Advancements In Renewable Energy

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***Abstract*—The paper focuses on discussing the technological and process-oriented advancements in the Renewable Energy Sector. In this regard, it has been identified that the use of renewable energy sources for both industrial and residential purposes is gaining traction, and such prevalence also showcases the importance of adopting renewable energy sources for energy consumption. In this regard, it was found that major renewable energy sources like Solar Energy, Bio Energy and Geothermal Energy are all gaining advanced technologies for enhancing the usage of such renewable energy sources. Furthermore, it was also found that the increased adoption of Renewable Energy is driven by market demand and growing awareness regarding sustainability. It is also found that the benefits of renewable energy consumption include economic, sustainability, environmental benefits and public health outcomes as well as job creation issues. Furthermore, challenges were also identified and relevant recommendations provided for enhancing the consumption of renewable energy on a large scale globally.**

***Index Terms*—Renewable Energy, Solar Energy, BioEnergy, Geothermal Energy, consumption, adoption**

I. INTRODUCTION

According to past researchers, there has been an increasing need for adopting renewable energy sources into the existing social infrastructure globally, as non-renewable energy sources like Fossil Fuels are becoming extinct in recent years. Herein, the 7th UN Sustainable Development Goal, which focuses on the promotion and increased adoption of clean and affordable energy, also promotes the increased development and transition of the infrastructure to clean renewable energy sources [1]. This further demonstrates the significance of renewable energy sources in the current global environment, which is fraught with increased global environmental degradation and pollution. Here, it was also identified that while most renewable energy sources globally have promising features for achieving environmental sustainability, they are often intermittent in nature, requiring integration of multiple renewable energy sources or incorporating a renewable energy source with an optimal energy storage system [2]. Herein, the present paper in this regard focuses on the advancements achieved globally in terms of Renewable Energy Sources. In this regard, aspects such as the Benefits and Challenges of Renewable Energy Sources, as well as their significance and prevalence, will be discussed. Furthermore, the reasons for the increased adoption of renewable energy sources will also be discussed alongside the advancements achieved globally across renewable energy sources like Solar Energy, Wind Energy, as well as Bioenergy and Geothermal Energy.

II. PREVALENCE AND IMPORTANCE OF RENEWABLE ENERGY

Renewable Energy Sources have become more beneficial and adoptable across most countries, globally, even though there is a major lack of infrastructure for large-scale incorporation of these renewable energy sources across the global markets [3]. In this regard, it was identified by the IEA that the global renewable energy capacity grew in 2023 at a pace faster than that of the last three decades [4]. Herein, it was also found by the IEA that the increase in the rate of renewable electricity generation provides the world with the opportunity to achieve its goal of tripling the global capacity of renewable electricity by 2030 [5]. In this regard, it was also identified that as of 2023, the amount of renewable energy used for electricity generation accounts for 30% of the global electricity generation capacity [6]. This further goes to show the prevalence of renewable energy sources globally, and their importance in achieving a more Sustainable Environment.

Researchers have identified here that the use of renewable energy sources provides substantial benefits to the world through reduced Carbon Emissions, while also enhancing water conservation efforts globally [7]. In this regard, it can also be suggested that the use of Renewable Energy Sources in Business Firms enhances firm reputation, further enhancing the economic benefits and the regulatory compliance performances of the businesses. Thus, it can be stated that Renewable Energy Sources are highly important for increased social and business success in the contemporary environment.

III. ADVANCEMENTS IN RENEWABLE ENERGY

A. Solar Energy

In terms of Solar Energy, it is one of the most researched fields of Renewable Energy, and therefore, the traditional applications of the Solar Energy Spectrum lie in the installation and application of Solar Panels for different infrastructures, from individual residential setups to large industrial plants. However, here, it has been found that there have been certain breakthroughs and advancements in the generation, storage and usage of Solar Energy more efficiently. It has been identified, for instance, that efficient photovoltaics which operate beyond the visible spectral range can be transparent enough to be easily integrated into silicon-based solar panels, which in turn preserves silicon absorption while also solving the issue of spectral losses [8]. In this regard, it has also been identified that the usage of doped semiconductor nanocrystals-based plasmonic solar cells have been found to be able to replace conventional photovoltaics, so as to become capable of absorbing the Near-Infrared aspects of the solar spectrum [8]. In this regard, it was identified that the focus of global renewable energy production has taken a pivotal shift, as it is found that Solar energy is more economically and ecologically sustainable and superior than other sources of renewable energy like Tidal, Hydro, and Wind Energy sources [9]. This can be mainly explained due to more consistent availability of the Solar Energy source, the Sun, in comparison to the Tides, Wind and Waterfalls, which are not consistent enough for large-scale renewable energy development. Herein, it was revealed that Generative AI Technologies can be fused with Solar Power to develop synergy, which in turn promises a pathway in prioritising renewable energy while also developing a blueprint for an energy-secure and sustainable future, and showcasing the capabilities of technological advancements towards addressing global challenges [9]. Thus, it can be stated that renewable energies like solar energy have strong advancements for achieving sustainability in a global environment.

B. BioEnergy and Geothermal Energy

Bioenergy derived from organic materials is a major alternative to renewable energy sources and Fossil Fuels utilised for the generation of non-renewable energy [10]. Herein, it is identified that the addition of innovative technologies for achieving advanced technologies for biomass conversion is a major field of advancements for BioEnergy [10]. Furthermore, it is also identified that the emerging trends of advanced biomass conversion through technologies like Genetic Engineering, Biorefineries, Supportive Policies, as well as algae-based bioenergy generation, can also help develop the future of Bioenergy application as a renewable energy source [10]. In this regard, it can be stated that there has been developments in the field of bioenergy management, wherein, Biorefineries help develop a spectrum of bio-based products like chemicals fuels, and materials from the initial biomass, wherein multiple processes like pyrolysis, fermentation and gasification are used to optimise resource utilisation and economic viability of Bioenergy plants [10]. In this regard, the selling of high-value process byproducts like bio-based chemicals, nutraceuticals and bioplastics can also enhance the economic sustainability of the Bioenergy plants [10]. This shows the innovative development of bioenergy applications, products and processes for achieving environmental and economic sustainability.

In terms of geothermal energy, it was identified that the global market is developing at a CAGR of 5.9% between 2022 and 2027, as the major drivers of such growth include geothermal heat pumps, which are in high demand, alongside the use of geothermal energy for power and electricity generation [11]. Furthermore, it is also found that the application of Geothermal Energy is advancing with the development of Geothermal Heat Pumps as well as the process of Electricity Generation from Geothermal Energy [11]. This further develops that alongside BioEnergy, other aspects like Geothermal Energy also

enhance advancements of Renewable Energy across the globe, based on the integration of Geothermal energy with other renewable energy sources like Solar, Tidal and Hydro Energy. This shows the advancements of renewable energies like BioEnergy, Geothermal Energy and Solar Energy towards achieving increased environmental sustainability on a global scale.

IV. INCREASED ADOPTION OF RENEWABLE ENERGY

Previous research has proven that there has been a trend of increase in adoption and consumption of Renewable Energy in domestic as well as industrial domains. However, it is also important to understand the drivers behind such a significant increase in Renewable Energy consumption. Herein, it has been found that the current energy transition from non-renewable energy consumption to renewable energy consumption involves the adoption of affordable, efficient and low-carbon technologies which can enable protection of the environment while also conserving resources towards achieving a healthier planet [12]. In this regard, one of the major drivers of the increased Renewable Energy Consumption is the eventual results of such consumption, wherein increased consumption can lead to reduced fossil fuel-based energy consumption as well as reduced Carbon Emissions [13]. In this regard, it is also identified that aggressive climate policies and investments for green technologies can help support the significant resource consumption for a low-carbon energy usage transition [13]. Herein, it is also identified that one of the major driver for the increased adoption and consumption of Renewable Energy includes the rapid technological development wherein the global capacity for renewable energy generation has expanded ten times between 2000 and 2021, while global renewable energy generation through solar photovoltaic installations have grown 21-fold between 2010 and 2021 [14]. This further dictates the increase in renewable energy consumption through an increase in competitiveness and accessibility of the energy sources. Thus, it can be stated that there are multiple factors and determinants supporting the increased adoption and consumption of renewable energy within the global residential and industrial sectors.

V. BENEFITS AND CHALLENGES OF RENEWABLE ENERGY ADOPTION

A. Benefits of Renewable Energy Adoption

The increased consumption of Renewable energy has several benefits for Society and the Environment. In this regard, it was found that the increased consumption of Renewable Energy in the US saved $249 billion in Environmental and Public Health Costs [15]. Herein, it was identified that the reduced consumption of fossil fuels as a result of renewable energy consumption provided environmental benefits by restoring the environment to a certain extent, while the exposure of the population to polluted air was also reduced, leading to better public health outcomes [15]. Furthermore, another benefit of the increased consumption of renewable energy is to increase in jobs and employment, which in turn enhances the economic health of the countries. Herein, researchers identified that the regions with higher consumption of renewable energy also resulted in increased demand for consumable renewable energy, which in turn results in job creation and economic sustainability in the firms within the clean energy sector [16]. This shows the major benefits of the consumption of Renewable Energy.

B. Challenges of Renewable Energy Adoption

One of the major challenges of the increased consumption of and dependency on Renewable Energy Adoptions is related to the variable nature of Solar and Wind Energy, which results in poor grid stability. This is further seen in the case of Spain and Portugal, as both countries faced severe blackouts due to their overdependency on solar energy-based electricity, which further led to grid instability and subsequent blackouts [17]. It was previously identified that designing and developing an optimal energy storage system for renewable energies, which are often intermittent in nature, is a major challenge which leads to Energy Storage Problems as well as Issues related to energy wastage [2]. This further demonstrates the major challenges of increased consumption of renewable energy across the globe.

VI. CONCLUSION AND RECOMMENDATIONS

Based on the above discussions, it can be suggested that there is an increasing trend of renewable energy adoption across both residential and Industrial

Domains, which is further informing the increasing demand for Renewable energy, which in turn is driving the significant growth rate of the global clean energy market. In this regard, it has also been identified that different types of Renewable Energy sources like Solar Energy as well as BioEnergy and Geothermal Energy has also been discussed, especially in relation to the new advancements, technological, or process-oriented which has improved the ease of consumption of renewable energy from sources like Solar Energy, Geothermal Energy and BioEnergy. Furthermore, it is identified that the increased adoption and consumption of renewable energy sources develop benefits for society and the environment by improving environmental conditions, public health outcomes, as well as economic sustainability, and job creation. On the other hand, this also creates challenges in relation to the lack of grid stability due to variations in the supply of renewable energy sources, as well as the lack of optimal storage facilities for renewable energy, which also leads to energy wastage upon production.

Recommendations in this regard:

- Development of optimal Energy Storage Systems which are compatible with storing energy produced from multiple renewable energy sources.
- Ensuring Grid Stability by developing hybrid power grids dependent on both renewable energy sources and non-renewable energy sources.

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