

# The Role of Renewable Energy in Combating Climate Change: Progress and Challenges

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## ABSTRACT

The urgency of addressing climate change has intensified the global shift towards renewable energy sources, which play a crucial role in reducing greenhouse gas emissions and promoting sustainability. This article explores the significance of renewable energy, highlighting its potential to combat climate change while discussing the progress made in technology, global adoption rates, and successful case studies. However, challenges such as infrastructure limitations, intermittency, policy barriers, and economic considerations persist, hindering the widespread implementation of renewable energy solutions. To overcome these challenges, innovative technologies, strategic policy recommendations, and international cooperation are essential. This article advocates for a collective effort to embrace renewable energy initiatives, emphasizing the need for individual action and global collaboration to achieve a sustainable energy future.

**Keywords:** Renewable energy, climate change, greenhouse gas emissions, energy sustainability, technological advancements, international cooperation, energy transition, energy storage, carbon pricing.

## INTRODUCTION

"As of 2021, approximately 80% of global energy consumption was derived from fossil fuels, contributing to over 70% of greenhouse gas emissions" (International Energy Agency [IEA], 2022). This statistic underscores the urgency of addressing climate change, as the effects of global warming become increasingly evident through rising sea levels, extreme weather events, and biodiversity loss. The transition from fossil fuels to renewable energy sources is not just a potential solution; it is an imperative to mitigate the catastrophic impacts of climate change. Energy production, primarily from coal, oil, and natural gas, is the largest single source of global greenhouse gas emissions (World Resources Institute [WRI], 2021).

In response to this critical challenge, renewable energy technologies—such as solar, wind, and hydropower—have gained momentum as viable alternatives that can significantly reduce carbon footprints. The advancements in these technologies over recent years have made them more efficient and accessible, propelling nations toward ambitious climate goals. However, despite notable progress, several challenges remain that hinder their widespread adoption. This article will explore the significant advancements in renewable energy technologies, showcase successful case studies, and discuss the barriers that must be overcome to accelerate the transition to a sustainable energy future.

## THE IMPORTANCE OF RENEWABLE ENERGY IN MITIGATING CLIMATE CHANGE

### Overview of Greenhouse Gas Emissions

Energy production is the leading contributor to greenhouse gas emissions, which are the primary drivers of climate change. According to the Intergovernmental Panel on Climate Change (IPCC), the energy sector accounted for approximately 73% of global greenhouse gas emissions in 2019, with fossil fuel combustion being the predominant source (IPCC, 2021). The burning of coal, oil, and natural gas releases significant

amounts of carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), and nitrous oxide (N<sub>2</sub>O) into the atmosphere, exacerbating the greenhouse effect and leading to global warming. The rise in atmospheric CO<sub>2</sub> levels, for instance, has increased from about 280 parts per million (ppm) before the Industrial Revolution to over 400 ppm today (National Oceanic and Atmospheric Administration [NOAA], 2023). This drastic increase underscores the urgent need for a paradigm shift in how we produce and consume energy.

Renewable energy refers to energy derived from natural processes that are replenished at a faster rate than they are consumed. Key renewable energy sources include:

- **Solar Energy:** Harnessed from sunlight through photovoltaic cells or solar thermal systems, solar energy is one of the most abundant energy resources available.
- **Wind Energy:** Generated by converting wind currents into electricity using wind turbines, this form of energy is clean and increasingly cost-effective.
- **Hydropower:** Produced by utilizing the flow of water, typically through dams or river systems, hydropower is one of the oldest and most established forms of renewable energy.
- **Geothermal Energy:** This energy is derived from the Earth's internal heat, harnessed for electricity generation and direct heating applications.
- **Biomass:** Organic materials, such as plant and animal waste, can be converted into energy through combustion or fermentation, making biomass a versatile energy source (International Renewable Energy Agency [IRENA], 2021).

Together, these renewable sources provide a sustainable alternative to fossil fuels, which are finite and environmentally damaging.

Shifting to renewable energy can significantly reduce carbon emissions, helping to combat climate change. A study by the International Renewable Energy Agency (IRENA) estimates that doubling the global share of renewable energy in the energy mix could reduce greenhouse gas emissions by up to 70% by 2050 (IRENA, 2019). For instance, transitioning to solar and wind energy can result in substantial reductions in CO<sub>2</sub> emissions when compared to traditional fossil fuel-based energy systems. In a report by the National Renewable Energy Laboratory (NREL), it was found that widespread adoption of renewable energy technologies could cut U.S. power sector emissions by 80% by 2050 (NREL, 2020).

Furthermore, renewable energy systems generally have a smaller carbon footprint over their entire lifecycle compared to fossil fuels. According to a comprehensive life-cycle assessment, wind and solar energy systems produce significantly fewer emissions during their operation and construction phases compared to coal and natural gas (LCA, 2020). As countries strive to meet their climate commitments under the Paris Agreement, the transition to renewable energy is essential not only for reducing emissions but also for fostering energy independence and economic resilience.

## PROGRESS IN RENEWABLE ENERGY TECHNOLOGIES

### Technological Advancements

Innovations in renewable energy technologies have significantly enhanced their efficiency and effectiveness in recent years. In solar energy, advancements in photovoltaic (PV) technology have led to an increase in solar panel efficiency, with new materials such as perovskite promising efficiencies of over 25%, surpassing traditional silicon-based panels (Green et al., 2020). This improvement not only increases the energy output from the same surface area but also reduces the overall cost of solar energy, making it more accessible to consumers and businesses alike.

In wind energy, design enhancements in turbine technology have resulted in larger, more efficient wind turbines. The development of larger rotor diameters and taller towers has allowed for increased energy capture in lower wind speed locations (Global Wind Energy Council [GWEC], 2021). Moreover, the integration of advanced materials and aerodynamics has led to significant increases in the capacity factors of modern wind farms, allowing them to generate more electricity from the same amount of wind.

Energy storage solutions, particularly lithium-ion batteries, have also seen remarkable advancements. The cost of battery storage has declined by over 80% since 2010, making it a viable option for balancing the intermittent nature of renewable energy sources like solar and wind (BloombergNEF, 2021). Emerging technologies, such as solid-state batteries and flow batteries, are being researched to further enhance energy storage capacity and lifespan, which is critical for stabilizing renewable energy supply and increasing grid reliability (Nykqvist & Nilsson, 2015).

In addition to these advancements, smart grids and energy management systems are transforming how energy is distributed and consumed. Smart grid technologies allow for real-time monitoring and management of energy resources, enabling better integration of renewable energy sources into the existing grid. These systems enhance grid resilience, optimize energy consumption, and facilitate demand response initiatives (International Energy Agency [IEA], 2020).

### **Global Adoption Rates**

The growth of renewable energy installations worldwide has been remarkable. According to the International Renewable Energy Agency (IRENA), the total installed capacity of renewable energy reached 2,799 gigawatts (GW) in 2020, marking a 10.3% increase from the previous year (IRENA, 2021). Solar and wind energy have led this expansion, with solar PV capacity alone growing to 773 GW globally, while wind energy capacity reached 743 GW (IRENA, 2021).

Leading countries in renewable energy adoption include China, the United States, and Germany. China has emerged as a global leader in renewable energy investments, accounting for over 50% of global solar panel manufacturing and a significant share of wind turbine production (Liu et al., 2021). The United States has also made substantial strides, with wind and solar power now representing over 20% of total electricity generation (U.S. Energy Information Administration [EIA], 2022). Meanwhile, Germany's Energiewende initiative has positioned the country as a pioneer in renewable energy policy and deployment, with renewables accounting for approximately 46% of its electricity generation in 2020 (Agora Energiewende, 2021).

### **Economic Growth**

The renewable energy sector is a significant driver of economic growth and job creation. According to IRENA, the renewable energy industry employed 11.5 million people globally in 2018, a number that has continued to grow as investments in clean energy technologies rise (IRENA, 2019). The solar photovoltaic sector alone employed around 3.8 million people, while the wind energy sector accounted for approximately 1.2 million jobs (IRENA, 2019).

Furthermore, investments in renewable energy have been shown to create more jobs per unit of electricity generated compared to fossil fuels. A study by the U.S. Department of Energy found that solar and wind energy jobs create approximately three to five times more jobs than fossil fuel energy jobs (U.S. Department of Energy, 2021). This job creation is not limited to energy generation; it also encompasses manufacturing, installation, and maintenance, further contributing to economic development in local communities.

### **CASE STUDIES OF SUCCESS**

Several countries around the world have successfully transitioned to renewable energy, showcasing effective strategies and ambitious initiatives. Denmark is often cited as a leading example in this regard. With a comprehensive approach to energy policy, Denmark has significantly increased its wind power capacity. As of 2021, wind energy accounted for approximately 47% of the country's total electricity consumption (Danish Energy Agency, 2021). The Danish government has implemented various initiatives, such as the "Green Transition," which focuses on reducing fossil fuel dependency and promoting renewable energy through subsidies, research, and development programs. One notable project is the Horns Rev 1 Offshore Wind Farm, which, upon completion, became the world's largest offshore wind farm, capable of powering over one million homes (Orsted, 2020).

Germany has also made remarkable strides in renewable energy adoption through its Energiewende (energy transition) policy. This ambitious initiative aims to transform the German energy system by increasing the share of renewables in total energy consumption. As of 2020, renewable energy sources provided approximately 46% of Germany's electricity (Agora Energiewende, 2021). Key projects include the Sonnenbatterie and the SolarPower Europe initiative, which have facilitated the growth of solar power and decentralized energy systems across the country. Additionally, Germany's Feed-in Tariff program incentivizes the production of renewable energy, allowing consumers and small producers to sell excess energy back to the grid at guaranteed rates (U.S. Department of Energy, 2019).

Costa Rica has garnered international recognition for its commitment to renewable energy, achieving 99% of its electricity generation from renewable sources since 2015 (ICE, 2021). The country relies heavily on hydropower, with projects like the Reventazón Hydroelectric Project, one of Central America's largest, contributing significantly to its renewable energy supply. Additionally, Costa Rica has invested in wind and solar energy, enhancing its energy diversity and sustainability. The government's proactive policies and long-term vision for sustainability have positioned Costa Rica as a global leader in clean energy initiatives (Mora et al., 2021).

Beyond national efforts, many corporations are investing heavily in renewable energy and sustainability practices. Google is a prominent example of a company committed to achieving carbon neutrality. In 2017, Google announced that it had achieved 100% renewable energy for its global data centers and offices, making it the first major company to do so (Google, 2020). This achievement was made possible through long-term power purchase agreements (PPAs) with renewable energy providers, enabling Google to invest in wind and solar projects around the world. The company continues to innovate, aiming to operate on 24/7 carbon-free energy by 2030, demonstrating leadership in corporate sustainability.

Unilever, another corporate leader, has also set ambitious sustainability goals. The company has committed to sourcing 100% of its energy from renewable sources by 2030 and aims to achieve net-zero emissions across its value chain by 2039 (Unilever, 2021). Initiatives such as the Unilever Sustainable Living Plan have guided the company's efforts in reducing greenhouse gas emissions and improving energy efficiency. Their investments in renewable energy projects, including solar and biomass, have not only reduced their carbon footprint but also resulted in significant cost savings.

Furthermore, IKEA has made significant strides in sustainability by investing heavily in renewable energy. The company aims to become climate positive by 2030, focusing on increasing its use of renewable energy across its operations. As of 2021, IKEA has invested over €2.5 billion in renewable energy projects, including onshore wind farms and solar installations, and is committed to producing more renewable energy than it consumes (IKEA, 2021). Their initiatives have positioned IKEA as a leader in sustainable business practices, inspiring other companies to follow suit.

These case studies illustrate that successful transitions to renewable energy are not only achievable at the national level but also at the corporate level. Through innovative policies, ambitious projects, and corporate commitments to sustainability, these countries and companies are paving the way for a cleaner, more sustainable energy future.

## CHALLENGES FACING RENEWABLE ENERGY ADOPTION

While the transition to renewable energy presents numerous benefits, several challenges hinder its widespread adoption. These challenges encompass infrastructure limitations, intermittency and reliability issues, policy and regulatory barriers, and economic considerations.

One of the primary obstacles to renewable energy adoption is the need for upgraded infrastructure to effectively integrate renewable sources into existing energy systems. The current electrical grid, in many regions, is not equipped to handle the variability and distributed nature of renewable energy sources like wind and solar (International Energy Agency [IEA], 2021). As renewable energy generation often occurs at different



times and locations from conventional energy sources, grid operators require advanced infrastructure, such as smart grids, to ensure efficient energy distribution and manage demand fluctuations.

Upgrading the grid infrastructure involves significant investments and coordination among multiple stakeholders, including utility companies, government agencies, and private investors. In the United States, for example, the American Society of Civil Engineers (ASCE) has estimated that an investment of approximately \$4.5 trillion is needed by 2025 to address the country's aging energy infrastructure and enhance its ability to incorporate renewable energy (ASCE, 2021). This necessity for infrastructure enhancement poses a significant challenge to the rapid deployment of renewable energy technologies.

Intermittency is a significant challenge associated with renewable energy sources, particularly solar and wind. These resources are inherently variable, with their energy output fluctuating based on weather conditions, time of day, and seasonal changes. For instance, solar energy generation is limited during cloudy days and non-daylight hours, while wind energy generation can vary based on wind speed and direction (Lund et al., 2020).

This variability creates reliability concerns, as traditional energy systems are designed to provide a consistent and stable power supply. To address these challenges, effective energy storage solutions are essential. However, current energy storage technologies, such as lithium-ion batteries, face limitations in terms of capacity, lifespan, and cost (Nykqvist & Nilsson, 2015). Although advancements are being made, such as the development of solid-state batteries and pumped hydro storage, the need for reliable, scalable, and cost-effective energy storage solutions remains a critical barrier to the integration of renewable energy into the grid.

The success of renewable energy initiatives is heavily influenced by policy and regulatory frameworks. In many cases, regulatory hurdles can impede the development and deployment of renewable energy projects. For instance, complex permitting processes, inconsistent regulations across regions, and lack of clear guidelines can slow project timelines and increase costs (Wiser et al., 2020).

Moreover, the absence of robust financial incentives can discourage investment in renewable energy. Policies such as feed-in tariffs, tax credits, and renewable portfolio standards have been instrumental in driving renewable energy adoption in several countries. However, the inconsistency of these incentives can create uncertainty for investors and developers (IRENA, 2020). Supportive policies that promote long-term investment in renewable energy technologies are essential to overcome these regulatory barriers and foster a conducive environment for sustainable energy solutions.

Economic factors also play a significant role in the adoption of renewable energy. While the costs of renewable energy technologies have decreased significantly in recent years, the initial investment required for projects can still be a barrier to entry. For instance, the installation of solar panels, wind turbines, and energy storage systems often requires substantial upfront capital, which may not be readily available for all potential investors (IRENA, 2021).

Additionally, market volatility can affect the financial viability of renewable energy projects. Fluctuations in commodity prices, such as those for metals used in solar panels and batteries, can impact overall project costs. Furthermore, securing financing for large-scale renewable energy projects can be challenging, particularly in emerging markets where access to capital may be limited (Gonzalez et al., 2021). To address these economic challenges, innovative financing options, such as green bonds and public-private partnerships, must be explored to facilitate investment in renewable energy.

## **FUTURE OUTLOOK AND SOLUTIONS**

As the world grapples with the urgent need to transition to renewable energy, innovative solutions, policy recommendations, and global cooperation will play critical roles in overcoming the current challenges. By harnessing emerging technologies and fostering collaboration across borders, we can accelerate the shift towards a sustainable energy future.

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## Innovative Solutions

Emerging technologies hold the potential to address many challenges currently facing renewable energy adoption. One of the most promising areas of innovation is improved battery technology. Advanced battery systems, such as solid-state batteries and flow batteries, promise higher energy densities, longer lifespans, and improved safety compared to traditional lithium-ion batteries (Nykvist & Nilsson, 2015). These advancements can enhance energy storage capacity, enabling better integration of intermittent renewable energy sources like solar and wind into the grid. For example, solid-state batteries could revolutionize energy storage by offering significantly faster charging times and greater longevity, addressing key reliability issues (Kraft et al., 2021).

Another exciting development is the advancement of hydrogen fuel technologies. Hydrogen, particularly green hydrogen produced through electrolysis powered by renewable energy, presents a versatile solution for energy storage and transportation. It can be stored and transported efficiently, and used in various applications, including heavy industry, shipping, and even as a fuel for vehicles. The International Renewable Energy Agency (IRENA) projects that hydrogen could provide up to 24% of the world's energy needs by 2050, thus playing a crucial role in decarbonizing hard-to-abate sectors (IRENA, 2020).

Moreover, the integration of smart grid technologies and the Internet of Things (IoT) can optimize energy distribution and consumption. These technologies allow for real-time monitoring and management of energy resources, enhancing grid resilience and facilitating demand response initiatives. Smart grids can enable the efficient use of renewable energy and minimize waste, providing a more stable and reliable energy supply (International Energy Agency [IEA], 2020).

## Policy Recommendations

To further promote the adoption of renewable energy, several policy recommendations can be implemented. First, governments should consider tax incentives for both consumers and businesses that invest in renewable energy technologies. For instance, extending tax credits for solar panel installations and electric vehicles can motivate more individuals and companies to adopt clean energy solutions (U.S. Department of Energy, 2021).

Subsidies for renewable energy projects can also help reduce the financial barriers associated with initial investments. By providing financial support to developers and investors, governments can stimulate the growth of renewable energy markets and attract private investment. Countries like Germany and the Netherlands have successfully utilized feed-in tariffs and capacity payments to incentivize renewable energy generation, resulting in substantial increases in installed capacity (Agora Energiewende, 2021).

Additionally, implementing a carbon pricing mechanism can effectively internalize the environmental costs of fossil fuel use. By establishing a price on carbon emissions, governments can create financial incentives for businesses and consumers to transition to cleaner energy sources. Such policies not only encourage renewable energy adoption but also promote energy efficiency and innovation across sectors (World Bank, 2021).

## Global Cooperation

The transition to renewable energy is a global challenge that necessitates international collaboration. Global agreements, such as the Paris Agreement, play a pivotal role in setting collective goals for emissions reduction and promoting renewable energy adoption. The agreement aims to limit global warming to well below 2 degrees Celsius, which requires significant increases in renewable energy capacity worldwide (United Nations Framework Convention on Climate Change [UNFCCC], 2015).

Furthermore, collaboration among countries can facilitate the sharing of best practices, technologies, and resources. Initiatives like the International Solar Alliance aim to promote solar energy deployment in member countries through capacity building, research, and investment (International Solar Alliance, 2021). By fostering partnerships, countries can leverage their unique strengths and resources to accelerate the global transition to renewable energy.

## CONCLUSION

The transition to renewable energy is not only vital for mitigating climate change but also presents a pathway to a more sustainable and resilient future. Throughout this discussion, we have explored the importance of renewable energy in reducing greenhouse gas emissions and promoting energy security. The progress made in technological advancements, global adoption rates, and successful case studies demonstrates the growing viability of renewable sources, such as solar, wind, and hydrogen. However, we also highlighted the challenges that remain, including infrastructure limitations, intermittency issues, policy barriers, and economic considerations that must be addressed to fully realize the potential of renewable energy.

As we look toward the future, it is essential for individuals, communities, and policymakers to advocate for and support renewable energy initiatives. We encourage readers to actively engage in discussions about renewable energy policies and to make personal choices that contribute to sustainability—whether that means reducing energy consumption, investing in energy-efficient appliances, or supporting local renewable energy projects. Every action counts in fostering a culture that prioritizes clean energy solutions.

The potential of renewable energy to transform the fight against climate change is immense. By harnessing innovative technologies, fostering supportive policies, and collaborating globally, we can create a cleaner, healthier planet for future generations. The transition to renewable energy is not merely an option; it is an imperative that holds the promise of a sustainable future, allowing us to confront the climate crisis with determination and hope. Together, we can usher in a new era of energy that benefits both people and the planet.

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