



RESEARCH ARTICLE

Renewable Energy as a catalyst for achieving Sustainable Development Goals

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ABSTRACT

The United Nations General Assembly has developed 17 SDGs to undo damage and impose discipline among the energy guzzling countries. Renewable energy sources seem to be the answer to many issues raised by the SDGs. But, how do renewable energy help to achieve the sustainable goals? At this stage, it is important to critically examine the reach and impact on each of the goals. This paper attempts to understand the issues involved, present a critical assessment and provide an overview that can suggest ways and means of fulfilling the objectives set up by the SDGs.

Keywords: Sustainable Goals, Renewable energy, Solar Energy, Environmental impact, social impact, Economic impact

INTRODUCTION

In 2015, the United Nations General Assembly developed Seventeen Sustainable goals to transform the world. The objective of these goals is to end poverty and inequality, protect the planet and ensure that all people enjoy health, justice and prosperity (Hak et al., 2016). These seventeen goals have 169 objectives. It is expected that the participating countries shall implement measures to achieve the objectives by 2030. The goals and objectives offer a comprehensive vision for sustainable development. These goals are not limited to developing countries and are pan-world. They emphasise equity and respect of human beings,

innovation, clean water, responsible consumption, sustainable finance and aim to strengthen health systems across the world. The participating countries have agreed to improve the infrastructure for generating clean energy. Clean energy shall help in achieving energy security for transportation, mechanical work and industry (seckin & Salvarli, 2020). Renewable energy generated from solar (Ahmad et al., 2020), wind (Olibi et al., 2021), hydro (sahin, 2020) and biomass sources are expected to meet fluctuating energy demands and shall play a major role in protecting the global environment. It has been envisaged as one of the sustainable solutions to the energy crisis the world is facing

today. Harnessing solar energy is one of the cheapest sources of electricity generation and has been at the forefront of power generation through renewable resources. The gap between the demand and supply of energy has accelerated the rapid development of renewable energy resources. However, sustainable development is not just bridging the energy gap but is more complex than it seems to be (Grigoroudis et al., 2021). Since the efficiency of renewable energy sources, except hydro,

is less than that of conventional fossil-based energy, hence it is not possible to replace all the conventional energy needs with that of renewable energy. However, renewable energy is widely accessible in rural areas, hence it helps in improving infrastructure and offer more opportunities for employment. To achieve the goals of sustainable development, India proposes to generate 50% of the energy required through renewable sources by 2030. India also proposes to be net-zero carbon emission by 2070.



The United Nations Sustainable Development Goals (SDGs)

Solar Energy

The generation of energy due to nuclear fusion within the sun is referred to as solar energy. The amount of energy received depends on geographical location and climate of the location. Energy harnessed from the heat waves of the Sun is a significant source of renewable energy. This is also called green energy as it does not use any of the other natural resources available in nature. It has played a major role in developing sustainable energy solutions. Scientists have estimated that the amount of solar energy being received by

the planet is enough to meet the power demand of the mother earth. This solar energy can be utilised by using different technologies which have been developed over a period of time (Xiao-Ya et al., 2014). It is one of the biggest sources of generating electricity. The photovoltaic photons are converted into electrons to generate electrical energy. In thermal applications, these photons are converted into heat energy. The heat so produced is used to increase the temperature of fluid that can be used for various applications. 86.2% solar optical efficiency has been achieved by using nanofluids. However, the efficiency of Photo Voltaic cells is

much lower and is around 15–20%. As innovations are happening fast, solar energy has been projected as a key driver for reducing toxic emissions and balancing three important aspects of environmental, social and economic aspects as defined in the Sustainable Development Goals (SDG). The adoption of solar energy as an important source of alternate energy will enhance energy security and mitigate climate change.

Wind Energy

Wind energy is another renewable energy that harnesses the power of the wind to generate electricity. Wind turbines are used to generate power by using the kinetic energy of air. The moving air pushes the blades of a turbine that are then connected to a generator for producing electrical energy. The generator is installed on top of a tower and moves as the blades get rotated. As the generator rotates, it produces power. However, this technology can be used only in the areas where there is free flow of high velocity winds.

Hydroelectric energy

Hydroelectric power is harnessed from water in motion. As the water falls from the waterfall, its energy is used to rotate the water turbine to produce electrical energy. Reservoirs are built to store water. The flow of water is controlled through a valve. The potential energy of water is converted into kinetic energy as water falls from a height in a controlled process. The reservoir is used to store water when the flow of water is more than required and is used when the flow is less than required. Hence the power



generated is available throughout the year and can be used as a major source of energy.

Tidal Energy

Tidal energy is a form of power harnessed as the tides rise and fall due to the gravitational forces of the Earth and Moon. When the water waves pass through constriction, which happens due to gravitational forces, tidal waves occur. The energy in these waves is harnessed through generators that generate power. However, this energy can be harnessed only when the tidal ways are high and have sufficient energy to rotate the generator. This is a nonlinear source of power generation, unlike hydro generators.

Geothermal Energy

Earth is hot from the inside. The energy stored inside the earth is called Geothermal energy. Since heat is continuously being produced inside the earth, this energy can be harnessed for heating buildings, generating power and as heat source in other applications.

Installed Renewable Energy Capacity (MW) in India

Sector	Cumulative (as on 31.03.2024)
Wind Power	45886.51
Solar Power*	81813.6
Small Hydro Power	5003.25
Biomass (Bagasse) Cogeneration	9433.56
Biomass (non-bagasse) Cogeneration	921.79
Waste to Power	249.74
Waste to Energy (off-grid)	336.06
Total	143644.51

IMPACT OF RENEWABLE ENERGY

India is one of the largest coal consumers in the world for the production of energy. To meet the increasing demand, the country has to import the crude oil. Both these fossil fuels are not environment friendly and emit greenhouse gases and pollute the atmosphere. About 74 % of the energy demand of India is met through these sources. To meet the growing demand of energy and reduce greenhouse gases, switching over to a renewable source of energy is the only solution in sight. Fossil fuel burning has a negative effect on the environment. Though it cannot be brought to zero, yet the effect can be mitigated by increasing the use of renewable energy (RE) as RE has much lower emissions or no emission. The growing demand of power can be met through

the use of these natural resources (Mahmoud et al., 2021). Most of the developed and developing countries have developed technology to harness solar energy and installation of Solar energy cell have been increasing over a period of time, thus reducing the effect of toxic gasses (Chrzanowski & Zawada, 2023). An average of 310 days of day light is available on earth, hence providing the most cost-effective power even to the remotest part of the world. This source of energy is not only cost effective it is ecofriendly and requires little maintenance (Alvarez, et al., 2020). As the use of solar PV increases, the Greenhouse effect will start declining, thereby mitigating the risk of a warmer climate.

ENVIRONMENTAL IMPACT

Environmental perspective is a crucial component of today's ecosystem. The balance of economic growth and environmental preservation is the pivot for implementing Industry 5.0. As the new technology gets implemented, optimisation of resource use promotes sustainability and reduces the impact of industrial processes on the environment. Many countries have set the



objective of Net-Zero by 2050 (Gupta & Gupta, 2024). The enhanced use of renewable energy sources is the mainplayer in achieving the target. Solar power has been propagated as a sustainable alternative to fossil fuels, but impacts the environment during the manufacturing process. The manufacturing process for Photovoltaics Cell is an energy intensive process. The manufacturing of solar panels involves usage of chemicals and raw materials such as silicon, glass, and metal frames. They have to be manufactured under controlled temperature and pressure. In addition, the usage of some hazardous gasses during manufacture is unavoidable. In case the energy generated by these cells needs to be stored for use during night, use of Lead- acid/ Li-on batteries is an essential requirement. The researchers are innovating new processes to reduce the use of gases and scarce minerals These barriers are preventing the use of PV cells to full potential. Several barriers could prevent solar energy from reaching its full potential. Another barrier in the use of PV cells is efficiency of these cells. The efficiency of c-Si solar cells is about 26%, however, the

thermodynamic efficiency of this technology is about 33% (NREL, 2021). However, the carbon emission during the manufacturing process is much lower as compared to the emission of fossil fuel plants. As the technology for manufacturing process improves, the efficiency of PV cells and the consumption of material resources will reduce. Another concern is the recycling of PV cells after their constructive life is complete. The researchers are innovating new recycling processes so that the used panels at the end-of-life cycle can be recycled. The major concern is disposal / reuse of toxic material. While solar panels are mostly made of glass and aluminum, which are recyclable, there are concerns about the proper disposal of panels containing toxic materials such as cadmium telluride or lead. Researchers have concluded that while solar power is not entirely without environmental impact, it is generally considered much

cleaner and more sustainable than fossil fuels when considering its full lifecycle. Continued research and innovation in solar technology and manufacturing processes aim to further reduce these impacts over time.

SOCIAL IMPACT

The lack of access to power can limit prospects of growth of a society and limit the satisfactory quality of life. One of the most significant social impacts of solar power is its role in improving energy access and alleviating poverty. In many parts of the world, especially in rural and remote areas, access to electricity is limited or non-existent. Availability of power is one of the major factors for the development of rural economy. Lack of access to power hinders economic development, limits educational opportunities and affects overall quality of life (Majeed et al., 2023). Providing power to the whole of the population, especially in rural areas, is not only essential but challenging too. Transmission of power from a fuel based generating station is not only costly but also requires huge infrastructure. The generation of solar power near the point of consumption saves the infrastructure cost in addition to other advantages. Solar power provides a sustainable solution to this challenge. Off-grid solar systems, such as solar home systems and mini-grids, can provide reliable electricity to communities that are not connected to the main power grid. This enables households to access lighting, charge mobile phones and power small appliances, improving quality of life and enhancing economic opportunities. Solar power can have significant health benefits, particularly in areas where indoor air pollution from traditional energy sources is a major concern. The use of kerosene lamps and biomass stoves for lighting and cooking can result in respiratory illnesses and other health problems, especially among women and children.

Solar power can play a crucial role in enhancing education and empowering communities, particularly in rural areas. Access to electricity enables students to study after dark, improving educational outcomes and expanding opportunities for learning.

Solar-powered computers and internet access can also bridge the digital divide, providing access to information and educational resources. Solar power can contribute to gender equality by empowering women and girls. In many communities, women and girls are responsible for collecting firewood and water, a task that can be dangerous and time-consuming. By providing access to clean and renewable energy, solar power can reduce the burden on women and girls, allowing them to pursue education and economic opportunities. Furthermore, solar power can empower women by providing opportunities for income generation and entrepreneurship. Solar power can free up time and resources, allowing women to pursue education, start businesses and participate more fully in economic activities.

Solar power can contribute to community development by providing a reliable and sustainable source of energy. Solar-powered mini-grids can support small businesses, power agricultural activities and provide lighting for streets and public spaces, enhancing overall quality of life and promoting economic development. Furthermore, solar power can enhance community resilience to climate change and natural disasters. Further solar power can enhance community resilience to climate change and natural disasters. Distributed solar systems, such as

rooftop solar panels, can continue to operate during outages, providing a reliable source of electricity during emergencies. This can help communities recover more quickly from disasters and build resilience to future challenges. By providing clean and renewable energy, solar power can reduce exposure to indoor air pollution and improve health outcomes. Solar powered lights and cook stoves can replace traditional sources, reducing the risk of respiratory illnesses and improving overall well-being. Solar power has the potential to bring about profound social impact, improving lives, empowering communities and fostering sustainable development. By promoting the use of solar power and

investing in solar energy infrastructure, governments, businesses and communities can harness the power of the sun to drive positive social change and create a more sustainable future for all.

ECONOMIC IMPACT

Renewable energy has emerged as a powerful source of energy as mankind embarks on the journey toward a sustainable future. It has also contributed significantly to economic growth and has been a big source of improving job opportunities. As countries work towards achieving the goals of sustainable development, they have encouraged innovations in RE field which has resulted in a transformative shift in the ecosystem. The developing and underdeveloped countries, where energy constraint was one of the reasons for slow economic progress are utilising these new resources to improve their infrastructure. As the technology is improved, the goals of —No Poverty’, Equality and Resilient infrastructure will be achieved (Nathwani & Kammen, 2019).

One of the most significant economic impacts of solar power generation is its role in job creation and economic growth. The rapid growth in RE sector has resulted in improving the job opportunity market by creating large number of jobs. From manufacturing and installation to maintenance and administration, solar power projects support a diverse range of employment opportunities. The growth of the solar energy sector has spurred innovation and technological advancements. Research and development in solar power technologies have led to increased efficiency and cost-effectiveness, making solar energy more accessible and attractive for a wider range of applications.

Moreover, the development of solar power has led to the creation of new technologies and industries, such as solar panel manufacturing, solar energy storage and solar-powered vehicles. These innovations have the potential to drive economic growth and create new job opportunities in the

SUSTAINABLE DEVELOPMENT GOALS (SDGS)

The Sustainable Development Goals (SDGs) serve several interconnected purposes aimed at addressing global challenges and fostering sustainable development. They provide a universal framework for countries, organizations, and individuals to guide their actions towards achieving sustainable development. The goals offer a shared vision and set of priorities for addressing pressing global issues, such as poverty, inequality, climate change and environmental degradation. By encompassing economic, social and environmental dimensions, the SDGs promote a holistic approach to development. They recognize that sustainable development requires addressing multiple interconnected challenges simultaneously and achieving balance between economic prosperity, social well-being, and environmental protection. They also emphasize the importance of addressing inequalities, promoting social inclusion, and advancing the rights of marginalized and vulnerable groups. The SDGs provide a long-term vision for transformative change, setting ambitious targets to be achieved by 2030. the purpose of the SDGs is to provide a comprehensive, inclusive and ambitious agenda for sustainable development that guides global efforts towards a more prosperous, equitable and environmentally sustainable future for everyone.

IMPORTANCE OF RENEWABLE ENERGY TO ACHIEVE SDGS

The SDGs proposes to reduce poverty, child labour and inequality to promote sustainable development. The RE provides opportunities to achieve these goals. These energy sources provide opportunities to poor counties and communities to have an access to the facilities which are essential to meet the goals and lay a roadmap for sustainable development. Every country needs to develop a monitoring frame work to assess the impact of renewable energy on

SDGs. The impact on the social, economic and environment front are the major parameters through which the impact can be measured. Renewable energy is one of the key resources for the development of a country as it is durable and offers a long-term solution to energy problems. According to various studies conducted by government agencies across nations, it has been concluded that the usage of renewable technologies works as catalyst to economic activity, creating jobs, reduces the gap between poor and rich, encourages innovations and provides a cleaner and better air quality for breathing (wang et al., 2017. According to Büyüközkan et al., renewable energy helps to reduce the climate change and helps to reduce the ill effects on health and environment. According to the studies mitigation of negative effect of climate change can be effectively carried out by increasing the use of renewable energy. As achieving the goals of sustainable development remains a priority for the developed countries, they have utilised the opportunity of giving a boost to renewable energy, thereby creating new job opportunities for their citizens. However, it is the nations that need to determine the cost involved in constructing the infrastructure and its upkeep to meet the increasing need for energy The studies have proved that the development of renewable energy. sources has resulted in improved availability of energy in remote areas of developing countries, which were deprived of such facilities due to the heavy cost of penetration into this area. According to Owuso et al. (2016) In the countries that have a climate favourable for RE generation plants, a large population has access to affordable

energy. These opportunities are a step towards achieving sustainable development. As the cost of power generation from RE further goes down, the poor countries will harvest the advantages in their remote, less accessible population. The innovation in the use of biofuels has facilitated the transport sector; whereas, the energy produced by biomass has helped in cooling, heating cooking and lighting without the use of power (Obaid et al., 2021). Also, the generation of solar energy for business at remote locations has provided much needed energy



at reduced cost, the business has been able to transfer excess energy back to the surrounding areas, thus adding revenue to their business. The business is now less dependent on the limited number of power suppliers and hence has improved economic stability, one of the objectives of SDGs.

ROLE OF RENEWABLE ENERGY IN SDGS

Achieving the Sustainable goals within the timeframe, though a difficult task, can be achieved through the generation of green energy. Till the last decade, energy generation was covered with the help of non-renewable fuels like fossil fuels. Unrestricted burning of these fuels has impacted the quality of the environment due to massive emission toxic gasses, which have led to the depleting of Ozone layer and global warming. The quality of life has been compromised due to Greenhouse effect. The cost of such fuels has been increasing over a period of time leading to increase in cost of production. Generation of power through renewable sources will be a catalyst in achieving sustainable development.

SDG-1: No poverty- This goal is achievable if the economic growth of any country is inclusive. Inclusive growth provides jobs for all and promotes equality. Providing green energy at the remote places at affordable cost helps to achieve economic growth of the country. Since this energy is available to all the citizens of the country, it helps in providing sustainable jobs promoting equality.

SDG-3: Good Health and Well-Being -The goal

emphasises on ensuring healthy lives and promoting wellbeing for all at all ages. Health benefits due to clean environment and improvement of air quality are some of the benefits achieved with the generation of clean energy. Generation of power with solar and Hydel energy emits no gasses, which keeps the environment clean. As the countries

move towards generation of clean energy, the air will become cleaner, thereby improving the health and wellbeing of the mankind.

SDG-4: Quality Education- Imparting quality education to the countries citizens is the foundation for sustainable development. An educated society is the backbone for improving the economic growth of a country. The role of renewable energy in improving access to education through electrification of schools and digital connectivity has been well accepted. As the availability of power in rural areas improves, the students get access to quality education at par with their peers in cities. The quality education not only promotes equality, it also becomes the cause for better employment opportunities.

SDG-5: Gender Equality- Gender equality is pathway to a prosperous country. It is fundamental right of the citizens and lays the foundation for a peaceful, prosperous and sustainable country. Opportunities for women's empowerment and gender equality in the renewable energy sector can be achieved. Green energy is transformative for gender equality. Opportunities for economic development and resilience gets multiplied when the women take advantage of energy which is available at their door steps. It also provides an opportunity to reduce labour segregation among people and improve labour opportunities for women.

SDG-7: Affordable and Clean Energy- Energy plays a crucial role in addressing various challenges and opportunities. Securing access to clean and cost-effective energy is essential for advancing sectors such as agriculture, business, communication, education, healthcare, and transportation. The provision of reliable and affordable energy is vital for sustaining life. However, energy consumption significantly contributes to climate change, accounting for approximately 60% of global greenhouse gas emissions. A well-established energy infrastructure is fundamental to supporting different industries, including business, healthcare, education, agriculture, infrastructure, communication, and technology. There has been a noticeable increase in access to electricity in developing



countries, improvements in energy efficiency, and considerable progress in the adoption of renewable energy sources.

SDG-9: Industry, Innovation, and Infrastructure-

Investments in infrastructure play a vital role in promoting sustainable development. Economic growth, social progress, and efforts towards addressing climate change greatly rely on investment in infrastructure, sustainable industrial growth, and technological advancement. As the global economy evolves rapidly and inequalities continue to rise, sustained growth requires ensuring inclusive opportunities through industrialization and innovation supported by strong and resilient infrastructure. Developing countries are increasingly investing in renewable energy for its cost benefits, driving improvements in infrastructure and industrial development.

SDG- 11: Sustainable Cities and Communities-

Cities should aim for sustainability by offering equal opportunities for everyone, including access to essential services like energy, housing, and transportation. The rapid growth of urban areas is leaving many cities unprepared, resulting in a lack of adequate housing, infrastructure, and services. This has led to the emergence of slums or similar living conditions. Renewable energy plays a crucial role in building strong, environmentally friendly cities and communities, especially in places where basic infrastructure is lacking.

SDG- 13: Climate Action-

Climate change, caused by human activities, poses a worldwide challenge impacting people globally. The acceleration of greenhouse gas emissions has led to climate change unfolding more rapidly than expected, resulting in severe consequences such as

fluctuating weather patterns and sea level rise. The surge in

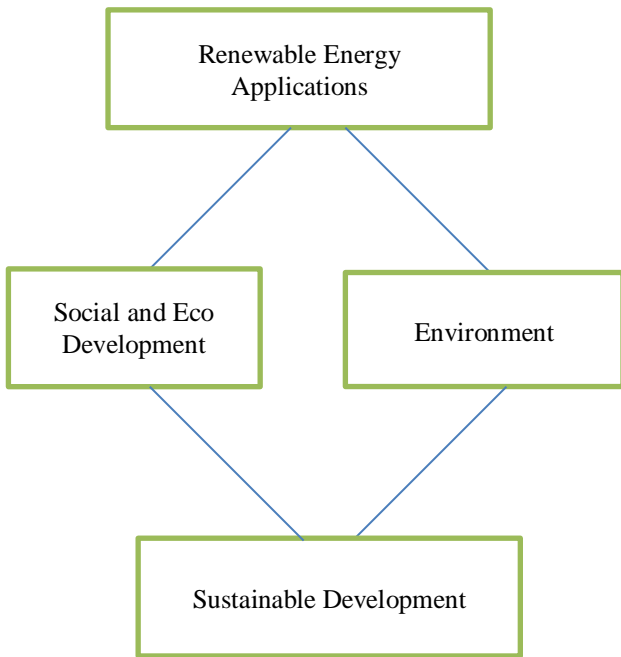
investments in renewable energy signifies a crucial step in combatting climate change by curbing greenhouse gas emissions. Businesses and investors are increasingly prioritizing emission reduction not only for ethical reasons but also due to its economic and business benefits.

SDG- 15: Life on Land-

Sustainably managing forests, combating desertification, halting and reversing land degradation, and stopping biodiversity loss are crucial tasks. It is essential to protect and restore terrestrial ecosystems, manage forests sustainability, combat desertification, and reverse land degradation to preserve biodiversity. The increasing use of renewable energy has aided in reducing deforestation and decreasing the burning of wood for energy, particularly in less developed nations.

SDG-17: Partnerships-

To achieve the Sustainable Development Goals, it is crucial to strengthen international cooperation and partnerships. This includes mobilizing various resources such as technology, finances and capacity building, while ensuring that no one is left behind in the development journey. Developed nations must also uphold their commitments to provide official development assistance (Obaideen et al., 2021). Multi- stakeholder partnerships play a key role in maximizing the synergy between the goals, enhancing their effectiveness and accelerating progress towards achieving them. The adoption of renewable energy sources is pivotal in promoting sustainable development, as advancements in renewable energy technology are making it more affordable and accessible, fostering global collaboration to combat environmental challenges and mitigate climate change



Contribution of Renewable energy on the three pillars of sustainable development (Obaideen et al, 2021),

CONCLUSION

Renewable energy offers clean environmental benefits compared to other energy sources as it is sustainable. These advantages include reducing greenhouse gas emissions, preventing toxic gas emissions, minimizing electricity grid infrastructure, enhancing quality of life, boosting energy independence, creating job opportunities and ensuring energy market stability. The use of solar energy can bring about a positive impact on society, the environment and the economy (Roskilly & Wang, 2018). By opting for renewable energy sources like solar power, the environmental impact on climate change and other categories like marine toxicity and fossil fuel depletion can be decreased. Addressing challenges like health issues and biodiversity loss resulting from climate change is crucial and the widespread adoption of renewables in government strategies worldwide is necessary (Gielen, 2018). Specifically, solar energy can reduce pollution levels and promote public health, leading governments to implement supportive policies to mitigate the health risks associated with energy production and consumption. Renewable Energy offers advantages that go beyond traditional economic measures, leading to a positive impact on global well-being.



Furthermore, it encourages the implementation of circular economy-focused policies and regulations. The circular economy concept promotes sustainable development and environmental conservation by emphasizing practices like eco-design, waste reduction and material recycling. In order to improve power supply in developing countries and lower greenhouse gas emissions, investing in a balanced combination of sustainable energy sources is essential. Governments would need to back initiatives that expand renewable energy resources to accelerate the adoption of these technologies.

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