. Prokop, and S. S. Ghoneim, "Robust optimization and power management of a triple junction photovoltaic electric vehicle with battery storage," *Sensors*, vol. 22(16), pp. 6123, 2022.
- [10] S. Tajjour, S. S. Chandel, M. A. Alotaibi, H. Malik, F. P. G. Márquez, and A. Afthanorhan, "Short-term solar irradiance forecasting using deep learning techniques: a comprehensive case study," *IEEE Access*, vol. 11, pp.119851-119861, 2023.
- [11] G. Verma, and V. Sharma, "A novel RF energy harvester for event-based environmental monitoring in wireless sensor networks," *IEEE Internet of Things Journal*, vol. 9(5), pp. 3189-3203, 2021.
- [12] B. R. Lingampalli, S. R. Kotamraju, M. K. Kumar, Ch. R. Reddy, M. Pushkarna, M. Bajaj, H. Kotb, S. Alphonse, "Integrated Microgrid Islanding Detection with Phase Angle Difference for Reduced Non-detection Zone," *International Journal of Energy Research*, vol. (1), pp. 2275191, 2023.