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**“Environment and Economics: A  
Perspective of Sustainable Development”**

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16.	An Analysis of Municipal Solid Waste Leachate: A Case Study of Latur City, Maharashtra, India and an Integrated Approach to Remediation	Mr. Nilesh D. Sable Dr. Amul M. Late	78
17.	Renewable Energy for Sustainable Development: Opportunities and Obstacles	Asst. Prof. Darole Akanksha Sanjay	87
18.	Synthesis and Characterization of Mesoporous Material SBA-16 : A Morphological Approach	Dr. S. B. Shete Dr. Manish Deshpande Mahesh Kanshette Mahesh Korke	90
19.	Nanotechnology for a Greener Tomorrow: Pathways, Challenges and Opportunities	Jayshree K. Khedkar	95
20.	A review on Physico-chemical status of Lonar Lake, District Buldhana (M.S)	Dr. Deshpande R. P. Dr. Ishrat Parveen	97
21.	Potential Organic Fertilizers from Banana Plant Waste	Bhise Onkar B. Bodhankar Anuradha S. Lolage Yogesh P.	101
22.	Phylogenetic Characterization of Endophytic Bacteria Isolated from High Yielding Varieties of Rice	S. V. Jadhav D. C. Kamthane N. S. Bhalerao	106
23.	Mathematics in Biology	Miss. Wabale Rina Ramesh	111
24.	Plastic Use Alternatives and Remedies in Maharashtra for Sustainable Development	Vinod K. Mukke Pradnya B.Bhole	115
25.	Water Quality Degradation and Eutrophication Analysis of Madhuganga Lake under Anthropogenic Stress in Kalmeshwar Tehsil, Maharashtra	Dr. Chetankumar B. Masram Dr. Pravin U. Meshram Shreya D. Indurkar	118
26.	Evaluation of Municipal Solid Waste and Impact on Ground Water Quality in Adjoining Area of Bhandewadi Dumping Site of Nagpur City	Mr. Prafful W. Bhokre Dr. P. U. Meshram	123
27.	Physicochemical Assessment of Water Quality in Dongergaon Tank, Latur District, Maharashtra	Dr. Rahul Jadhav	132
28.	Synthesis of SBA-15 Mesoporous Material Using Rice Husk Ash as Silica Source: A Green Study	Dr. S.B. Shete Dr. Manish Deshpande Mahesh Korke Mahesh Kanshette	135
29.	Status of Endangered Species in Maharashtra: A Review of Trends, Challenges and Conservation Strategies	Mr. Abhijit Madhav Chavan	141
30.	Plastic Recycling is a Myth: Insights from Policies, Practices and Ground Reality	Mr. Shivam A. Bhosle Dr. Sudhir V. Shivanikar	145
31.	Significance of Environment in Human Health: A Rview	Sunita Ramlu Mukkawar	148

# “Renewable Energy for Sustainable Development: Opportunities and Obstacles”

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(Head of Physics Department , Nutan Art’s College, Rajapur)

## **Abstract**

Renewable energy, derived from naturally replenishing resources such as solar, wind, hydro, geothermal, and biomass, is increasingly vital in addressing global energy demands and environmental challenges. This paper summarizes the key benefits and disadvantages of renewable energy, highlighting its role in sustainable development and the challenges that hinder its widespread adoption. Renewable energy technologies have advanced significantly by 2025, driven by innovations in solar, wind, and other sources such as geothermal, bioenergy, and tidal energy. This paper reviews key developments, including perovskite solar cells, larger offshore wind turbines, and enhanced geothermal systems, while evaluating their economic benefits like job creation and cost reductions, environmental advantages such as greenhouse gas mitigation, and social impacts including improved energy access. It also analyzes barriers, notably supply chain vulnerabilities and policy gaps, that hinder widespread adoption. The analysis underscores the need for integrated strategies to overcome these challenges for a sustainable energy transition.

## **Introduction**

The global energy landscape is shifting toward renewable sources to mitigate climate change, reduce dependence on fossil fuels, and promote sustainability. Renewable energy technologies harness natural processes to generate power, offering a cleaner alternative to traditional energy systems. However, their implementation faces technical, economic, and logistical challenges. This paper evaluates the primary advantages and drawbacks of renewable energy to provide a balanced perspective. The global energy landscape is undergoing a profound transformation, with renewable sources playing a pivotal role in addressing climate change, energy security, and sustainable development. As of 2025, renewables—including solar, wind, hydropower, geothermal, bioenergy, and emerging tidal technologies—account for a growing share of electricity generation, surpassing coal in some projections and poised to overtake hydropower as the leading clean energy source. This shift is fueled by technological advancements that enhance efficiency and reduce costs, amid urgent calls for net-zero emissions by mid-century. However, the transition faces multifaceted challenges, from economic viability to environmental trade-offs and social equity concerns.

## **Objective:**

- (1) to review key innovations in solar, wind, and other renewables as of 2025;
- (2) to evaluate their economic, environmental, and social impacts;
- (3) Benefits and Disadvantages of Renewable energy

## **Benefits of Renewable Energy**

### **Environmental Sustainability**

Renewable energy sources produce little to no greenhouse gas emissions during operation, significantly reducing the carbon footprint compared to fossil fuels. For instance, solar and wind energy help mitigate climate change by curbing CO<sub>2</sub> emissions, contributing to global efforts to meet Paris Agreement targets.

### **Energy Security and Independence**

By utilizing abundant local resources like sunlight and wind, countries can reduce reliance on imported fossil fuels, enhancing energy security. This diversification strengthens resilience against global energy market fluctuations.

### **Public Health Benefits**

Reduced air and water pollution from renewable energy lowers health risks associated with fossil fuel combustion, such as respiratory diseases and premature deaths. Cleaner energy systems improve quality of life, particularly in urban areas.

#### **Technological Advancements**

Ongoing innovations in energy storage (e.g., lithium-ion batteries), grid integration, and efficiency improvements make renewables increasingly competitive. For example, solar photovoltaic costs have dropped significantly over the past decade, enhancing accessibility.

#### **Disadvantages of Renewable Energy**

##### **Intermittency and Reliability**

Solar and wind energy depend on weather conditions, leading to inconsistent power generation. Without robust energy storage or backup systems, this intermittency can challenge grid stability, requiring investment in advanced infrastructure.

##### **High Initial Costs**

The upfront capital investment for renewable energy infrastructure, such as wind turbines or solar farms, can be substantial. While long-term savings are significant, initial costs may deter adoption, particularly in developing regions.

##### **Land Use and Environmental Impact**

Large-scale renewable projects, like wind farms or hydropower dams, can disrupt ecosystems, affect wildlife, and require significant land. For instance, hydropower projects may lead to habitat loss and displacement of communities.

##### **Energy Storage and Grid Integration**

Effective storage solutions, such as batteries, are costly and face technical limitations. Integrating renewables into existing grids requires upgrades to handle variable energy inputs, posing logistical challenges.

#### **Key Innovations in Renewable Energy Technologies as of 2025**

##### **Solar Energy Innovations**

Solar photovoltaic (PV) technology has seen remarkable progress, with perovskite solar cells emerging as a game-changer due to their low cost, flexibility, and potential for higher efficiency compared to traditional silicon panels. These cells can be layered with silicon to create tandem structures, boosting conversion rates beyond 30% in some prototypes. Bifacial panels, which capture sunlight from both sides, have gained traction, increasing output by 5-30% depending on installation conditions, making them ideal for large-scale farms. Additionally, floating solar farms are expanding, utilizing water bodies to reduce land use and enhance cooling efficiency. Integration of artificial intelligence (AI) and Internet of Things (IoT) enables predictive maintenance and optimization, further driving down operational costs. By 2025, these advancements position solar as the fastest-growing renewable, with global capacity projected to double.

##### **Wind Energy Innovations**

Wind energy innovations focus on scaling and efficiency, with larger turbines featuring rotors exceeding 200 meters in diameter, enabling higher energy capture in lower wind speeds. Offshore wind farms are expanding rapidly, incorporating floating platforms for deep-water sites and segmented blades made from carbon fiber to facilitate transport and installation. AI-optimized operations, including predictive analytics for turbine performance, minimize downtime and enhance grid integration. By 2025, wind is expected to become the second-largest renewable electricity source, surpassing hydropower, with innovations like underwater energy storage addressing intermittency.

##### **Innovations in Other Renewables**

Beyond solar and wind, hydropower innovations include pumped storage systems for energy balancing and small-scale run-of-river projects that minimize environmental disruption. Geothermal energy advances with enhanced geothermal systems (EGS), which fracture hot rocks to access heat in non-volcanic areas, expanding its viability. Bioenergy sees progress in advanced biofuels from algae and waste, reducing competition with food crops. Tidal and wave energy

technologies, such as hydrokinetic turbines and underwater storage, are gaining momentum, offering predictable power in coastal regions. Green hydrogen production, often paired with renewables, serves as a versatile storage and fuel option, with electrolysis efficiency improving through advanced catalysts.

### **Evaluation of Economic, Environmental, and Social Impacts**

#### **Economic Impacts**

Renewables drive economic growth by creating jobs—over 1.7 million in the U.S. alone by 2025—and reducing energy costs through falling technology prices. Solar and wind are now cheaper than fossil fuels in many regions, fostering energy independence and attracting investments in green infrastructure. However, initial capital requirements remain high, though offset by long-term savings and incentives.

#### **Environmental Impacts**

Environmentally, renewables emit minimal greenhouse gases, mitigating climate change and improving air quality. Solar and wind reduce water usage compared to thermal plants, but challenges include land disruption for large installations and wildlife impacts from turbines. Overall, positive global effects outweigh local negatives, with innovations like bird-friendly designs addressing concerns.

#### **Social Impacts**

Socially, renewables enhance energy access in underserved areas, promote health by curbing pollution, and support community-led projects for equity. They empower vulnerable groups through job training and decentralized systems, though disparities in adoption persist in developing regions.

#### **Conclusion**

Renewable energy offers substantial benefits, including environmental sustainability, energy security, and economic growth, making it a cornerstone of global efforts to combat climate change. However, challenges such as intermittency, high initial costs, and environmental impacts necessitate strategic solutions, including policy support, technological innovation, and international cooperation. By addressing these drawbacks, renewable energy can play a pivotal role in achieving a sustainable and equitable energy future.

As of 2025, innovations in solar, wind, and other renewables offer promising pathways to a sustainable energy future, delivering substantial economic growth, environmental protection, and social benefits. However, barriers like supply chain dependencies and policy inconsistencies must be urgently addressed through diversified sourcing, robust incentives, and global collaboration. By overcoming these hurdles, renewables can achieve their full potential, ensuring equitable and resilient energy systems for generations to come. Future research should focus on integrating these technologies with emerging solutions like AI-driven grids to accelerate the transition.

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5. Notes for Use
6. This summary is designed for a research paper context, providing a balanced and concise overview. For a full paper, expand each section with detailed data, case studies, and citations.
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This is to certify that, Prof./Dr./Mr./Mrs./Ms Daxela Akanksha Sanjay

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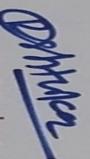
Conference on "Environment and Economics: A Perspective of Sustainable Development" (offline) held on Tuesday,

16th September 2025 as a Resource person / Chairperson / Co-chairperson / Participant / Research Student. He/ She has

presented a Research Paper (oral/poster) on Renewable Energy for Sustainable Development opportunities and obstacles.

  
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