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Renewable energy sources, sustainability aspects and climate alteration: A comprehensive review

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Abstract. The increasing global demand for energy is transforming our world into a closely connected community, yet the Earth remains unchanged in its capacity. As the world population seeks more energy to fuel social, economic, and developmental needs, along with health and well-being, the call for sustainable solutions intensifies. Unfortunately, escalating energy consumption contributes to rising greenhouse gas emissions and environmental harm. Embracing renewable energies becomes crucial for combating climate change, but such a shift must be sustainable to fulfill the energy requirements of future generations. A comprehensive strategy combining energy management and renewable sources is required to address these issues. An overview of current energy consumption trends, energy management techniques, and renewable energy sources is provided in this article. The results show that an integrated strategy that includes renewable energy sources and energy management techniques can dramatically reduce energy consumption and greenhouse gas emissions while also providing economic benefits. The article's conclusion highlights how important it is to implement an integrated strategy for energy management and renewable energy sources in order to achieve efficient and sustainable energy use.

Introduction

Global energy consumption has surged due to increased urbanization, industrialization, and population growth, causing adverse environmental effects such as climate change, air pollution, and resource depletion [1]. An integrated strategy including energy management techniques and renewable energy sources is necessary to address these issues [2]. An extensive analysis of energy use, energy management techniques, and renewable energy sources is given in this article. Analyzing recent studies, case studies, and assessing the efficacy of different energy management and renewable energy technologies are all part of the study technique [3]. Energy is essential for economic expansion, but the present fossil fuel dependency is unsustainable, requiring a move to renewable alternatives in order to lessen environmental effects [4]. Energy consumption and greenhouse gas emissions can be considerably decreased while providing economic advantages by putting energy management concepts into practice and switching to renewable energy sources. Strategies include using energy-efficient technologies, adopting practices, and employing management systems for monitoring and controlling energy usage [5]. Renewable sources like solar, wind, hydro, and geothermal provide sustainable alternatives, with global adoption increasing due to government incentives and declining technology costs [6]. Energy consumption, particularly in sectors like transportation, residential, commercial, and industrial, contributes significantly to greenhouse gas emissions. The International Energy Agency (IEA) reported a 2.3% global energy consumption increase in 2019, with the transportation sector leading at 32%, followed by residential (23%), commercial (12%), and industrial (37%) sectors. Fossil fuels, constituting coal, oil, and natural gas, accounted for 84% of global energy consumption in 2019 [7].

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Sources of Renewable Energy

Renewable energy emerges as a pivotal solution to address these challenges [8]. Notably, in 2012, these sources contributed 22% to global energy generation, indicating a significant shift. Reliable energy supply is indispensable for heating, lighting, industry, and transportation, playing a crucial role in global economies. The substitution of fossil fuels with renewables substantially reduces greenhouse gas emissions. However, challenges like intermittent generation due to seasonal variations exist, necessitating intricate design and optimization methods. Fortunately, advancements in computer hardware and software empower researchers to overcome these challenges, fostering progress in the renewable and sustainable energy field [9].

Technology and Renewable Energy

Renewable energy sources derive from continual natural energy flows in our environment: bioenergy, solar, geothermal, hydropower, wind, and ocean energy.

Hydro energy. One important energy source that is obtained from the flow of water from higher to lower elevations is hydropower, which is mainly used to turn turbines and produce electricity. There are many different types of hydropower projects, such as in-stream projects, run-of-river projects, and dam projects with reservoirs. Hydropower is a technologically advanced resource that uses a variable resource over time. Hydropower reservoirs are used for navigation, irrigation, drinking water production, flood and drought control, and other uses. The main source of energy for hydropower is gravity plus the height at which the water descends onto the turbine. The potential energy relies on the mass of the water, the gravity factor ($g = 9.81\ ms^{-2}$), and the head, defined as the difference between the dam and tail water levels. Turbines are engineered to accommodate an optimal water flow. Hydropower exhibits minimal particulate pollution, rapid upgradability, and the capability to store energy for extended periods.

Energy of Biomass. Bioenergy, a renewable energy source sourced from biological materials, plays a vital role in various applications. It serves as a versatile energy provider for transportation through biodiesel, electricity generation, and heating for cooking. Electricity derived from bioenergy encompasses diverse sources like wood residues from forests, agricultural byproducts such as sugar cane waste, and animal husbandry residue like cow dung. A notable advantage lies in the fact that the fuel for biomass-based electricity often originates from by-products or waste, avoiding competition between land designated for food and that for fuel. While global biofuel production is currently modest, it exhibits a continuous upward trend. In the United States, annual biodiesel consumption reached 15 billion liters in 2006, with a growth rate of 30–50% annually, aiming for 30 billion liters by the end of 2012 [10].

Solar Power. "Direct" solar energy pertains to renewable energy technologies that directly harness the Sun's energy. Unlike some renewables like wind and ocean thermal, which utilize solar energy after its absorption on Earth, solar energy technologies directly capture sunlight. Photovoltaic (PV) systems convert solar irradiance into electricity, and concentrating solar power (CSP) generates thermal energy. Solar energy not only fulfills direct lighting needs but also has the potential to produce fuels for transportation and other purposes [11]. The World Energy Council (2013) notes that solar radiation falling on Earth exceeds 7,500 times the world's annual primary energy consumption of 450 EJ [9].

Geothermal power. Geothermal power is harnessed from the interior of the earth as a natural source of energy, rooted in the planet's internal structure and associated physical processes. Despite substantial heat existing in the Earth's crust, it is often not equally distributed, hardly concentrated, and frequently lies at depths challenging for mechanical exploitation. The geothermal gradient, averaging about 30 °C/km, varies across the Earth's interior, with some regions attainable by digging exhibiting gradients well above average [12]. Geothermal reservoirs, mined for heat through wells and other methods, include naturally hot and permeable hydrothermal reservoirs and enhanced geothermal systems (ESG), which are sufficiently hot but benefit from hydraulic

stimulation. Extracted fluids, varying in temperature, can then be used for electricity generation and other applications requiring heat energy [9].

Wind energy. Wind has emerged as a leading global energy source among renewables due to its widespread presence, especially in areas with substantial energy density [13]. Harnessing kinetic energy from moving air, wind energy is vital for mitigating climate change by generating electricity through large turbines positioned onshore or offshore [14]. Large-scale production and implementation of onshore wind technology have previously occurred [9]. Wind turbines efficiently convert wind energy into electricity, marking a significant stride in renewable energy solutions.

Ocean energy (tide and wave). Surface waves form when wind moves over water, particularly in the ocean. The duration, speed, and distance of sustained wind directly impact wave height and the energy produced. The ocean possesses vast energy potential stored in waves, tides, currents, and temperature differences. In 2008, the first commercial sea energy devices debuted with installations like the UK's SeaGen and Portugal's Pelamis. Currently, ocean energy areas are derived through wind, tides, waves, and thermal disparities between deep and shallow sea water [15].

Sustainable development and Renewable energy

Because it promotes economic productivity and human growth, renewable energy is essential to sustainable development. Prospects for energy security, social and economic advancement, increased energy accessibility, reducing the effects of climate change, and improving the environment and human health are presented by these energy sources [16].

Energy security. The concept of energy security lacks a universally agreed-upon definition, leading to varied interpretations. Nevertheless, the underlying concern for energy security revolves around ensuring a continuous and reliable energy supply, a fundamental requirement for sustaining economic operations [17]. Given the intrinsic connection between economic growth and energy consumption, maintaining stable energy access is a significant challenge for both developed and developing nations, posing potential economic and functional challenges in case of prolonged disruptions [15]. Renewable energy sources, unlike fossil fuels, are globally distributed and less subject to market trading. Introducing renewables not only reduces dependence on energy imports but also diversifies the supply portfolio, lessening vulnerability to price volatility and fostering global energy security. Additionally, renewable energy integration enhances the reliability of energy services, particularly in areas with inadequate grid access, contributing to overall energy security through a well-managed and diversified energy portfolio [16].

Economic and Social development. Economic growth and rising energy consumption have historically been strongly correlated, making the energy sector essential to economic development. Per capita income and energy consumption are positively correlated globally, indicating that economic expansion is the main cause of the recent increase in energy consumption. This growth also generates employment, with a 2008 study indicating around 2.3 million jobs worldwide in renewable energy technologies, contributing to enhanced health, education, gender equality, and environmental safety [9].

Energy access. Sustainable Development Goal Seven focuses on ensuring universal access to clean, affordable, and available energy. The use of renewable energy sources, widely distributed globally, is key to achieving this goal. Addressing access discrepancies requires a local understanding, particularly in regions like sub-Saharan Africa and South Asia, where urban and rural electrification differences are evident [18]. Renewable energy-based distributed grids prove more competitive in rural areas, offering substantial opportunities for mini-grid systems to enhance electricity access.

Effect of Climate change on Environmental and health. The renewable energy source utilization in power generation plays a pivotal role in curbing the emission of greenhouse gases,

mitigating climate change, and lessening effect on environment and health associated with fossil fuel-derived pollutants. GHG emissions per capita also saw a 22% reduction from 1990 to 2012, as shown in Figure 3 (EEA, 2016). As mentioned carbon dioxide emissions in the United States from 1990 to 2013, exemplifying a decrease in CO_2 levels due to a transition from fossil fuels to available energy sources [19].

Renewable Energy Source Challenges

In low-carbon economies, renewable energy sources have the potential to dominate the energy supply, requiring significant adjustments to all energy systems. The main problem of the first half of the twenty-first century is generally recognized to be the shift from non-sustainable to renewable energy [20]. Notably, a country's policies and instruments significantly impact the adoption of renewable energy, influencing costs and technological advancements. Technological innovations, in turn, influence costs, contributing to market failures and limited adoption. An effective renewable energy policy must consider these interconnected factors to foster sustainability.

The study proposes several policy recommendations to effectively alleviate changes in climate and its impacts.

- Encourage all fields and areas to invest in technologies of renewable energy and adopt policies promoting their use, fostering a collective effort in reducing carbon emissions.
- Advocate for lifestyle and behavioral changes to reduce individual carbon footprints, emphasizing the significant contribution of personal choices to climate change mitigation.
- Support research into revolution and mechineries that minimize land use, prevent accidents associated with renewable energy sources, and address resource competition, particularly in bioenergy where food production competes with energy generation.
- Strengthen international collaboration and assistance for developing countries, facilitating infrastructure expansion and technology upgrades to enable modern and sustainable energy services. This approach aims to mitigate climate change and its adverse effects on a global scale.

Conclusion

Energy is a fundamental requirement in our daily lives, crucial for human development, economic growth, and productivity. Shifting towards renewable energy is recognized as a significant step in mitigating climate change, but its sustainability is paramount for securing a future that meets energy needs for generations to come. The goal of this study is to ascertain the sustainability of renewable sources and their potential to mitigate the effects of climate change by examining the relationship between sustainable development and green energy. Qualitative research was conducted through a comprehensive review of relevant literature within the study's scope. While renewable energy sources exhibit no net emissions throughout their lifecycle, barriers such as cost, pricing structures, political environments, and market conditions hinder their full utilization in emerging, minimum-developed, and developed nations. To address these challenges, the study advocates for the creation of global opportunities through international interactions. Supporting developing nations in accessing green energy, enhancing energy productivity, investing in clean energy utilization, and encouraging research and energy infrastructure to lower the cost of renewable energy and remove inefficiencies, and contribute to climate change mitigation. Opportunities related to renewable energy sources are identified in the report, including enhanced energy security, social and economic development, and climate change mitigation. However, obstacles like communication gaps, market failures, raw material availability issues, and inefficient energy use pose a danger to renewable energy's sustainability and ability to mitigate climate change.

Future Recommendations

Policy formulation and technological improvement: Encourage policy discussions across sectors to enhance technologies in the renewable sector for sustained development.

- Advocate for more efficient energy use at individual and global levels. Implement global energy efficiency programs, offering tax exemptions for energy-efficient initiatives and product designs.
- Invest in research to address concerns and potential risks associated with renewable energy.
- Raise public knowledge and education about effect reduction, adaptation, and mitigation of climate change.

In addition to addressing the sustainability of renewable energy, putting these recommendations into practice would support the seventh and thirteenth goals of sustainable development, which call for preventing climate change and its effects as well as guaranteeing that everyone has access to affordable, dependable, and sustainable energy.

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