IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.67
Volume 5, Issue 4, March 2025

Advancement in Renewable Energy Technology

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Abstract: *This article examines some of the latest findings in the exploitation of renewable energy sources (RES) for sustainable development. It outlines some of the latest findings at the system level – e.g., local systems, community systems, and assemblies of buildings – as well as some of the main components in future renewable energy systems. This includes solar technologies, where particular attention is given to the cooling of photovoltaic panels to improve conversion efficiency. Hydrogen – in one way or the other – will play a role as a storage medium or as a means of electrifying otherwise hard-to-electrify sectors. Bioenergy is a valuable but restricted source in the energy system, hence different processes are investigated to optimize the use of different biomass waste streams. Lastly, wind power is addressed as one of the key constituents of future renewable energy-based energy systems.*

Keywords: renewable energy sources

I. INTRODUCTION

The 21st century has witnessed an increasing recognition of the limitations and environmental repercussions associated with conventional energy sources. The extraction, combustion, and utilization of fossil fuels have not only contributed significantly to global warming but have also led to geopolitical tensions and resource depletion. In this context, renewable energy sources have emerged as a promising alternative, harnessing the inexhaustible power of natural elements to meet the world's growing energy demands. Motivated by environmental imperatives and the need for energy security, governments, industries, and research institutions globally have intensified efforts to explore and enhance the potential of renewable energy technologies. The quest for sustainable energy solutions has led to remarkable strides in the development of solar ,wind, hydropower, geothermal, and biomass technologies. These advancements not only promise cleaner energy but also herald economic opportunities and increased energy independence for nations. The energy potential of RES on a planetary and individual country scale is many times the current level of energy consumption, and therefore they can be considered as a possible source of energy production. Well-known prerequisites for the development of mankind suggest the need for a broad study of renewable energy sources already in management, both due to the inevitable increase in production and increase in the cost of oil, gas and coal, as well as for environmental reasons (CO2 emissions and other harmful consequences of economic policy on the environment). The use of renewable energy sources, as a rule, does not have a serious negative impact on the environment; for the most part, they are environmentally friendly and widely available sources of energy.

Serious disadvantages of RES that limit their widespread use include the low density of energy flows and their variability over time and, as a consequence, the need for significant costs for equipment that collects, accumulates and converts energy . For example, the flux density of solar radiation on the surface of the earth at noon on a clear dayis only about 1 kW/m2, and its average annual value, considering seasonal and weather fluctuations, for the sunniest regions of the globe does not exceed 250 W/m2 . The average specific energy density of a wind flow also, as a rule, does not exceed several hundred W/m2 at a wind speed of 10 m/s, the specific energy density is approximately 500W/m2. The energy density of a water flow with a speed of 1 m/s is also is only about 500 W/m2. For comparison, we point out that the heat flux density on the furnace walls of a modern steam boiler reaches several hundred kW/m.

At the same time, technologies for using various renewable energy sources are actively developing in many countries ofthe world, many of them have reached commercial maturity and successfully compete in the energy services market, including in the production of electrical and thermal energy.

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Solar Energy Advancements

India has made remarkable progress in advancing its solar energy technologies, with a focus on enhancing the efficiency of photovoltaic cells, exploring innovative solar panel designs, and developing energy storage solutions. These advancements are essential in harnessing solar energy more effectively and sustainably. One notable area of advancement is in photovoltaic cell efficiency. Indian researchers and manufacturers have been at the forefront of developing high-efficiency solar cells, such as PERC (Passivated Emitter and Rear Cell) and Bifacial solar cells. PERC technology, which reduces recombination losses and improves light absorption, has contributed to higher efficiency (The Economic Times, 2019). Bifacial solar cells, capable of capturing sunlight from both sides of the panel, have been gaining attention in India, promising increased energy generation (Indian Express, 2021). These developments hold the potential to significantly enhance solar energy conversion rates. Innovative solar panel designs have also emerged as a crucial area of progress in India. India's progress in solar energy technologies showcases its commitment to a sustainable and cleaner energy future. Advances in photovoltaic cell efficiency, innovative panel designs, and energy storage solutions are pivotal in maximizing the benefits of solar energy and accelerating the nation's transition to cleaner and more sustainable power sources. These advancements not only contribute to India's energy security but also have the potential to set an example for global renewable energy innovation and adoption.

Wind Energy Developments

India has been actively exploring innovations in wind energy technology and turbine design to harness wind power more efficiently. These innovations include the development of larger and more efficient wind turbines, which have contributed to the growth of wind energy capacity in the country. Additionally, several successful wind energy installations have had a significant impact on electricity generation.

Innovations in Wind Energy Technology and Turbine Design

One notable innovation in wind energy technology is the development of larger and more efficient wind turbines. These advancements aim to capture more energy from the wind and improve the overall performance of wind farms. In India, manufacturers and researchers have been working on:

Higher Capacity Wind Turbines: India has seen the introduction of higher- capacitywind turbines with larger rotor diameters, enabling them to capture .more wind energy. These turbines are designed to operate efficiently in lower wind speeds, expanding the geographical reach of wind power generation (The Hindu Business Line, 2018).

ii. Advanced Blade Design: Innovations in blade design have led to more aerodynamic and efficient rotor blades. These blades are designed to maximize energy capture while minimizing turbulence and noise, enhancing the overall performance of wind turbines (The Times of India, 2020).

The impact of these and other successful wind energy installations in India goes beyond electricity generation. They have played a crucial role in reducing carbon emissions, enhancing energy security, and providing economic benefits to local communities through job creation and infrastructure development. India's wind energy sector has witnessed innovations in turbine design and technology, resulting in larger and more efficient wind turbines. These innovations, coupled with successful wind energy installations, have significantly contributed to India's renewable energy capacity and its efforts to transition to cleaner and more sustainable energy sources.

Biomass and Bioenergy Innovations

India has been actively pursuing advancements in biomass and bioenergy technologies as part of its commitment to sustainable energy production. These innovations encompass efficient biogas production, the development of biomass power plants, and ongoing research in the field of biofuels. Research and development efforts in India have been focused on biofuels derived from organic sources such as vegetable oils, jatropha seeds, and sugarcane molasses. Advanced processes, including enzymatic hydrolysis and the production of second-generation biofuels from lignocellulosic biomass, are being explored to enhance the viability and sustainability of biofuels (Business Standard, 2020).

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Geothermal

Geothermal power plants (large-scale) and geothermal heat pumps (GHPs) (small-scale) convert heat from the Earth's interior into electricity using steam or hydrocarbon. Geothermal energy was once location dependent—requiring access to geothermal reservoirs deep under the Earth's crust. The latest research is helping to make geothermal more location agnostic.

Enhanced geothermal systems (EGS) bring the necessary water from below the Earth's surface to where it isn't, enabling geothermal energy production in places around the globe where it wasn't previously possible. And as ESG technology evolves, tapping into the Earth's inexhaustible supply of heat has the potential to provide limitless amounts of clean, low-cost energy for all.

Hydropower

Hydropower energy systems use water movement including river and stream flow, marine and tidal energy, reservoirs and dams to spin turbines to generate electricity. According to the IEA, hydro will remain the largest clean energy provider through 2030 with exciting new technologies on the horizon.[6]

For example, small-scale hydro uses mini-and micro-grids to provide renewable energy to rural areas and areas where larger infrastructure (such as dams) may not be feasible. Using a pump, turbine or waterwheel to convert the natural flow of small rivers and streams into electricity, small-scale hydro provides a sustainable energy source with minimal impact to local ecosystems. In many cases, communities can connect into a centralized grid and sell back excess power produced.

In 2021, the National Renewable Energy Laboratory (NREL) placed three turbines made of a new thermoplastic composite material that's less corrodible and more recyclable than traditional materials into New York City's East River. The new turbines generated the same amount of energy in the same amount of time as their predecessors but with no discernable structural damage.[7] Extreme condition testing is still necessary, but this low-cost, recyclable material has the potential to revolutionize the hydropower market if adopted for widespread use.

II. CONCLUSION

The section devoted to solar PV technology included improvements in solar cell efficiency, the emergence of novel materials, and breakthroughs in thin-film technologies. Furthermore, the integration of solar energy into the grid, advancements in energy storage solutions for solar installations, and innovations are thoroughly explored.The section on geothermal energy provided insights into advancements in enhanced geothermal systems, drilling technologies, and reservoir management. The paper explored the potential for direct use applications of geothermal energy and assessed the environmental viability of geothermal power generation.In conclusion, this brief review synthesized recent advancements across various renewable energy sources, especially solar and geothermal energy. By examining the technological, environmental, practical and theoretical dimensions, this paper provided a valuable resource for researchers, policymakers, and industry stakeholders working towards a sustainable and resilient energy future.

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