Systemic Analytics

www.sa-journal.org

Syst. Anal. Vol. 2, No. 2 (2024) 315-334.

Paper Type: Original Article

A Comprehensive Review on Green Energy Technologies: An Approach for Environmental Sustainability and Eco-Friendliness

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Citation:

Received: 22 August 2024 *Revised: 24 October 2024* *Accepted: 29 November 2024*	Etebom Itiat, N., Ime Ekanem, I., & Essienubong Ikpe, A. (2024). A comprehensive review on green energy technologies: An approach for environmental sustainability and eco-friendliness. *Systemic Analytics, 2*(2), 315-334.

Abstract

The reliance on fossil fuels for energy production has led to environmental degradation and climate change. The burning of fossil fuels releases greenhouse gases into the atmosphere, contributing to global warming and air pollution. As a result, there is a pressing need for alternative energy sources that are sustainable and eco-friendly. Green energy technologies offer a promising solution to this problem by harnessing renewable resources such as sunlight, wind, and water to generate clean energy. However, the adoption of green energy technologies faces challenges such as high initial costs and limited infrastructure. This study aims to explore the potential of green energy technologies in addressing environmental sustainability and promoting eco-friendliness. This paper employed a literature review methodology to examine the current state of green energy technologies and their impact on the environment. The review includes studies, reports, and articles on various green energy technologies, such as solar power, wind energy, and hydropower. The literature review also explored the benefits of green energy technologies, including reduced greenhouse gas emissions, improved air quality, and energy security. Additionally, the review examines the challenges and barriers to the adoption of green energy technologies, such as policy constraints and technological limitations. The findings revealed that green energy technologies have a positive impact on the environment. Solar power, for example, is a clean and renewable energy source that can reduce greenhouse gas emissions and air pollution. Wind energy is another green energy technology that can help mitigate climate change and promote sustainable development. Hydropower, biomass, and geothermal energy are also viable options for generating clean energy. Despite the benefits of green energy technologies, challenges such as high costs and limited infrastructure remain barriers to their widespread adoption. Ultimately, investing in green energy technologies is essential for achieving environmental sustainability and ensuring a cleaner, healthier planet for future generations.

Keywords: Green energy technologies, Environmental sustainability, Eco-friendliness, Climate change, Greenhouse gas emissions.

1 | Introduction

Green energy technology refers to the various methods and technologies that harness renewable energy sources such as solar, wind, hydro, geothermal, and biomass to generate electricity and heat [1], [2].

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https://doi.org/10.31181/sa22202427

These technologies are crucial in the transition towards a more sustainable and eco-friendly energy system, as they help reduce greenhouse gas emissions and dependence on fossil fuels. The principles of green energy technologies are rooted in the concept of sustainability, which aims to meet the needs of the present without compromising the ability of future generations to meet their own needs. This involves the efficient use of resources, minimizing environmental impact, and promoting social equity. Green energy technologies adhere to these principles by utilizing renewable energy sources that are abundant, clean, and readily available, thereby reducing the reliance on finite and polluting fossil fuels [3], [4].

The introduction of green energy technologies has been driven by the urgent need to address climate change and reduce the environmental impact of energy production. The burning of fossil fuels for electricity and heat generation is a major contributor to greenhouse gas emissions, which are responsible for global warming and climate change [5]. By transitioning to green energy technologies, we can significantly reduce these emissions and mitigate the negative effects of climate change. These processes involved in green energy technologies vary depending on the specific technology being used. Solar energy technologies, for example, harness sunlight to generate electricity through photovoltaic cells or concentrated solar power systems [6], [7].

Wind energy technologies use wind turbines to convert the kinetic energy of the wind into electricity. Hydroelectric power plants utilize the energy of flowing water to generate electricity, while geothermal energy technologies tap into the heat of the Earth's core to produce electricity and heat. Biomass energy technologies convert organic materials such as wood, crop residues, and animal waste into biofuels for heat and electricity generation [8], [9]. Numerous studies have been conducted to evaluate the environmental and economic benefits of green energy technologies. These studies have consistently shown that green energy technologies offer significant advantages over conventional fossil fuel-based energy systems in terms of reducing greenhouse gas emissions, improving air quality, and enhancing energy security. Furthermore, the deployment of green energy technologies has the potential to create new job opportunities, stimulate economic growth, and enhance energy access in remote and underserved communities [10].

2|Advancements in Green Energy Technologies

In recent years, there have been significant advancements in green energy technologies that have paved the way for a more sustainable and eco-friendly future. These key milestones in the development of green energy technologies have not only helped to reduce our reliance on fossil fuels but have also contributed to the preservation of the environment and the promotion of eco-friendliness. Some of the key milestones in the recent advancements in green energy technologies include:

I. Widespread adoption of solar power: solar power has become increasingly affordable and efficient, making it a viable alternative to traditional forms of energy generation. The development of solar panels and solar farms has allowed for the harnessing of the sun's energy to power homes, businesses, and even entire communities. This shift towards solar power has significantly reduced our carbon footprint and has helped to mitigate the effects of climate change [11], [12].

II. The advancement of wind power: wind turbines have become a common sight in many parts of the world, generating clean and renewable energy from the power of the wind. The development of offshore wind farms has further expanded the potential of wind power, allowing for the generation of electricity in areas with strong and consistent winds. Wind power has proven to be a reliable and sustainable source of energy, helping to reduce our reliance on fossil fuels and decrease harmful emissions [13], [14].

III. Advancements in energy storage technologies have also played a crucial role in the development of green energy solutions, the development of batteries and other energy storage systems has allowed for the efficient storage and distribution of renewable energy, making it possible to use solar and wind power even when the sun is not shining, or the wind is not blowing. Energy storage technologies have helped to overcome the intermittent nature of renewable energy sources, making them more reliable and practical for everyday use [6], [15].

These key milestones in the recent advancements in green energy technologies have paved the way for a more sustainable and eco-friendly future. By harnessing the power of the sun and wind and by developing innovative energy storage solutions, we can reduce our impact on the environment and promote a cleaner and healthier planet for future generations. We must continue to invest in and support the development of green energy technologies in order to achieve environmental sustainability and eco-friendliness.

3 | Classifications of Green Energy Systems

Green energy systems are becoming increasingly popular as the world seeks to reduce its reliance on fossil fuels and combat climate change. These systems harness renewable sources of energy such as sunlight, wind, and water to generate electricity and heat. Some of the classifications of green energy systems are as follows:

I. The green energy system is based on the source of energy they harness: Solar energy systems, for example, capture sunlight using photovoltaic cells or solar thermal collectors. Wind energy systems, on the other hand, use turbines to convert the kinetic energy of the wind into electricity [16]. Hydropower systems harness the energy of flowing water to generate electricity (*Fig. 1*), while geothermal systems tap into the heat of the Earth's core.

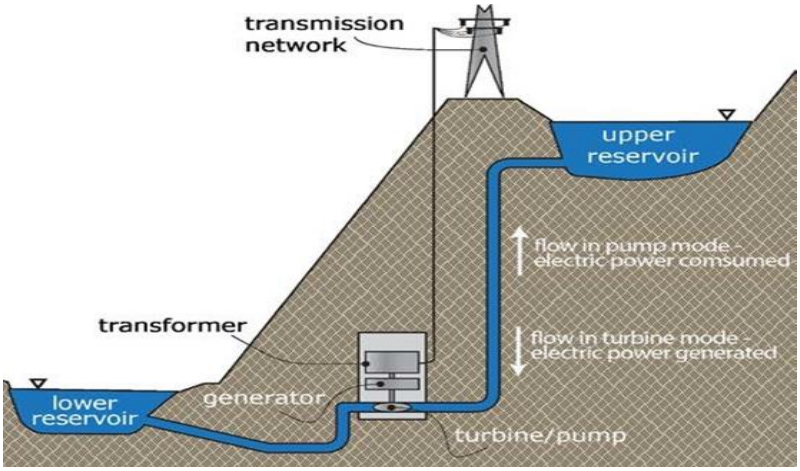

Fig. 1. Pumped storage hydro plants system [17].

II. The green energy system is based on its scale and location: distributed energy systems, such as rooftop solar panels and small wind turbines, are installed at or near the point of use. These systems can provide energy independence and resilience to individual homes and businesses. Utility-scale energy systems, on the other hand, are large installations that feed electricity into the grid. These systems can provide clean energy to a wider population but may face challenges related to land use and transmission infrastructure [18], [19].

III. The green energy system is based on its storage capabilities: some systems, such as solar panels and wind turbines, generate electricity only when the sun is shining or the wind is blowing. To overcome this intermittency, energy storage systems such as batteries or pumped hydro storage can be used to store excess energy for use when the renewable source is not available. This can help to ensure a reliable and stable supply of green energy [20].

Green energy systems can be classified based on the source of energy they harness, their scale and location, and their storage capabilities. Each classification has its advantages and limitations, and the choice of system will depend on factors such as resource availability, energy demand, and cost. By understanding these classifications, policymakers, businesses, and individuals can make informed decisions about the adoption of green energy systems to help transition to a more sustainable and low-carbon energy future.

4 | Types of Green Energy Resources

Green energy resources are becoming increasingly important in the fight against climate change and the depletion of non-renewable resources. Several types of green energy resources are being utilized to reduce carbon emissions and promote sustainability. This includes solar power, wind power, hydropower, and geothermal energy, which are listed as follows:

I. Solar power: this is one of the most widely used green energy resources, harnessing the power of the sun to generate electricity. Solar panels are installed on rooftops or in solar farms to capture sunlight and convert it into usable energy (*Fig. 2*). This type of energy resource is abundant and renewable, making it a sustainable alternative to fossil fuels. Additionally, solar power systems can be installed on a small scale for individual homes or businesses or on a larger scale to power entire communities [21].

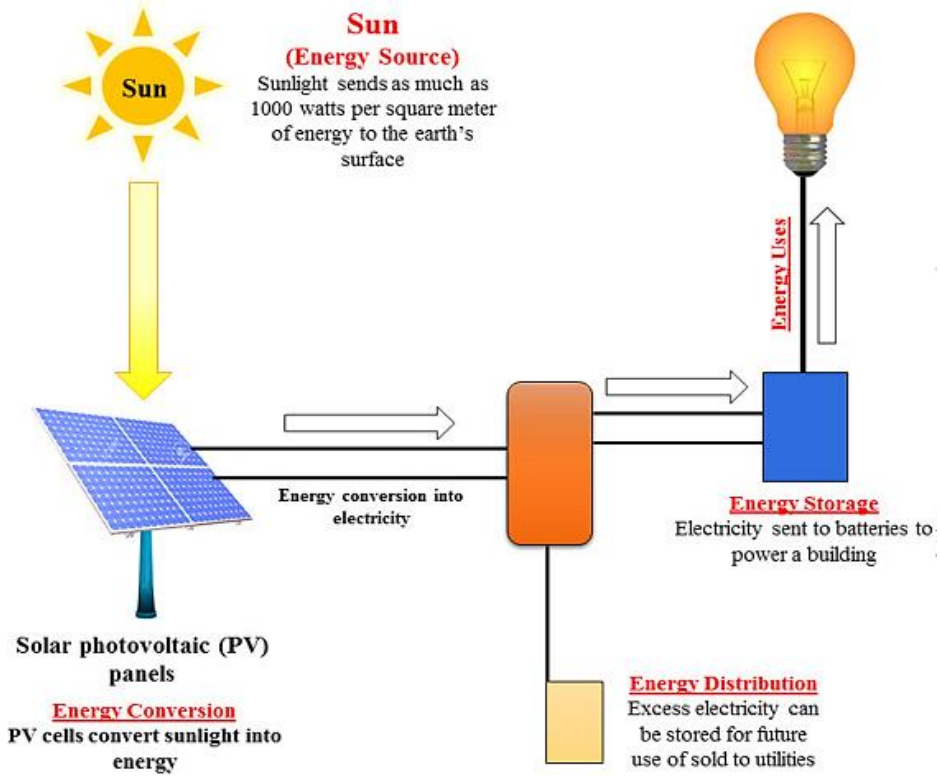

Fig. 2. solar radiation through a photovoltaic solar panel for energy uses [22].

II. Wind power: this is another popular green energy resource, utilizing wind turbines to generate electricity. Wind turbines are typically installed in windy areas such as coastal regions or open plains (*Fig. 3*), where they can capture the energy of the wind and convert it into electricity. Wind power is also a renewable resource, as natural processes constantly replenish wind. While wind power can be intermittent depending on weather conditions, advancements in technology have made it a reliable source of energy for many communities [23], [24].

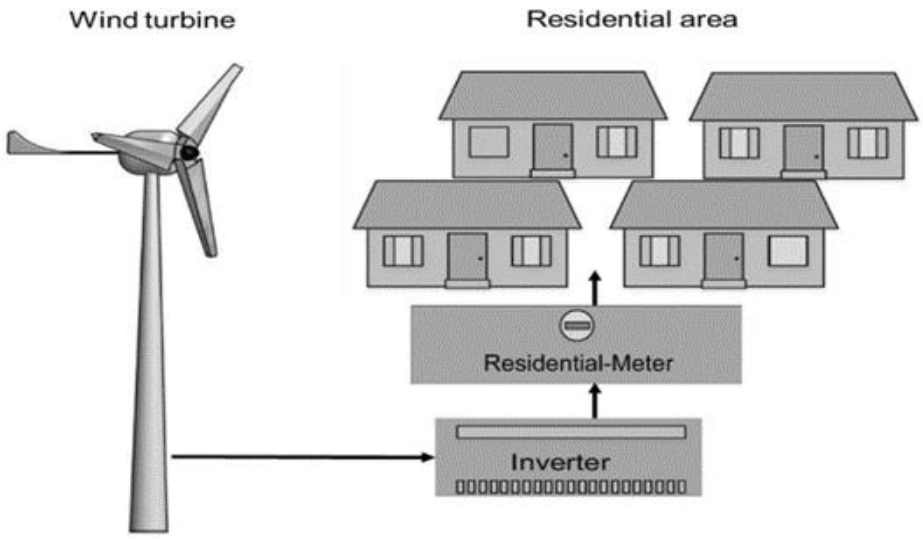

Fig. 3. Wind power [25].

III. Hydropower: this is a green energy resource that harnesses the power of flowing water to generate electricity. Dams are built on rivers or streams to create reservoirs of water, which can then be released to turn turbines and generate electricity (*Fig. 4*). Hydropower is a reliable and consistent source of energy, as water flow can be controlled to meet demand. However, the construction of dams can have negative environmental impacts, such as disrupting ecosystems and displacing communities [26], [27].

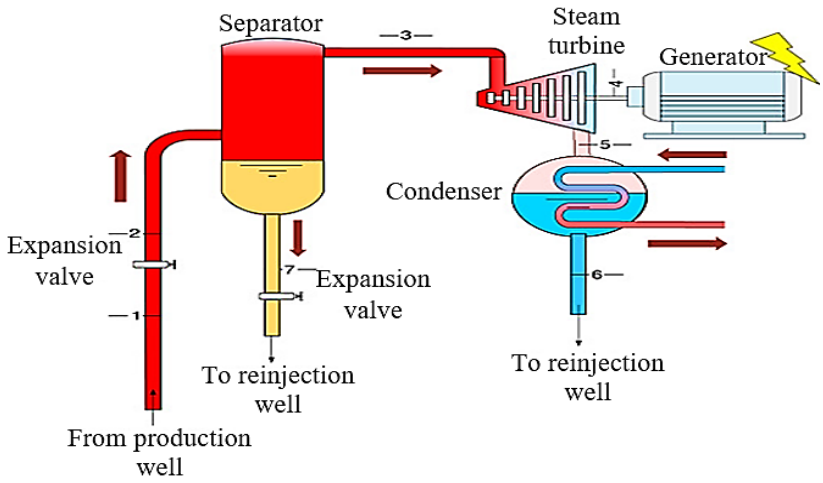

Fig. 4. Hydropower [28].

IV. eothermal energy: this is a green energy resource that utilizes the heat from the Earth's core to generate electricity. Geothermal power plants are built near geothermal hotspots, where steam or hot water can be extracted from underground reservoirs and used to turn turbines (*Fig. 5*). Geothermal energy is a renewable resource that produces minimal greenhouse gas emissions, making it a clean alternative to fossil fuels. Geothermal power plants can be expensive to build and are limited to areas with geothermal activity [29], [30].

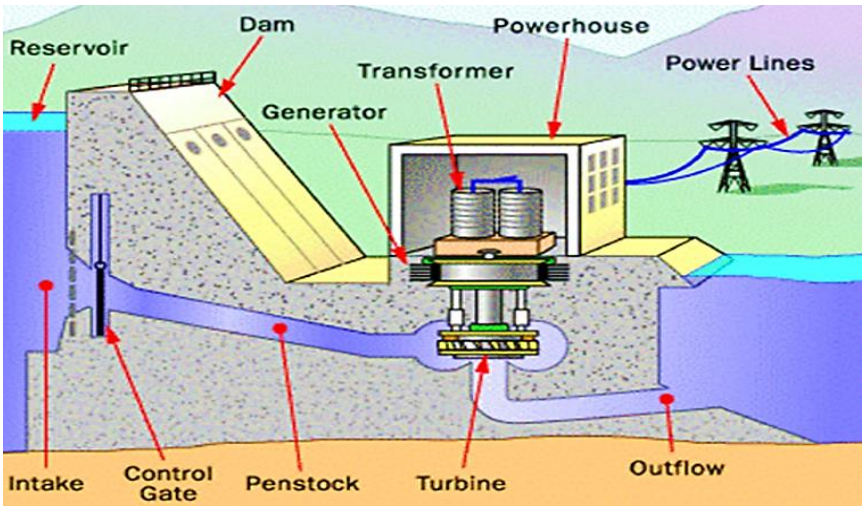

Fig. 5. Geothermal electricity generation [31].

Several types of green energy resources are being utilized to reduce carbon emissions and promote sustainability. Solar power, wind power, hydropower, and geothermal energy are all renewable resources that offer clean alternatives to fossil fuels. While each type of green energy resource has its advantages and limitations, they all play a crucial role in the transition to a more sustainable energy future.

5 | Contribution of Green Energy to Urban Development

In urban areas, where the majority of the world's population resides, the integration of green energy technologies has the potential to significantly impact urban development positively. The contributions of green energy to urban development are as follows:

I. Reduction of greenhouse gas emissions: by utilizing renewable energy sources such as solar, wind, and hydropower, cities can significantly reduce their carbon footprint and mitigate the effects of climate change. This reduction in emissions not only benefits the environment but also improves air quality and public health in urban areas [32], [33].

II. Creation of green jobs and economic growth: the renewable energy sector has been growing rapidly in recent years, creating new job opportunities and stimulating economic development in urban areas. By investing in green energy technologies, cities can attract new businesses, spur innovation, and create a more sustainable and resilient economy [34], [35].

III. Enhancement of energy security and independence: by diversifying their energy sources and reducing reliance on imported fossil fuels, cities can increase their energy security and resilience to external shocks. This is particularly important in the face of increasing geopolitical tensions and volatile energy markets [36].

IV. Promotion of energy efficiency and conservation: green energy technologies are often more efficient than traditional fossil fuel-based systems, leading to lower energy consumption and cost savings for urban residents and businesses. By promoting energy efficiency and conservation measures, cities can reduce their overall energy demand and improve their energy resilience [37], [38].

The contributions of green energy to urban development are clear and compelling. By reducing greenhouse gas emissions, creating green jobs, enhancing energy security, and promoting energy efficiency, green energy technologies have the potential to transform urban areas into sustainable and resilient cities. Cities must prioritize the integration of green energy into their development plans in order to create a more sustainable future for all.

6 | Sustainability of Green Energy

The recognition of the detrimental impact of traditional fossil fuels on the environment, including air and water pollution, deforestation, and greenhouse gas emissions, has driven the shift towards green energy. The sustainability impact of green energy technologies includes:

I. Minimal impact on the environment: unlike fossil fuels, which release harmful pollutants into the atmosphere when burned, green energy sources produce little to no emissions. For example, solar panels harness energy from the sun without emitting any greenhouse gases, while wind turbines generate electricity without producing air pollutants. By transitioning to green energy, we can significantly reduce our carbon footprint and mitigate the effects of climate change [39], [40].

II. Promotion of environmental sustainability via conservation of natural resources: fossil fuels are finite resources that are being depleted at an alarming rate, leading to increased competition and conflict over access to these resources. In contrast, renewable energy sources are abundant and widely available, making them a more sustainable option for meeting our energy needs in the long term. By investing in green energy infrastructure, we can reduce our dependence on finite resources and ensure a more secure and stable energy supply for future generations [41], [42].

III. Economic impact: the renewable energy sector has been experiencing rapid growth in recent years, creating new job opportunities and driving innovation in clean energy technologies. By investing in green energy, countries can stimulate economic growth, reduce energy costs, and enhance energy security. Furthermore, the transition to green energy can help diversify energy sources and reduce reliance on imported fossil fuels, thereby increasing energy independence and resilience [43], [44].

IV. Cost of implications: the transition to green energy is not without challenges. The initial cost of implementing renewable energy technologies is higher than traditional fossil fuel infrastructure. However, the long-term benefits of green energy, including reduced environmental impact and lower operating costs, outweigh the upfront investment. Governments and businesses must prioritize sustainable energy policies and incentives to accelerate the transition to green energy and overcome financial barriers [45], [46].

Green energy plays a crucial role in promoting environmental sustainability and mitigating the effects of climate change. By harnessing renewable energy sources such as solar, wind, and hydroelectric power, we can reduce our carbon footprint, conserve natural resources, and stimulate economic growth. The transition to green energy is a necessary step toward building a more sustainable and resilient energy system for future generations. Governments, businesses, and individuals must work together to accelerate the adoption of green energy and create a more sustainable future for all.

7 | Green Energy Policies at Local, National and International Levels

Green energy utilization has become a critical issue in the global effort to combat climate change and reduce reliance on fossil fuels. Governments at the local, national, and international levels have implemented various policies to promote the use of renewable energy sources such as solar, wind, and hydropower, some of which include the following:

I. At the local level, many cities and municipalities have implemented policies to promote the use of green energy. For example, some cities have set targets for the percentage of energy that must come from renewable sources, while others have implemented incentives such as tax breaks or subsidies for businesses and homeowners who install solar panels or other renewable energy systems. These local policies are often aimed at reducing greenhouse gas emissions and promoting sustainable development within the community [47], [48].

II. At the national level, many countries have implemented policies to promote the use of green energy. For example, some countries have set Renewable Energy Targets (RETs) that must be met by a certain date, while others have implemented Feed-in Tariffs (FITs) that guarantee a fixed price for electricity generated

from renewable sources. These national policies are often aimed at reducing dependence on imported fossil fuels and promoting economic growth in the renewable energy sector [49], [50].

III. Internationally, there are also a number of policies in place to promote green energy utilization. For example, the United Nations Framework Convention on Climate Change (UNFCCC) has established the Clean Development Mechanism (CDM), which allows developed countries to invest in green energy projects in developing countries as a way to offset their emissions. Additionally, the Paris Agreement, which was signed by nearly 200 countries in 2015, sets targets for reducing greenhouse gas emissions and promoting the use of renewable energy on a global scale [51], [52]. There are a wide range of policies at the local, national, and international levels that are aimed at promoting the use of green energy. These policies are essential for reducing greenhouse gas emissions, combating climate change, and promoting sustainable development. By continuing to implement and strengthen these policies, governments can help to create a more sustainable and environmentally friendly energy system for future generations.

8 | List of Green Energy Policies

Green energy policies are essential for promoting the use of renewable energy sources and reducing our reliance on fossil fuels. The various green energy policies that can be implemented to accelerate the transition to a more sustainable energy system are as follows:

I. Renewable Portfolio Standards (RPS): one of the most common green energy policies is the implementation of RPS, which require utilities to generate a certain percentage of their electricity from renewable sources. This policy has been successful in increasing the deployment of renewable energy technologies in many states [53], [54].

II. Feed-in tariffs: another effective policy tool is the use of FITs, which guarantee a fixed price for electricity generated from renewable sources. This provides a stable revenue stream for renewable energy projects and incentivizes investment in clean energy technologies [55].

III. Tax incentives: tax incentives, such as investment tax credits and production tax credits, can help reduce the cost of renewable energy projects and make them more competitive with fossil fuels. These incentives have been instrumental in driving the growth of the renewable energy industry [56].

IV. Net metering: net metering policies allow customers with rooftop solar panels or other distributed generation systems to sell excess electricity back to the grid at retail rates. This provides a financial incentive for homeowners and businesses to invest in renewable energy systems [57].

V. Energy efficiency standards: improving energy efficiency is a key component of any green energy policy. Setting energy efficiency standards for appliances, buildings, and vehicles can help reduce energy consumption and greenhouse gas emissions [58], [59].

VI. Carbon Pricing: implementing a carbon pricing mechanism, such as a carbon tax or cap-and-trade system, can help internalize the external costs of carbon emissions and incentivize the transition to cleaner energy sources [60].

VII. Research and development funding: investing in research and development for new clean energy technologies is crucial for driving innovation and reducing the cost of renewable energy. Government funding for research programs can help accelerate the development and deployment of green energy solutions [61].

Implementing a comprehensive set of green energy policies is essential for transitioning to a more sustainable energy system. By combining regulatory measures, financial incentives, and research and development funding, policymakers can create a supportive environment for the growth of renewable energy technologies. Governments at all levels must take action to address the urgent challenges of climate change and promote the adoption of clean energy solutions.

9 | Procedure for Integrating Green Energy into Industrial Operations

Green energy can be integrated into industrial operations to reduce carbon emissions and promote a more sustainable future using the following procedures:

I. The first procedure in incorporating green energy into industrial operations is to conduct a thorough energy audit to identify areas where energy efficiency can be improved. This may involve upgrading equipment to more energy-efficient models, implementing energy management systems, and optimizing processes to reduce energy consumption [62], [63].

II. Once energy efficiency measures have been implemented, the next step is to assess the feasibility of incorporating renewable energy sources such as solar, wind, or hydropower into the industrial operation. This may involve conducting a site assessment to determine the potential for renewable energy generation, evaluating the costs and benefits of different renewable energy technologies, and securing financing for the installation of renewable energy systems [64], [65].

III. After renewable energy systems have been installed, the next step is to integrate them into the industrial operation and optimize their performance. This may involve implementing smart grid technologies to manage energy production and consumption, developing energy storage solutions to store excess energy for later use, and implementing energy management systems to monitor and control energy usage [66].

Finally, ongoing monitoring and maintenance of green energy systems are essential to ensure their continued performance and reliability. This may involve regular inspections, maintenance, and repairs of renewable energy systems, as well as monitoring energy production and consumption to identify opportunities for further optimization [67]. Integration of green energy into industrial operations is essential for reducing carbon emissions, promoting sustainability, and ensuring the long-term viability of industrial operations. By following the aforementioned procedure outlined in this study, industrial operators can successfully transition to a more sustainable energy future while also reducing their environmental impact.

10 | Comparison between Green Energy and Non-Green Energy

Green energy is energy sources that are environmentally friendly and sustainable, such as solar, wind, and hydroelectric power, while non-green energy, or conventional energy, includes fossil fuels like coal, oil, and natural gas. The comparison between green energy and non-green energy is as follows:

I. One of the key differences between green energy and non-green energy lies in their environmental impact. Green energy sources produce significantly lower levels of greenhouse gas emissions compared to non-green energy sources. For example, solar and wind power generate electricity without releasing harmful pollutants into the atmosphere, whereas coal-fired power plants are major contributors to air pollution and climate change. This difference in environmental impact is a crucial factor to consider when evaluating the sustainability of energy sources [68], [69].

II. The availability and accessibility of green energy versus non-green energy also differ significantly. Green energy sources, such as sunlight and wind, are abundant and widely distributed, making them accessible in many regions around the world. In contrast, non-green energy sources like fossil fuels are finite resources that are concentrated in specific geographic locations. This disparity in availability has important implications for energy security and independence, as countries that rely heavily on non-green energy sources may be vulnerable to supply disruptions and price fluctuations [70].

III. In terms of cost, green energy has traditionally been more expensive to produce and implement compared to non-green energy. However, advancements in technology and economies of scale have led to significant reductions in the cost of renewable energy sources in recent years. In fact, in many cases, green energy is now cost-competitive with non-green energy, making it a viable alternative for meeting energy needs. Additionally, the long-term benefits of green energy, such as reduced environmental damage and improved public health, can outweigh the initial investment costs [71].

Another important consideration when comparing green energy and non-green energy is their impact on public health and safety. Non-green energy sources, particularly fossil fuels, are associated with a range of health problems, including respiratory illnesses, cardiovascular diseases, and premature death. In contrast, green energy sources have minimal negative health impacts and can contribute to improved air quality and overall well-being. This difference in health outcomes underscores the importance of transitioning to cleaner and more sustainable energy sources [72].

The comparison between green energy and non-green energy reveals a clear preference for renewable energy sources in terms of environmental sustainability, availability, cost-effectiveness, and public health benefits. While there are challenges and barriers to overcome in the transition to a greener energy system, the long-term benefits of investing in renewable energy far outweigh the costs. By prioritizing the development and deployment of green energy technologies, we can create a more sustainable and resilient energy future for generations to come.

11 | Anatomy of Green Energy Systems

Green energy systems harness renewable sources of energy such as sunlight, wind, and water to generate electricity in a sustainable and environmentally friendly manner. The detailed anatomy of green energy systems is as follows:

I. The collection of renewable energy from natural sources: solar panels, wind turbines, and hydroelectric dams are commonly used to capture energy from the sun, wind, and water, respectively. These systems convert energy into electricity through a process known as photovoltaic conversion, wind power generation, or hydroelectric power generation [73].

II. Once the renewable energy has been collected, it is typically stored in batteries or fed directly into the electrical grid for distribution. Battery storage systems are essential for ensuring a reliable and continuous power supply, especially when the sun is not shining or the wind is not blowing. Grid-connected systems, on the other hand, allow excess energy to be sold back to the grid, providing an additional source of income for green energy system owners [74].

III. The conversion of the collected energy into usable electricity: this process involves the use of inverters, transformers, and other electrical components to convert the direct current (DC) electricity generated by solar panels or wind turbines into alternating current (AC) electricity that can be used to power homes, businesses, and other electrical devices [75].

IV. Green energy systems also require monitoring and control systems to ensure optimal performance and efficiency. These systems use sensors, meters, and software to track energy production, consumption, and storage, allowing system owners to optimize their energy usage and reduce their carbon footprint [76].

Green energy systems are complex and multifaceted systems that require careful planning, design, and implementation to ensure their success. By understanding the anatomy of these systems, the importance of renewable energy sources in the transition to a more sustainable and environmentally friendly energy future can better be appreciated.

12 | Procedure for Harnessing and Storing of Green Energy

Harnessing and storing green energy is crucial in the transition towards a more sustainable and environmentally friendly energy system. Green energy sources such as solar, wind, and hydroelectric power have the potential to significantly reduce our reliance on fossil fuels and mitigate the impacts of climate change. In this study, the procedures for harnessing and storing green energy are highlighted as follows:

I. Identify suitable locations for renewable energy installations: this involves conducting thorough assessments of the available resources, such as sunlight, wind, or water flow, to determine the feasibility of implementing solar panels, wind turbines, or hydroelectric dams. Site selection is crucial in maximizing the efficiency and output of green energy systems, as well as minimizing environmental impacts [77].

II. Install the necessary infrastructure for harnessing green energy: this may involve installing solar panels on rooftops or open fields, erecting wind turbines in windy areas, or constructing hydroelectric dams on rivers or streams. The installation process requires careful planning and coordination to ensure that the systems are properly designed and implemented to maximize energy production [78], [79].

III. Connect them to the grid or storage systems: grid connection allows for the integration of renewable energy into the existing power infrastructure, enabling the excess energy generated to be fed back into the grid for use by other consumers. Alternatively, energy storage systems such as batteries or pumped hydro storage can be used to store excess energy for use during periods of low renewable energy production [80].

IV. Energy storage is a critical component of the green energy system, as it allows for the efficient utilization of renewable energy and helps to balance supply and demand. Energy storage systems can store excess energy generated during peak production periods and release it during times of high demand, ensuring a reliable and stable energy supply [81]. Additionally, energy storage systems can help to mitigate the variability of renewable energy sources such as solar and wind power, making them more reliable and consistent sources of energy.

Harnessing and storing green energy is essential in the transition towards a more sustainable and environmentally friendly energy system. By following the aforementioned procedure that includes site selection, installation of infrastructure, grid connection, and energy storage, the power of renewable energy sources can be effectively harnessed, and the reliance on fossil fuels can be reduced. This process is crucial in achieving a more sustainable future and mitigating the impacts of climate change.

13 | Regulatory Bodies for Green Energy Systems

In the rapidly evolving field of green energy systems, regulatory bodies play a crucial role in ensuring the safety, efficiency, and sustainability of renewable energy technologies. The following regulatory bodies are responsible for setting standards, enforcing regulations, and monitoring compliance within the green energy sector:

I. The Environmental Protection Agency (EPA): the EPA is a federal agency in the United States that is responsible for regulating greenhouse gas emissions and enforcing environmental laws related to renewable energy sources. The EPA plays a key role in setting emissions standards for power plants and other sources of pollution, as well as promoting the development of clean energy technologies [82].

II. The Federal Energy Regulatory Commission (FERC): FERC is an independent regulatory agency that oversees the interstate transmission of electricity, natural gas, and oil. FERC plays a critical role in regulating the energy markets and ensuring fair competition among energy providers. The commission also promotes the development of renewable energy resources through its regulatory authority.

III. The Department of Energy (DOE): the DOE is a federal agency that is responsible for promoting energy efficiency and renewable energy technologies in the United States. The DOE funds research and development projects in the green energy sector, as well as providing technical assistance and financial incentives for renewable energy projects [83].

IV. The International Renewable Energy Agency (IRENA): IRENA is an intergovernmental organization that promotes the widespread adoption of renewable energy technologies around the world. IRENA provides policy advice, technical assistance, and capacity-building support to countries seeking to transition to a more sustainable energy system [84].

V. The Clean Energy Regulator (CER): the CER is an Australian government agency that is responsible for administering and enforcing the RET scheme. The CER monitors compliance with the RET scheme, which requires electricity retailers to source a certain percentage of their energy from renewable sources [85].

VI. The european commission: the european commission plays a key role in setting energy policy and regulations for the European Union. The commission has established ambitious targets for reducing greenhouse gas emissions and increasing the share of renewable energy in the EU's energy mix [86].

Regulatory bodies play a critical role in promoting the development and adoption of green energy systems. By setting standards, enforcing regulations, and monitoring compliance, these regulatory bodies help to ensure the safety, efficiency, and sustainability of renewable energy technologies. Policymakers, industry stakeholders, and the public need to work together with regulatory bodies to accelerate the transition to a more sustainable energy future.

14 | Factors Affecting the Widespread Adoption of Green Energy Resources

Green energy resources have gained significant attention in recent years as a sustainable alternative to traditional fossil fuels. Despite the numerous benefits associated with green energy, including reduced greenhouse gas emissions and lower long-term costs, the widespread adoption of these resources has been hindered by the following factors:

I. The high initial cost of implementation: while green energy technologies have become more affordable in recent years, the upfront costs of installing solar panels or wind turbines can still be prohibitive for many individuals and businesses. Additionally, the lack of government incentives and subsidies for green energy projects can further deter potential adopters [87].

II. Intermittent nature of renewable energy sources: unlike traditional fossil fuels, which can be easily stored and used on demand, green energy sources such as solar and wind power are dependent on weather conditions. This variability can make it difficult to rely solely on green energy for consistent power generation, especially in regions with unpredictable weather patterns [88], [89].

III. Lack of infrastructure to support green energy resources: Many existing power grids are not equipped to handle the fluctuations in energy production that come with renewable sources. Upgrading and modernizing these grids to accommodate green energy can be a costly and time-consuming process, further delaying the transition to sustainable energy sources [90].

IV. Social and political factors: public perception and acceptance of renewable energy technologies can vary widely, with some individuals expressing concerns about the aesthetics of solar panels or wind turbines in their communities. Political opposition to green energy initiatives, often driven by vested interests in the fossil fuel industry, can also impede progress toward a more sustainable energy future [91].

Addressing the high upfront costs, improving energy storage capabilities, investing in infrastructure upgrades, and overcoming social and political barriers are all essential steps towards accelerating the transition to a more sustainable energy system. By addressing these factors and working towards a more inclusive and supportive environment for green energy, we can move closer to achieving a cleaner and more sustainable future for generations to come.

15 | Applications of Green Energy

The various applications of green energy resources that have increased their widespread adoption in the global energy mix are as follows:

I. Electricity generation: solar panels, wind turbines, and hydroelectric dams can all be used to generate electricity cleanly and sustainably. By harnessing the power of the sun, wind, and water, we can reduce our reliance on fossil fuels and decrease our carbon footprint. In addition, green energy sources are abundant and widely available, making them a reliable and cost-effective option for electricity generation [35], [92].

II. Transportation: electric vehicles powered by renewable energy sources are becoming increasingly popular as a cleaner and more sustainable alternative to traditional gasoline-powered cars. By transitioning to electric vehicles and charging them with green energy, we can significantly reduce emissions from the transportation sector and improve air quality in our cities [93], [94].

III. Heating and cooling purposes: geothermal heat pumps, for example, use the natural heat stored in the earth to provide heating and cooling for buildings. This technology is not only environmentally friendly but also

cost-effective and energy-efficient, making it a practical solution for reducing energy consumption in residential and commercial buildings [95], [96].

The applications of green energy resources are vast and varied, offering numerous benefits for the environment, economy, and society as a whole. By embracing renewable energy sources such as solar, wind, and hydroelectric power, we can reduce our dependence on fossil fuels, mitigate climate change, and create a more sustainable future for generations to come. Policymakers, businesses, and individuals alike must prioritize the adoption of green energy resources in order to achieve a cleaner, greener, and more sustainable energy system.

16 | Conclusion

The findings from this study on green energy technologies clearly indicate that these technologies offer a promising approach to achieving environmental sustainability and eco-friendliness. The study has shown that green energy technologies have the potential to significantly reduce greenhouse gas emissions and mitigate the impacts of climate change. It has also provided a compelling argument for their adoption as a key strategy for achieving environmental sustainability and eco-friendliness.

One of the key advantages of green energy technologies is their renewable nature, which means that they can be continuously replenished and do not deplete finite resources. This stands in stark contrast to traditional fossil fuels, which are non-renewable and contribute to environmental degradation through pollution and carbon emissions. It has shown to have a positive impact on local economies, creating jobs and stimulating economic growth in communities that invest in renewable energy infrastructure. This not only benefits the environment but also contributes to social equity and sustainable development.

However, some potential challenges include issues related to intermittency, storage, and grid integration, as well as the need for continued research and development to improve the efficiency and cost-effectiveness of these technologies. In light of the evidence presented in this review, it is clear that investing in green energy technologies is not only a sound environmental decision but also a smart economic one.

By transitioning to a more sustainable energy system, the reliance on reliance on fossil fuels can be minimized, mitigate the impacts of climate change, and create a more resilient and prosperous future for generations to come. Based on the findings from this study, the following recommendations are suggested to improve environmental sustainability and eco-friendliness.

I. It is essential to prioritize the development and deployment of renewable energy sources such as solar, wind, and hydroelectric power. These sources have been proven to be more environmentally friendly compared to traditional fossil fuels, which contribute significantly to greenhouse gas emissions and air pollution. By investing in renewable energy technologies, countries can reduce their carbon footprint and mitigate the impacts of climate change.

II. Policymakers and stakeholders should focus on improving energy efficiency in buildings, transportation, and industrial processes. Energy efficiency measures can help reduce energy consumption and lower greenhouse gas emissions, leading to a more sustainable and eco-friendly energy system. Additionally, promoting energy conservation practices among consumers can further contribute to environmental sustainability.

III. It is crucial to invest in research and development to advance green energy technologies and overcome existing challenges. Conventional studies have identified various barriers to the widespread adoption of renewable energy, such as high costs, intermittency, and grid integration issues. By supporting research and innovation in this field, policymakers can address these challenges and accelerate the transition to a more sustainable energy system.

By implementing the recommendations outlined above, policymakers can accelerate the transition to a more sustainable energy system and mitigate the impacts of climate change.

Author Contributions

Ndifreke Etebom Itiat, Imoh Ime Ekanem, and Aniekan Essienubong Ikpe contributed equally to this study. Ndifreke Etebom Itiat led the conceptualization and methodology design. Imoh Ime Ekanem conducted the literature review and analysis of green energy technologies. Aniekan Essienubong Ikpe focused on the evaluation of environmental sustainability and eco-friendliness. All authors collaborated on writing, editing, and finalizing the manuscript, and approved its submission.

Funding

This research did not receive external funding and was conducted as part of the authors' independent academic work.

Data Availability

All data utilized in this study, including literature sources and analysis results, are available within the manuscript. Additional information can be provided by the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflicts of interest concerning the publication of this review.

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