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Evaluate renewable energy meets global energy demands and its potential for future sustainability

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Abstract
Energy has been an important part of every life[1]. There has been shift from traditional energy sources to renewable energy in the global scenario. It is the key element of sustainable, environmental friendly, and cost effective electricity generation. Renewable energy is power generated from natural sources that never run out, such as the sun, wind, water, and earth's heat. Unlike fossil fuels (coal, oil, and gas), these energy sources are sustainable, cleaner, and help reduce pollution. In addition, renewable energy has the potential to create many employment opportunities at all levels, especially in rural areas. The Ministry of New and Renewable Energy ("MNRE") has been taking several steps to ensure a clean energy future for the country. This analysis aims to evaluate how effectively renewable energy meets global energy demands and its potential for future sustainability.

Keywords: Sustainable energy, clean power, energy efficiency, carbon reduction grid integration, cost effective, low emissions, renewable resources, green technology, climate friendly

Introduction

Renewable Energy Sources (RES) have been attracting attention as it is environmentally friendly and sustainable energy resources. The rising challenges of energy production and climate change necessitate a transition towards RES to reduce the impact of carbon emissions and ensure a sustainable future. Renewable energy is a sustainable alternative to fossil fuels, offering clean and efficient power from sources like solar, wind, hydro, and biomass. RE helps reducing pollution, slowing down climate change, and making us less dependent on fossil fuels like coal and oil. While renewable energy is cleaner and safer, it also has some challenges, for example Solar panels don't work at night, and wind turbines need wind to generate power. However, new technology is helping us store energy in a better way and make these sources more reliable. RERs are primarily characterized by global occurrence and negligible environmental effects. For example - Solar and wind powers, almost everywhere in the world with varying intensities, and no energy introduction is needed [2]. The author discussed in depth the crucial and important role of renewable energy resources (RERs) with the United Nations' Sustainable Development Goals (SDGs). This becomes clearer when SDG-7, which supports "Affordable and Clean Energy," and SDG-13, which calls for urgent "Climate Action," are highlighted.]

The text points out the inherent necessity of the extensive and expansive use of renewable energy resources, arguing that it is an absolutely imperative prerequisite for the attainment not only of the long-term well-being of humankind but for the attainment of the well-being of our planet as well. This main goal embraces all of its irreplaceable components necessarily the biosphere, atmosphere, geosphere, and hydrosphere emphasizing the interdependence of the latter in striving for sustainable development [3,4]. India's transition away from traditional sources of energy along with renewable energy as the nation is leading the initiative to increase the clean energy quotient. The Ministry of New and Renewable Energy (MNRE) has initiated various programs to support a sustainable future for energy. As Indian consumers are becoming ever more environmentally concerned about traditional energy sources, they are ever more receptive to options like solar, wind, hydro, and biomass. Falling prices of renewable technology, along with government incentives, have further influenced this shift. The research studies societal attitudes and the readiness to accept alternative energy sources, in particular, as related to the policies of the government in securing public awareness and participation [5]. The effectiveness of renewable energy in addressing climate change based on data from 138 nations for 27 years (1995–2021)].

It applies regression analysis in an attempt to quantify the Influence of renewable energy on CO2 emmission. Key Insights: Inverse Relationship: research concludes that increased use of renewable energy reduces CO_2 emissions [6–8]. The effect of consumption of renewable energy on carbon dioxide (CO_2) emissions using panel data from 138 countries.

Most nations, except Canada, showed a declining trend in CO_2 emissions, indicating the potential of higher consumption of renewable energy as a viable way to cut emissions and fight climate change. Policy Implications: For countries with the highest CO_2 emissions, embracing and shifting to renewable energy sources is recommended to attain meaningful emission cuts and effectively combat climate change.

Renewable Energy

Renewable energy is defined as energy produced
from sources of natural resources that continuously and sustainably renewed [9]. Renewable energy sources have the potential to produce an unlimited supply of energy, in contrast to fossil fuels, which
are limited and non-renewable**.**

Measuring Instruments: Sensors, meters, and monitoring equipment to measure energy production, efficiency, and environmental footprint.

Fig 1: Renewable energy data tracking the growing use of resources Every type of renewable energy has unique system components based on specific materials

a. Solar Power PV Cells: Silicon (thin-film, single crystal, multi-crystal) Solar Panels- Glass, aluminum, encapsulant materials Batteries- Energy can be stored by lithium-ion, lead acid, or flow batteries Charge Controllers and Inverters- Devices that aid in the effective conversion of energy

b. Wind Power Blades: Fiber glass, carbon fiber, or composite materials Towers- Steel concrete or composite structure

c. Hydropower Turbines [10,11]: Composite materials with aluminum and stainless-steel Dams & Reservoirs- Reinforced steel and concrete Pipes and penstocks- Plastic and steel of high durability

d. Biomass Energy Bioreactors: Stainless steel used in fermentation technologies Feedstock-Orthophosphate, waste, organic, and wood pellets Gasifiers- Heat resistant alloys Cermics.

Data Collection

1. Gather data on energy generation, efficiency, and carbon footprint from clean sources.
2. Read scientific reports, business studies, and government policies in renewable energy.

a. Renewable power system

- It needs to be evaluated, designed, and optimized systematically.

System Design and Modeling

- Set parameters for system dimension, efficiency, and output.

b. Fabrication and Test:

- Build preliminary designs of solar panels, windmills, and bioreactors.
- Conduct efficiency tests, load tests, simulate continuously operating tests.

c. Verification of Performance

- Track energy production through IoT-based smart meters.
- Evaluate cost savings and ecological benefits in comparison with grid electricity.

d. Environmental and Economic Assessment

- Environmental impact should be analyzed using Life Cycle Assessment (LCA).
- Cost-benefit analysis (CBA) should be done to check if the project is feasible.

Result and Discussions

[7,10]According to the results that have been obtained from different research studies that have been carried out, it is confirmed that technologies that utilize renewable energy sources have been successful in reducing the release of greenhouse gases to a considerable extent. Evolution in electricity capacity of Renewable Energy. India's installed renewable energy capacity is the fourth largest in the world. Renewable Energy Hubs situated in India are shown below:
(i)Rajasthan (ii) Gujarat (iii) Andhra Pradesh
(iv) Karnataka (v) Telangana (vi) Tamil Nadu

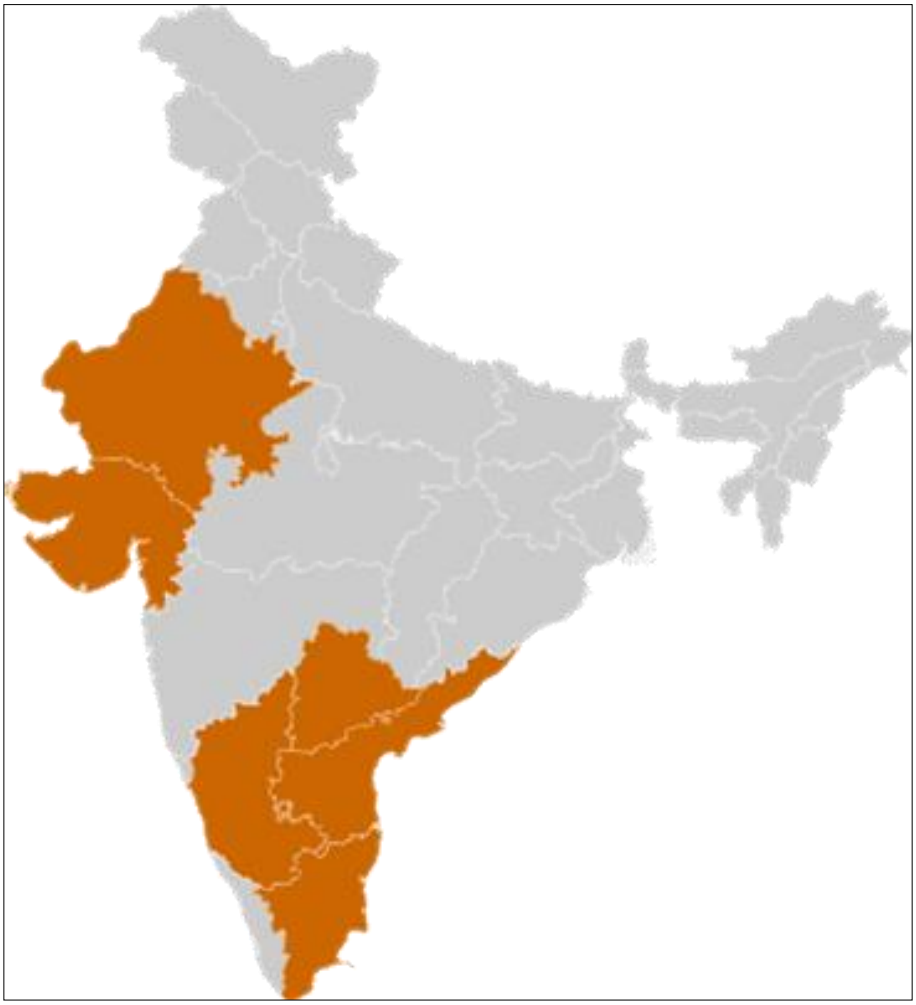


Fig 2: Renewable Energy hubs situated in India Apart from this RE sources include biomass, solar, wind, hydro, and geothermal which are described below

Types of Renewable Energy

1. **Solar power:** Solar energy is a renewable energy source that produces electricity by the help of solar panels using sunlight a natural source of light from sun.

How It Works

Solar Panels (Photovoltaic Cells): Convert sunlight into electricity.
Solar Thermal Systems: Utilize sunlight to warm water or air.
Concentrated Solar Power (CSP): Uses mirrors to concentrate sunlight and produce electricity.

Benefits of Solar Energy

- Eco-Friendly: No harmful emissions.
- Cost-Effective: Reduces electricity bills.
- Renewable: Unlimited supply from the sun.
- Low Maintenance: Once installed, requires minimal upkeep.

2. **Wind power** [12, 15]**-** Wind energy is a renewable energy source that converts wind kinetic energy into mechanical energy or electricity through wind turbines. It is one of the fast-increasing and most sustainable energy sources in the world.

How Wind Power Works

Wind Power Harnesses Renewable Energy
Large blades spin when the wind passes through, transferring its kinetic energy.
Kinetic Energy is converted into Mechanical Energy.
The spinning blades power a connected shaft that provides energy to the generator.
Generating Electricity
The generator also converts mechanical energy into electrical energy. The electrical energy is supplied to the grid or to the batteries.

Transmission: The generated electricity is sent through lines to be used by people and industries.

3. **Geothermal power**[16–19]**:** Geothermal power is energy generated from the Earth's internal heat. This heat originates from the molten core of the Earth and is harnessed using steam or hot water from underground reservoirs to produce electricity.

How Does Geothermal Power Work

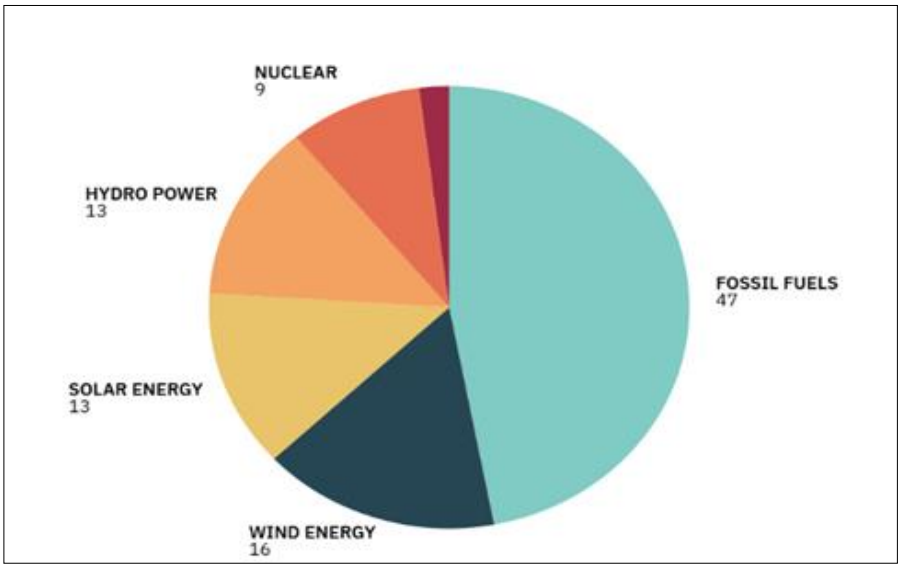
1. Heat Source: Magma beneath the Earth heats underground water, forming steam or hot water reservoirs.
2. Drilling & Extraction: Wells are drilled deep into the Earth to access this heat.
3. Steam Turbines: The extracted steam turns turbines, which generate electricity.
4. Cooling & Recycling: The steam is cooled back into water and reinjected into the ground to sustain the cycle.

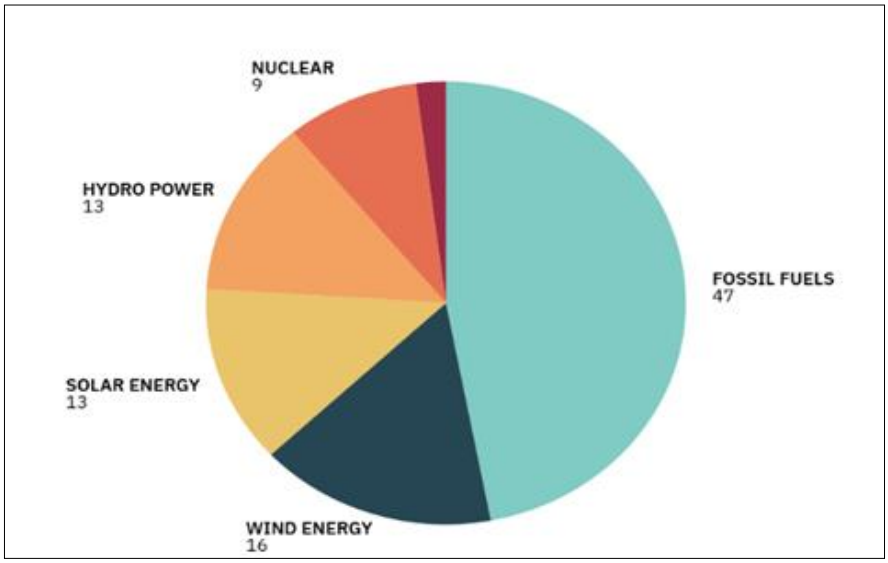
4. **Biomass:** Biomass is renewable energy that employs organic matter such as plants, crop residues, and animal feces. The source of energy is among the oldest employed by humans and continues to be a vital component in today's renewable energy schemes.

How Biomass Works

Biomass energy comes from the conversion of living organic material into useful energy forms, such as heat, electricity, or biofuels. These are: Combustion:[18–27] Biomass pyrolysis for production of heat and power generation for electricity. Anaerobic Digestion: Microbial breakdown of organic materials to form biogas (methane). Gasification: It transforms biomass into syngas (carbon monoxide, hydrogen) as a fuel source. Fermentation: It generates ethanol (biofuel) from sugars present in plants.

Non-Hydro Renewables Share of Global Electricity Generation (2022 numbers are estimates, 2032 numbers are forecasts.





(2022) (Self) (2032) (self)

Key Observations

1. **Fossil Fuels Decreasing**
- In 2022, fossil fuels accounted for 61% of global electricity generation.
- By 2032, this is expected to reduce to 47%, indicating a shift towards cleaner energy sources.

2. **Increase in Renewable Energy (Solar & Wind)**
- Solar power is expected to grow from 4% in 2022 to 13% in 2032.
- Wind power is projected to increase from 7% to 16% in the same period.
- This highlights the rapid adoption of solar and wind energy globally.

3. **Hydropower Remains Stable**
- Hydropower contributed 15% in 2022 and is forecasted to slightly decrease to 13% by 2032.

4. **Other Renewables and Nuclear Energy**
- Nuclear energy is expected to drop slightly from 10% to 9%.
- Other renewable sources (like geothermal, biomass) reduce marginally from 3% to 2%.

Conclusion

This study has looked into how well renewable energy sources work and what they could do to meet global energy needs and tackle environmental issues. [19,28–34]As the global energy landscape evolves, the integration of renewable energy into power grids and industries will play a pivotal role in mitigating climate change and reducing dependence on fossil fuels. The findings show that renewable energy - like solar, wind, hydro, geothermal, and biomass - offers a lasting option instead of fossil fuels cutting down on greenhouse gases and boosting energy security. There are still hurdles to overcome such as the cost of building infrastructure storing energy, and policy limits. But improvements in tech and a growing worldwide push for clean energy keep things moving forward.

In the coming years, we should zero in on making these sources more efficient coming up with better ways to store energy, and putting helpful policies in place to speed up the switch to renewable energy. As we keep coming up with new ideas and putting money into this field renewable energy can make a big difference in creating a sustainable and tough energy future.

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