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The role of renewable energy in environmental protection for achieving sustainable development and a green economy: A review

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ABSTRACT

The aims of this research are to utilize clean and renewable energy sources in the context of sustainable development and the transition to a green economy. Since clean and renewable energy sources are essential for sustainable development and are essential resources that support a wide range of human activities, it is necessary to ensure the sustainability and continuity of the required and sufficient quantity of these resources to meet the needs of present and future generations in a fair manner and in a clean and healthy environment free of all forms of pollution. Compared to traditional depleting energy sources such as coal, oil and other fossil fuels, the generated energies also support energy efficiency and reduce greenhouse gas emissions. Therefore, environmental sustainability is an essential part of human development. Since the environment is an integral part of our daily lives and its sustainability must be emphasized in the sense that using too little does not meet human needs and using too much leaves negative environmental impacts. In order to preserve traditional non-renewable resources such as coal, oil, etc., renewable energy relies on sustainable natural sources such as the sun, wind, and water. Moreover, the creation of renewable energy reduces waste production compared to traditional power plants, which reduces the occurrence of environmental pollution. Moreover, as countries, regional organizations, and international organizations, the world's top priority is sustainable development. Moreover, energy is the basic force and active component of all growth and development processes. It is the basic component of all economic sectors and forms part of human existence. Moreover, all energies consumed globally are traditional and unsustainable.

Keywords: Renewable energy, Sustainable development, Greenhouse gases, Conventional energy, Environmental pollution, Clean environment, Waste management.

Introduction

Fossil fuels; coal, oil, and gas are by far the biggest contributor to global climate change given that many nations suffer from the issues of climate change and global warming, the use of fossil fuels for energy production, which has a detrimental effect on food production, the waste of natural resources, the wealth gap, the severe water scarcity predicted for 2050, the global financial crisis that engulfed the world in 2008, and the growing environmental pressure brought on by various commitments and activities that support the economy, particularly in major industrialized nation Gas and oil-are by far the biggest causes of climate change worldwide. They account for around 90% of all carbon dioxide emissions and more than 75% of greenhouse gas emissions worldwide. Greenhouse gas emissions trap solar heat due to their existence in the Earth's atmosphere. Climate change and global warming result

from this case (Tita *et al.*, 2025). The current rate of global warming is greater than it has ever been. Rising temperatures will eventually cause weather patterns to shift and the natural equilibrium to be upset, endangering humanity and all other life forms on Earth. Due to all of these reasons, the world's countries must alter the brown or black economic environment and take the required steps to reduce the risks of shocks and crises that are becoming more and more ingrained in the current traditional development model, which has disregarded the environmental perspective in economic development. This shift has been led by the United Nations Environment Programmed (UNEP), which started its own drive to transition to a green economy in 2008. This is a new model of economic development that serves as a new engine for fostering economic growth and development, generating new employment opportunities, bolstering social equality, relying on clean and renewable energy that protects the environment from pollution, protecting future generations' right to development, improving the efficiency of economic resource use, ensuring a safe climate free of carbon oxides, and attaining human well-being. This new strategy, which connects humans, the environment, and the economy, has emerged as a crucial prerequisite (Farah *et al.*, 2025). As a new approach to lowering the environmental dangers connected to economic activity, the world has started to move toward what is known as the "green economy." Sustainable development without harming the environment is the goal of the green economy. Energy that comes from natural sources and is replaced more quickly than it is consumed is referred to as renewable energy. For instance, sources like sunlight and wind are continually replenishing. These renewable energy sources are widely available and ubiquitous (Morales Pedraza, 2023). On the other hand, it takes hundreds of millions of years for fossil fuels like coal, oil, gas, and other non-renewable resources to originate. Fossil fuels release dangerous greenhouse gases, including carbon dioxide, when they are burned to generate energy. Compared to burning fossil fuels, emissions from the production of renewable energy are far lower. Therefore, the key to solving the climate catastrophe is switching from fossil fuels, which now produce the majority of emissions, to renewable energy. In most nations today, renewable energy is more affordable and generates three times as many jobs as fossil fuels (United Nations, 2025).

Some of the most important sources of renewable and clean energy: Clean energy generates electricity without contributing to global warming or adverse environmental effects like the emission of greenhouse gases like carbon dioxide. A large portion of clean energy comes from renewable sources, such as solar power generation, wind power, and some hydroelectric resources. The majority of the world's nations have access to renewable energy, which comes from endless and continuously replenishing natural resources like the sun, wind, and water. Geothermal energy, wave and tidal movements, and other inventions can also generate it. Fossil fuels like coal, oil, and natural gas are fundamentally different from renewable energy. The dangerous byproducts of fossil fuels, such carbon dioxide (CO2), which contributes to greater global warming, are often not produced by renewable energy. The use of biofuels to produce energy from plant resources is an exception. Biofuels can be sustainable and are regarded as renewable energy sources by both the European Union and the United Nations, despite the fact that they do produce byproducts that contribute to global warming. Because nuclear reactors emit hazardous radioactive waste, the use of nuclear fuel is likewise prohibited by renewable energy (Alini *et al.*, 2024).

1. Solar Power: The most plentiful energy source is solar energy, which can even be produced on overcast days. The rate of solar energy interception on Earth is approximately 10,000 times higher than the rate of energy use by humans. For a variety of uses, solar energy systems can supply fuel, electricity, natural lighting, heat, and cooling. These systems use mirrors that focus solar radiation or photovoltaic panels to transform sunlight into electrical energy. Even while not every nation has equal access to solar energy, every nation has the potential for direct solar energy to make a substantial contribution to the energy mix. Since the cost of producing solar panels has drastically dropped over the past ten years, solar energy is now more widely available and frequently the most economical choice. Depending on the materials used in their manufacture, solar panels can endure anywhere from 30 to more years. Photovoltaic converters or thermo mechanical engines are used to convert solar energy into electricity. But active energy systems are the name given to these technologies. Employing daylight, hot water, and high temperatures for industrial purposes, or even using thermal energy for cooking or storing thermal energy for later use, as well as transforming solar energy into other forms that might not be electrical. Passive energy systems, on the other hand, use solar energy by oriented buildings toward the sun, choosing materials with appropriate thermal mass or light-scattering qualities, and creating environments that encourage natural air circulation (Farah *et al.*, 2025).

2. Solar Power Cells: Direct sunlight is converted into electricity via solar cells, which are photovoltaic converters. They are photosensitive and semiconductor

devices with a conductive sheath on the front and back. Through a number of chemical, physical, and electrical processes, a variety of methods have been created to produce solar cells, leading to either highly automated or self-contained capacitors. Elements like silicon and compounds like gallium arsenide, cadmium sulfide, indium phosphide, copper sulfide, and other potential materials for photovoltaic applications are among the materials utilized in the production of solar cells (Hossain *et al.*, 2025).

The Commercial Solar Cell Types:

A. Solar cells made of monocrystalline silicon: To create these solar cells, silicon rods are grown, rolled into wafers, and then subjected to a series of chemical and physical processing steps. These cells have a high efficiency, ranging from 9% to 17%. Polycrystalline silicon cells are less costly than monocrystalline cells, but they are also less effective. Monocrystalline silicon cells are costly because of the intricacy of the technology and their high energy consumption (Sharma and Mishra, 2025).

B. Solar cells made of amorphous silicon: These cells are made of silicon, whose crystalline structure has been broken by the deliberate introduction of hydrogen or other elements to give it particular electrical characteristics (Huang and Tong, 2017). Because amorphous silicon cells are produced as a thin film using modest amounts of raw materials, they are less expensive than crystalline silicon cells. Although solar radiation affects their stability, these cells' efficiency ranges from 4% to 9% for big surface areas and slightly more for small surface areas (ElKhamisy *et al.*, 2024). As shown in Figure 1.

Figure (1): Solar cells for generating electricity (Huang and Tong, 2017)

2. Wind Power: Large wind turbines situated on land, in the ocean, or in freshwater (marine) are used to harness the kinetic energy of the wind. Although wind energy has been used for thousands of years, current advancements in onshore and offshore wind energy technologies have allowed for the production of substantially bigger amounts of electricity using larger rotor diameters and taller turbines. The global technological potential of wind energy greatly surpasses the global output of electricity, and there is sufficient potential in most regions of the world to permit the widespread deployment of wind energy, even though average wind speeds vary significantly by location. Strong winds are common in many parts of the world, yet often the ideal places to generate wind power are far away (Kaldellis and Zafirakis, 2024). As shown in Figure 2.

Figure (2): Wind turbines (Musial *et al.*, 2020).

Benefits of Wind Power: Because wind energy doesn't emit greenhouse gases or pollutants like carbon dioxide, nitric oxide, or methane, it has a less detrimental effect on the environment than other renewable energy sources. Turbines can be mounted on rooftops, and 95% of the land used for wind farms can be utilized for other uses like grazing or agriculture. According to a recent study, 440–460 jobs are created for every million kilowatt-hours of wind energy produced annually (Lee and Patel, 2024).

Technology for Wind Power Generation: The fastest-growing new electricity source in the world is wind power producing technology. Three-bladed turbines installed atop tall towers generate wind energy. In reverse, these turbines function similarly to windmills. These turbines harness the wind to create energy rather than electricity. In order to power an electric generator, the wind rotates the turbine blades, which in turn rotate a shaft that is attached to a gearbox. The capacity of large turbines intended for the production of public electricity ranges from 650 kW to 1.5 MW. A single, smaller turbine with a maximum output of 100 kW is frequently used for homes, telecoms, and water pumps, especially in isolated locations without public electricity generation and distribution firms (Younis *et al.*, 2024).

3- Geothermal Power: The thermal energy found in the Earth is used via geothermal energy. Wells and other techniques are used to harvest heat from geothermal reserves. Hydrothermal reservoirs are naturally sufficiently hot and permeable, whereas enhanced geothermal systems are sufficiently hot reservoirs that have been stimulated hydraulically. Fluids with varying temperatures can be utilized to produce energy once the heat reaches the surface. With more than a century of experience, hydrothermal energy technology is well-established and dependable geothermal energy uses heat from the Earth's interior to heat water, which powers turbines to produce electricity. In frigid climates, it is also utilized for home heating. It is regarded as one of the most significant and popular energy production techniques because of its sustainability. As seen in Figure 3, Iceland is among the top nations that depend on this kind of energy (Lund and Boyd, 2021).

Figure (3): Generating electricity from geothermal (ground) energy (Lund and Boyd, 2021).

4. Hydropower: The energy of water moving from a higher to a lower level is used in hydropower. Rivers and reservoirs can produce it. While downstream hydropower facilities use the energy from the river's flow, storage hydropower plants rely on water kept in a reservoir. Hydropower reservoirs are frequently used for a variety of purposes, including electric generation, navigation services, flood and drought management, and the provision of drinking and irrigation water. At the moment, hydropower is the biggest renewable energy source used to generate electricity. It can be adversely impacted by droughts or changes in ecosystems that disrupt rainfall patterns, and it typically depends on steady rainfall patterns (Zhai *et al.*, 2022). Then the Ecosystems may be adversely affected by the infrastructure needed to generate hydroelectric power. Because of this, many people believe that small-scale hydroelectric power is a more environmentally benign choice, especially for isolated populations. Another form of renewable energy is hydropower, which produces electricity by using the kinetic energy of flowing water to power turbines attached to an electric generator that rotates inside a magnetic field (Nilsson *et al.*, 2005). As shown in Figure 4.

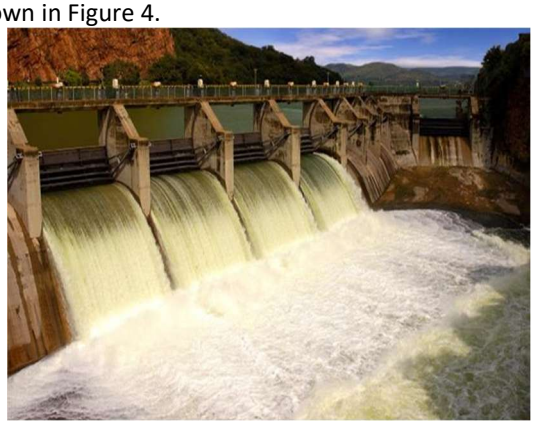

Figure (4): Generating electrical energy from water power (hydroelectric power) (Liu and Yang, 2022).

The kinetic energy of water can be converted into electricity in a number of ways, such as:

A. Using water's potential energy to generate electricity: When there is an excess in regular electricity generation, pumps are used to elevate water to a specific level and keep it there. The water that was kept at a high level is dropped in certain amounts through pipes until it reaches a turbine attached to an electric generator when the demand for electricity during peak hours exceeds the power plant's output capacity. Electricity is generated when the turbine rotates, which in turn rotates the generator (this process is somewhat comparable to a battery, where energy is stored and retrieved when needed) (Carrasco *et al*., 2019).

B. Researcher of Al-Ibady (2025) also demonstrated how green nanotechnology can be used to build smart and sustainable cities that promote a clean environment. This is achieved through the application of nanomaterial's and nanotechnology in applications such as wastewater treatment, soil and contaminated water treatment, and improving energy efficiency in buildings. The paper is likely to explore how these nanotechnology solutions contribute to environmental sustainability, economic viability, and social well-being in urban areas.

C. Using River kinetic energy to generate electricity: Rivers' kinetic energy is used to power turbines that are connected to an electric generator. (Dams are used to regulate the amount of water flowing through the turbines and, thus, the amount of energy produced because this method generates erratic electricity) (Paish, 2002).

5. Energy from the sea: Technologies that use the thermal and kinetic energy of seawater-such as waves or currents-to generate heat or electricity are known as marine energy. A number of prototype wave and tidal

current devices are being investigated, although marine energy systems are still in their infancy. The potential of marine energy is significantly more than what is now needed by humans (Bahaj, 2020). As shown in Figure 5.

Figure (5): Wave energy (marine energy) for generating electricity (Bahaj, 2020).

6. Bioenergy: A range of organic materials, referred to as biomass, are used to make bioenergy, including wood, charcoal, rot, and other natural fertilizers for the generation of heat and energy, as well as agricultural crops for liquid biofuel. The poorest people in developing nations typically use the majority of biomass for cooking, lighting, and heating in rural regions. Dedicated crops or trees, forestry and agricultural wastes, and other organic waste streams are examples of modern biomass systems (Demirbaş, 2021). Burning biomass releases greenhouse gases into the atmosphere, although not as much as burning fossil fuels like coal, oil, or gas. However, given the possible adverse environmental effects of large-scale increases in forestry and bioenergy production, as well as the ensuing deforestation and changes in land use, bioenergy should only be employed in specific applications. Gathering gasses from plant waste—such as trees, vegetables, sugarcane residue, and other emission materials—is the process of producing bioenergy. Similar to natural gas derived from the earth, methane is one such gas that is collected and used for a variety of purposes, including burning it to power electricity producing plants (Liu *et al*., 2022). Nowadays, the majority of renewable energy is produced by hydroelectric power plants that use big dams wherever there are suitable sites on rivers and waterfalls. Both industrialized and some developing nations make extensive use of solar and wind power producing technology. Renewable energy sources are now widely used to produce electricity, and several nations have plans to boost their output of renewable energy to meet 20% of their energy needs by 2020. In order to prevent the major threats of climate change caused by pollution and the depletion of fossil fuels, as well as the social and political risks associated with fossil fuels and nuclear power, the majority of world leaders have agreed to fight global warming by reducing greenhouse gas emissions in the coming years, in accordance with the Kyoto Protocol (REN21, 2023). As shown in Figure 6. Production of renewable energy can be interpreted in a number of ways. The Scandinavian nations, together with Iceland, Canada, and New Zealand, lead the world in the use of renewable energy based on the quantity of energy generated by each nation relative to its population. In the 2000s, the usage of renewable energy increased even more in German-speaking nations. Germany is the third-largest producer of renewable energy overall, behind China and the United States of America, and it leads the main world economies in terms of the quantity of renewable energy produced relative to its population (REN21, 2023). Recently, there has been a spike in the popularity of the renewable energy trade, a sort of business that involves turning renewable energy sources into cash streams and promoting them. About 65 countries are planning to invest in renewable energy and have put policies in place to develop and encourage such investment, including financial incentives and feed-in tariffs, despite a number of non-technical barriers preventing the widespread adoption of renewable energy, such as high initial investment costs (IRENA.2023). Investment in renewable energy in Arab nations has dropped by 8% over the past two years, despite the fact that interest in renewable energy has increased recently in the Middle East, coinciding with falling oil prices. Despite efforts by oil-producing Gulf governments, especially Saudi Arabia, where the private sector has started making significant investments in the renewable energy industry, this reduction has occurred (Dii Desert Energy, 2025). Paradoxically, Morocco, Egypt, and Jordan are the three most active renewable energy marketplaces in North Africa and the Middle East, with almost $15 billion in sales between 2015 and 2019 (IRENA, 2021).

Benefits of renewable energy:

1. Accessible in the majority of nations worldwide.
2. Preserves the health of living things and doesn't contaminate the environment.
3. Cost-effective in numerous applications.
4. Guarantees its constant accessibility.
5. Makes use of basic technology.
6. Endlessly replenished.
7. Does not add to emissions of greenhouse gases.
8. Lowers heat emissions from the production of electricity (IRENA, 2022).

Figure (6): Green hydrogen (biomass) production technology (IRENA, 2021).

The Green Economy's Contribution to Environmental Protection through Sustainable Development: The integration of the four facets of sustainable development—environmental, social, economic, and technological (or administrative)—is made easier by the green economy. The green economy must be tailored to the goals and conditions of the country. To guarantee a voluntary shift to a green economy, the shared responsibility concept among pertinent state entities must be implemented. The integration of the four facets of sustainable development-environmental, social, economic, and technological (or administrative)—is made easier by the green economy (UNEP, 2023). The necessity of adjusting the green economy to the goals and conditions of the country. Applying the shared responsibility principle among pertinent state agencies is essential for a voluntary shift to a green economy. A new understanding of the interdependence of the social, environmental, and economic facets of sustainable development is reflected in the growth of the green economy. By embracing a new conceptual framework that strengthens the integration of sustainable development's features rather than replacing it, it also makes it possible to mobilize support for attaining sustainable development (Qureshi *et al.*, 2024). Since the green economy reflects the environmental aspect of sustainable development in addition to the other aspects, it is possible to say that the relationship between the two is one of a portion to the whole (Amankwah Amoah *et al.*, 2023). The green economy is a useful instrument that aids in achieving sustainable development, not a substitute for it. Sustainable development is the ultimate aim that nations aspire to. The shift from the generalities of sustainable development to specificity is represented by the green economy, which defines targeted sectors, policies and methods for preparing these sectors, finance mechanisms for their preparation, and the transformation's outcomes. In order to help nations prepare their economies in a way that best suits their needs and circumstances in order to achieve sustainable development, the United Nations Environment Programme (UNEP) has created a comprehensive scenario for preparing the global economy (Lozano and Huisingh, 2022). Demonstrates the instruments used to achieve a green economy. The country's current organizational structure in terms of the nature of the relationship between the public and private sectors and the local community in general, the role of financial and media policies and the degree to which they stimulate awareness of the advantages of the green economy, and tools that reduce the risks associated with traditional economic practices and the post-transition period to a green economy are some of the most significant of these tools (Qureshi *et al.*, 2024). Additionally, it entails establishing suitable pricing structures for different environmental services and making sure that these instruments are applicable to both public and private investments in the ten sectors that UNEP identified as needing to be ready to achieve a low-carbon economy. With effectiveness, adaptability, and inclusivity, leading to the accomplishment of sustainable development and the end of poverty (Barbier, 2023). In the context of attaining sustainable development, the expected results of the green economy model suggest investing 2% of the projected $1.3 trillion in global GDP annually in both the traditional and green economies over the next few decades. Ten major industries-agriculture, construction, energy, forestry, tourism, transportation, waste management, and water-would receive the majority of this investment. The energy sector would receive half of this investment in order to improve its efficiency, especially in the transportation, industry, and building sectors. The following lists the most important effects of this strategy in comparison to the conventional economy through 2050 (Parrique *et al.*, 2019).

1. Instead of increasing to 0.2 in the traditional economy, lower the global ecological footprint from its current value of 1.5 to 1.2 by 2050, which is near the sustainability threshold of 0.1.
2. Although energy demand will rise, it will reach its current levels by 2050, which is almost 40% less than what the conventional economy predicted.
3. By 2050, cut carbon dioxide emissions by one-third.
4. Raise the forestry industry's added value by roughly 20%.
5. Increase key agricultural yields worldwide by 10% over the conventional economy and improve soil quality.
6. Cut the amount of water used by a fifth (Newell and Mulvaney, 2013).

Goals and Objectives for Sustainable Development from an Arab Perspective after 2015: The expectations for future development in the Arab world are reflected in the Sustainable Development Goals (SDGs), which were suggested for the period after 2015 and are to be accomplished by 2030:

1: is to end extreme poverty.
2: Assure quality labor.
3: Give everyone access to high-quality education and opportunities for lifelong learning.
4: Achieve gender equality, empower women and girls, and fully fulfill the human rights of women.
5: Promote health.
6: Promote the sustainable use and management of natural resources and guarantee that everyone has access to water and sanitation (Abou Taleb and Radwan, 2021).
7: Make sure everyone has access to sustainable energy.
8: Promote sustainable agriculture and eradicate food insecurity and malnutrition.
9. SDG 9: Ensure enough housing and promote sustainable, inclusive cities and human settlements.
10. SDG 10: Assure functional institutions and peaceful society.
11. Strengthening international collaborations for sustainable development is the eleventh objective (Kabbani and Kanaan, 2022).

Conclusions

1. The economic, social, and environmental aspects of sustainable development are all attained by the green economy. It tackles the problems of climate change, lowers greenhouse gas emissions, shields the environment from pollution, and gives jobless people more clean employment options (green jobs).
2. By displacing the fossil fuel economy, which depends on oil, natural gas, and shale gas, the green economy achieves economic diversity, prosperity, and economic recovery. Future resource depletion and the loss of rights for future generations are long-term consequences of this economy.
3. The green economy can offer the essential and suitable techniques and approaches to deal with present and upcoming difficulties.
4. Since most Arab and developing nations have attained advanced levels globally in these metrics, the focus on making the shift to a green economy is no longer exclusive to industrialized nations.

Recommendations

1. Based on environmental concerns, we need to grow low-emission businesses such energy conservation, sewage and industrial wastewater treatment, and the processing and recycling of industrial and agricultural waste.
2. To stop meddling with and disturbing natural ecosystems, enforce deterrent environmental laws and tax offenders, particularly tribal regulations pertaining to water conservation.
3. Establish an atmosphere that encourages the private sector to expand its projects and investments in cutting-edge technology and renewable energy, as well as to accomplish sustainable development frameworks in all three dimensions.
4. In schools, universities, and kindergartens, raise public awareness of environmental issues and advance the ideals and concepts of green culture and the green economy. This can be accomplished by providing university students from specialized institutions with specialized courses and programs, as well as by adding chapters on the green economy to school textbooks. Future resource conservation and environmental protection will be positively impacted by this. 5. Creating a comprehensive plan for the state's transition to a green economy that involves both the public and private sectors and prioritizes private initiatives aimed at advancing waste recycling, solar energy, wind energy, and renewable energy.

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