IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Renewable Energy As A Catalyst For India's Economic And Environmental Sustainability

Dr. Ruma Das
Assistant Professor
Department of Physics
Lalbaba College, Belur, Howrah, India

Abstract- Energy is a key driver of economic development and social progress. In recent decades, a global transition has occurred from fossil-fuel–based energy sources to renewable alternatives such as solar, wind, hydropower, geothermal energy, and green hydrogen. These resources are considered clean and sustainable as they reduce greenhouse gas emissions and help mitigate climate change while offering significant socio-economic benefits. Rapid population growth and industrial expansion have intensified energy demand, making the adoption of alternative energy sources essential. For India, renewable energy provides a practical solution to its rising energy requirements. Government initiatives such as the Make in India program, along with supportive policies, have encouraged domestic manufacturing and attracted foreign investment, generating employment opportunities across sectors. In 2022, India became the world's fourth-largest producer of renewable energy, strengthening energy security and promoting sustainable development. The target of achieving 500 GW by 2030 further enhances opportunities for private-sector participation and technological advancement.

Keywords- Renewable energy, socio-economic, sustainable, greenhouse gas.

I. INTRODUCTION

Energy is a major driver of national economic development [1]. Energy resources are broadly categorized into conventional and non-conventional sources, where conventional energy mainly comprises fossil fuels such as coal, petroleum, and natural gas [2]. These resources have dominated global energy consumption for over a century and currently account for more than 80% of the world's energy supply, but their continued dependence is unsustainable due to their contribution to nearly 89% of global greenhouse gas emissions, rising energy security risks, and environmental and geopolitical challenges [3–5]. In contrast, renewable energy sources—including solar, wind, biomass, hydropower, geothermal, and ocean energy—are sustainable and environmentally friendly alternatives that significantly contribute to climate change mitigation and improved public health [6–8]. Renewable technologies are also becoming more cost-effective and reliable, while energy efficiency remains a key factor in enhancing energy security [9]. At present, renewables supply 15–20% of global energy demand and are expected to dominate future energy systems [3].

India is the world's third-largest energy consumer, driven by rapid population growth and economic expansion [10]. The country remains heavily dependent on coal and imported fossil fuels; in 2017–2018 alone, coal imports reached 213 million tons [11]. To address energy insecurity, India has implemented policies and large-scale initiatives to promote renewable deployment, aligning with its commitments under the Paris Climate Agreement. India currently ranks fourth globally in total renewable, wind, and solar power capacity (REN21, 2022) and has set a target of 500 GW by 2030. This paper discusses India's policy

and regulatory frameworks, investment strategies, employment potential, R&D initiatives, and the challenges and prospects of achieving sustainable growth through renewable energy [12–14].

II. RENEWABLE ENERGY IN INDIA

India has emerged as the world's third-largest energy-consuming nation, driven by rapid economic expansion, industrialization, and population growth. With a population of 1.368 billion as of January 2019—about 17.74% of the global total—and an annual growth rate of 1.18%, rising incomes and living standards have significantly increased energy demand through greater adoption of household appliances, air conditioning, and transport vehicles [15]. National energy consumption trends (Fig. 1) demonstrate a steady rise, with a temporary decline in 2020–21 due to disruptions caused by the COVID-19 pandemic [16]. India's energy demand is projected to grow faster than that of any other major economy by 2040.

Figure 1: Trend of total consumption of Energy in India during FY: 2014-15 to FY: 2023-24 [16]

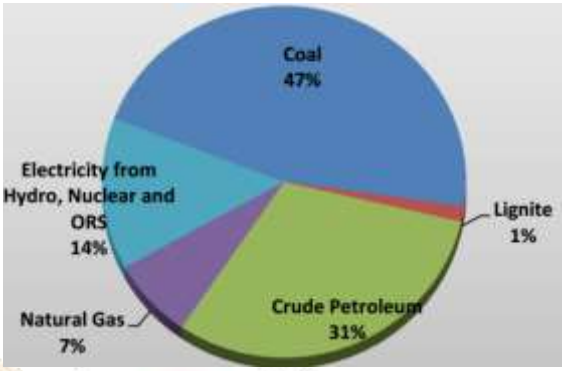

Figure 2: Source wise Consumption of Energy during 2023-24 [16]

Since independence, India has relied predominantly on coal and other fossil fuels, which still supply nearly 80% of total energy demand (Fig. 2) [16]. The country is one of the largest coal consumers globally and remains heavily dependent on costly fossil-fuel imports [17]. Fossil-fuel use has also made India the fourth-largest emitter of greenhouse gases worldwide, contributing about 6.65% of global carbon emissions, after China, the USA, and the EU [18,19]. Consequently, there is an urgent need to diversify toward cleaner energy sources.

India's renewable energy initiatives began in 1981 with the establishment of the Commission on Additional Sources of Energy (CASE), followed by the Department of Non-Conventional Energy Sources (DNES) in 1982 and the formation of a dedicated ministry in 1992. Technological progress has since reduced costs and environmental impacts. India now ranks fourth globally in installed renewable capacity, with renewables accounting for 26.53% of total installed power generation capacity [20]. Although coal is expected to remain a major contributor, renewables are projected to play a leading role in meeting future demand and enabling sustainable growth. Some of the renewable energy sources are discussed below-

A. HYDROPOWER

India's renewable energy journey began with hydropower, with large hydroelectric projects forming the foundation of the country's electricity sector. At present, India ranks fifth globally in terms of exploitable hydropower potential, and hydropower continues to be one of the country's oldest and most reliable sources of low-carbon electricity. The commissioning of the Darjeeling and Shivanasamudra hydroelectric power stations in 1898 and 1902, respectively, marked some of the earliest installations in Asia, establishing India as an early contributor to global hydropower development [21]. In addition to domestic

Figure. 3. hydroelectric power, electricity produced from generators driven by turbines that convert the potential energy of falling.

generation, India imports surplus hydropower from Bhutan to supplement its electricity supply. In the Indian regulatory framework, small hydropower projects—defined as those with installed capacities up to 25 MW—are administered by the Ministry of New and Renewable Energy (MNRE), whereas large hydropower projects above 25 MW fall under the jurisdiction of the Ministry of Power [22].

B. WIND ENERGY

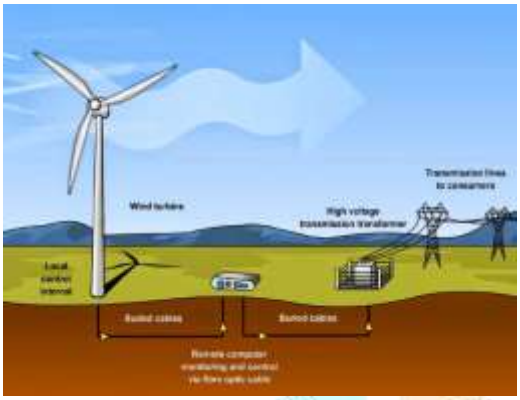

Figure 4: Transformation of wind energy to electricity

Wind energy represents one of the most abundant and environmentally sustainable sources of power generation. Electricity from wind is produced by turbines that convert the kinetic energy of moving air into mechanical energy, which is subsequently transformed into electrical energy and supplied to the national grid. In India, research and development on wind energy began in the 1960s, when the National Aeronautical Laboratory (NAL) designed and deployed windmills primarily for irrigation purposes [23]. Since then, wind power has evolved into a major component of the country's renewable energy portfolio. Owing to favorable wind conditions—particularly across the southern, western, and northwestern regions—India has emerged as the fourth-largest country globally in terms of installed wind power capacity. Furthermore, wind power installations recorded a 31% increase in the financial year (FY) compared to FY 2018–19, reflecting the rapid expansion and growing significance of this sector in meeting India's energy demands [24].

C. SOLAR ENERGY

Figure 5: Solar Pannels in India

Solar energy is one of the most abundant and freely available renewable resources on Earth. However, its effective utilization varies with time of day, seasonal changes, and geographical location. In India, solar-based technologies have significantly contributed to meeting energy requirements for cooking, lighting, irrigation through water pumping, and other domestic and industrial applications in an environmentally sustainable manner. Solar technologies encompass solar heating systems, photovoltaic (PV) power generation, rooftop solar installations, solar thermal systems, and emerging concepts such as artificial photosynthesis. Over the next two decades, solar power is expected to experience rapid expansion, substantially increasing its share in India's electricity generation mix. Building on its large-scale achievements in solar deployment, India has taken a leadership role by spearheading the International Solar Alliance (ISA), an initiative aimed at promoting global cooperation in solar energy deployment, reducing dependence on fossil fuels, and supporting the transition toward a cleaner and more sustainable energy future [24].

D. BIOMASS ENERGY

Figure 6: Biomass plant in India

Traditional biomass—primarily fuelwood, along with animal waste and charcoal—was the largest source of energy in India after coal in 2000, contributing nearly one-fourth of the total primary energy mix. Biomass continues to play a vital role in India's energy landscape due to its renewable nature, widespread availability, carbon-neutral potential, and capacity to generate employment in rural areas. Each year, India produces a substantial quantity of agricultural residue, a large portion of which remains underutilized. Advances in energy-conversion technologies have improved the efficiency and economic viability of biomass-based power generation. In particular, biomass co-firing with coal has emerged as a practical approach for producing low-carbon electricity while leveraging existing coal-fired power infrastructure. To date, more than 800 biomass-based power generation and cogeneration projects using bagasse and non-bagasse feedstocks have been commissioned across the country, demonstrating the growing role of biomass in India's transition toward a more sustainable energy system.

E. GEOTHERMAL ENERGY

Geothermal energy utilizes the natural heat stored beneath the Earth's surface for direct heating applications as well as for electricity generation, offering a reliable and low-carbon source of energy. In India, the first geothermal power project was established in the Balrampur district of Chhattisgarh through a collaborative initiative between the National Thermal Power Corporation (NTPC) and the Chhattisgarh Renewable Energy Development Agency (CREDA). This project marked a significant milestone in India's efforts to diversify its renewable energy portfolio and explore alternative clean energy resources with long-term sustainability potential.

Figure 7: Geothermal Energy Station.

III. TARGETS AND ACHIEVEMENTS

At the UN Climate Change Conference (COP-21) in Paris in December 2015, India committed to achieving 40% of its installed electricity capacity from non-fossil sources by 2030 and to limiting long-term global warming to about 2.5 °C. In line with these pledges, the Government of India set targets to cut cumulative emissions by 1 billion tonnes by 2030, reduce emissions intensity by 45%, achieve net-zero by 2070, and scale renewable capacity to 500 GW by 2030 [24]. An interim goal of 175 GW by 2022—100 GW solar, 60 GW wind, 10 GW bio-power, and 5 GW small hydro—was also announced [25].

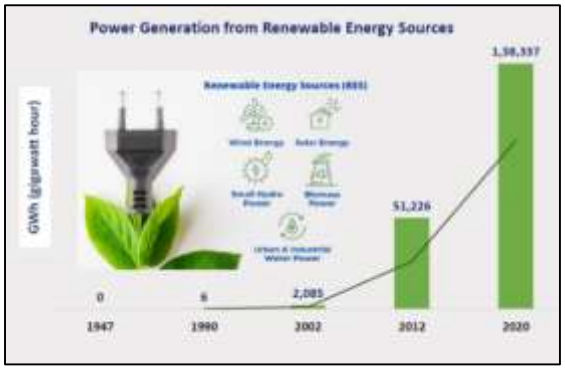

Figure. 8. Power generation from renewable energy sources

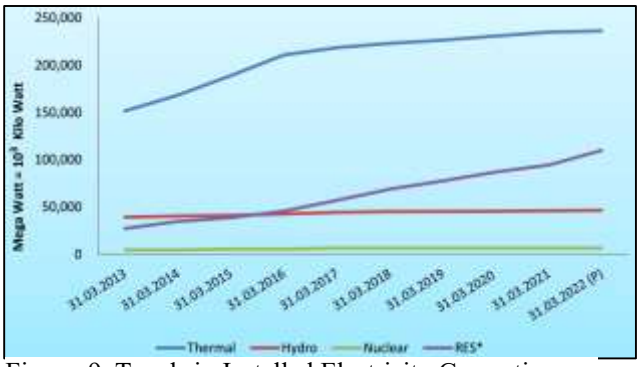

Figure. 9. Trends in Installed Electricity Generation Capacity from sourcewise during the period 2012-13 to 2021-22

Fig. 8 and 9 clearly show how India is rising in its clean energy sector. As of 30-11-2021, India's renewable capacity reached 150.54 GW (solar 48.55, wind 40.03, small hydro 4.83, bio-power 10.62, large hydro 46.51 GW), with nuclear at 6.78 GW, taking non-fossil capacity to 157.32 GW (40.1% of total) [24]. India ranked fourth globally in renewables, fourth in wind, and sixth in solar. Policy support, dedicated institutions, and programs such as UJALA (cutting ~40 $MtCO_2$ annually) have accelerated deployment. International Energy Agency has highlighted India's rapid electrification and leadership in solar, while International Renewable Energy Agency projects that renewables could meet ~25% of India's energy needs and exceed one-third of power generation by 2030 [26].

IV. SOCIO-ECONOMIC IMPACTS

In the contemporary policy and development context, the renewable energy sector in India influences not only electricity generation but also broader socio-economic dimensions, including economic growth, investment patterns, environmental sustainability, policy stability, and employment generation. The transition to renewable energy has contributed to climate change mitigation and improved public health outcomes through reduced greenhouse gas emissions and air pollution. Technological advances in renewable energy have also supported poverty alleviation, particularly in rural areas, by promoting decentralized energy access and fostering local entrepreneurship. Moreover, renewable energy deployment has facilitated rural livelihood diversification, strengthened farm-based income opportunities, and contributed to gender equity by reducing reliance on traditional biomass, which poses serious health risks to women in rural households [27].

Renewable energy development aligns closely with rural transformation in India, where agriculture accounts for nearly one-fifth of national GDP. Rural development strategies increasingly emphasize sustainable livelihoods through integration of renewable technologies. Improved access to modern energy services—particularly for cooking, lighting, and heating—has been associated with enhanced living standards and increased per capita income [28]. Rural regions are well suited for renewable deployment due to the availability of land and biomass resources, enabling the expansion of wind, solar photovoltaic, and biomass-based systems [29]. Furthermore, rural electrification through renewable energy has stimulated non-farm employment, improved quality of public services, increased energy reliability, and contributed to poverty reduction. Studies indicate that biomass-based hybrid systems can offer environmentally and economically viable solutions for rural energy needs, while techno-economic assessments identify photovoltaic–biogas hybrid microgrids as cost-effective models for states such as Punjab [30].

From a global perspective, renewable energy has become a major source of employment. According to the 2018 annual review by International Renewable Energy Agency, global employment in the renewable energy sector reached 10.3 million jobs in 2017, reflecting a 5.3% increase over 2016 [31]. Employment generation has been particularly concentrated in countries including China, Brazil, the United States, Germany, Japan, and India. The International Labour Organization projects that India's transition to a green economy could create nearly 3 million jobs by 2030. As reported by IndiaSpend, the renewable energy sector generated approximately 47,000 new jobs in 2017, taking total employment in the sector to about 432,000, with a year-on-year growth of 12% [32]. Complementing this, the Indian Institute for Human Settlements forecasts substantial growth in green jobs across cities and towns in sectors such as renewable energy, waste management, sustainable transportation, and urban agriculture. India's renewable energy expansion is strongly supported by private investment, which reached US$ 11.2 billion in 2019, creating new business opportunities and positioning India as an increasingly attractive destination for global renewable energy investment.

V. GOVERNMENT INITIATIVES AND POLICIES

India's ambitious clean energy targets are driving a transformative shift in the country's power sector. A key priority is the decarbonization of the industrial sector through expanded electrification, enhanced material and energy efficiency, adoption of advanced technologies, and a transition to lower-carbon fuels. These measures are also critical for developing sustainable transport infrastructure, including the planned electrification of India's railways and a shift of freight movement to this low-carbon mode. Achieving these systemic changes will require innovation, strategic partnerships, and significant investment. Well-designed

government policies to accelerate India's clean energy transition are therefore essential to ensure long-term energy security, economic resilience, and sustainable prosperity [24]-

- Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM-KUSUM): To provide energy and water security, de-dieselise the farm sector and also generate additional income for farmers by producing solar power. The Scheme aims to add 30.8 GW of solar capacity with central financial support of over Rs. 34,000 Crore.
- Green Energy Corridor: The Green Energy Corridor (GEC) projects have been initiated to facilitate renewable power evacuation and reshaping the grid for future requirements.
- Hydrogen Mission: The goal of this mission is to make India a global hub for Green Hydrogen production and export.
- International Solar Alliance: International Solar Alliance (ISA) was launched by Hon'ble Prime Minister of India, and the President of France on 30.11.2015 at Paris, France.
- Wind energy: Government of India has notified the offshore Wind Energy Policy to harness the potential of offshore wind energy along India's coastline mainly in Gujarat and Tamil Nadu.
- Roof Top Solar programme.
- Aatma Nirbhar Bharat.
- Atal Jyoti Yojana (AJAY).
- Decrease constraints on FDI provide open, transparent, and dependable conditions for foreign and domestic firms.

VI. CHALLENGES AND OBSTACLES

The deployment of renewable energy technologies, while essential for sustainable development, is associated with several environmental, social, and technical challenges.

A. Environmental Impacts: Certain renewable technologies can have significant ecological effects. Hydroelectric power plants exert the greatest influence on aquatic ecosystems, while geothermal and biomass plants have comparatively lower impacts. Solar photovoltaic (PV) systems pose socio-environmental challenges related to end-of-life recycling and waste management. Concentrated solar power (CSP) and PV systems may also contribute to ozone depletion and greenhouse gas emissions. Wind turbines and CSP installations can interfere with air and sea transportation. Hydropower projects, in particular, can induce soil erosion, eutrophication, increased suspended sediments, and alterations in water temperature, oxygen levels, and the morphology of lagoons and deltas [24].

B. Land Acquisition: Land availability and acquisition remain critical bottlenecks. Identifying suitable land, securing clearances under land ceiling regulations, negotiating lease agreements, and obtaining approvals from revenue and other authorities can be time-consuming [24].

C. Financial Constraints: High initial capital costs are a major barrier. For instance, coal-based plants require approximately INR 4 crore/MW, whereas wind-based plants with 25% capacity utilization require about INR 6 crore/MW. Investments in large-scale storage infrastructure are also necessary to address the intermittent nature of renewables. Weak domestic manufacturing capacity increases dependence on imports and limits the creation of local employment opportunities, hindering initiatives such as Atma Nirbhar Bharat [24].

D. Reliability: Solar and wind energy are inherently variable across geographic regions and seasons, necessitating integration with conventional power sources to ensure grid stability [24].

E. Social Acceptance: Urban adoption of renewable energy remains limited despite substantial government subsidies for solar water heaters and lighting systems, reflecting low social acceptance [24].

F. Awareness, Education, and Training: The sector faces a shortage of skilled human resources, limited technical expertise, and inadequate public awareness programs, constraining workforce development [24].

G. Rural Development Challenges: Renewable energy deployment in rural areas is hindered by economic poverty, underdeveloped infrastructure, low public service levels, fragile ecosystems, and limited technological capacity, delaying adoption and sustainable development [24].

These multifaceted challenges necessitate coordinated policy measures, technological innovation, financial incentives, and capacity-building programs to accelerate renewable energy adoption while minimizing social and environmental risks.

VII. FUTURE POTENTIALS

India's energy demand is rising rapidly due to economic growth, population expansion, urbanization, and industrialization. According to the International Energy Agency (IEA), India is projected to experience the largest increase in energy demand globally across all scenarios through 2040. Energy demand for road transport is expected to more than double over the next two decades, reflecting ongoing expansion in transportation infrastructure. Similarly, India's building stock is projected to more than double, with 70% of new construction occurring in urban areas. This urban transition is shifting residential energy consumption from traditional biomass to electricity and modern fuels, driven by rising appliance ownership and cooling demand, causing the share of electricity in residential energy use to nearly triple. Nonetheless, firewood and other traditional fuels are expected to continue being used for cooking by 2030 [24].

IEA projections indicate that India's oil demand could rise by nearly 4 million barrels per day (mb/d), reaching 8.7 mb/d by 2040—the largest global increase. In the Sustainable Development Scenario, aggressive electrification, energy efficiency improvements, and fuel switching limit oil demand growth to under 1 mb/d. Coal's dominance in the power sector is declining, with industrial use accounting for most growth; coal's share in the overall energy mix is projected to decrease from 44% in 2019 to 34% in 2040 [24].

Renewable energy, particularly solar power, is expected to grow exponentially, potentially matching coal's share in India's electricity mix within two decades or sooner under sustainable development scenarios. Currently, solar contributes less than 4% of electricity generation, whereas coal accounts for nearly 70%. By 2040, solar's share is projected to exceed 30%, driven by India's target of 500 GW renewable capacity by 2030 and the increasing cost-competitiveness of solar technologies, including battery storage [24].

India has already surpassed its Nationally Determined Contribution (NDC) targets under the Paris Agreement. The emissions intensity of its economy is projected to improve by 40% from 2005 to 2030, exceeding the 33–35% NDC target, while non-fossil fuel electricity generation capacity is expected to reach nearly 60%, well above the pledged 40%. India's leadership in clean energy deployment is anticipated to expand its domestic and global markets for solar PV, wind turbines, and lithium-ion battery equipment to over US$40 billion annually by 2040 [24].

VIII. CONCLUSION

This study examines the growth and potential of India's clean energy sector in meeting rising energy demand. India's abundant solar irradiance and 7,500 km coastline provide significant opportunities for solar and wind energy generation. Achieving sustainable growth requires advanced technologies, effective policies, and efficient grid integration. Renewable energy also offers substantial employment opportunities in manufacturing, installation, and maintenance. India is well-positioned to demonstrate a model of low-carbon, inclusive growth, as reflected in national policies and the Sustainable Development Scenario guiding the path toward net-zero emissions. Despite rapid economic expansion, energy scarcity persists, highlighting the need to diversify and expand energy sources to meet future demand sustainably.

IX. ACKNOWLEDGEMENTS

The author gratefully acknowledges the support provided by Lalbaba College, Belur, Howrah, India.

RFERENCES

[1] C. R. Kumar. J, V. D. Kumar. and M.A. Majid, "Wind energy programme in India: emerging energy alternatives for sustainable growth", Energy & Environment, vol. 30, no. 7, pp. 1135-1189, 2019.

[2] B. Viswanathan, Energy Sources, Fundamentals of Chemical Conversion Processes and Applications, August 24, 2016.

[3] IRENA (2022), "Renewable Power Generation Costs in 2021", Accessed 1 Sept 2022, https://www.irena.org/publications/2022/Jul/Renewable-Power-Gener ation-Costs-in-2021.

[4] M. Farghali, AI. Osman, K. Umetsu and DW. Rooney, "Integration of biogas systems into a carbon zero and hydrogen economy: a review," Environ Chem Lett. Vol, 20, pp. 2853–2927, July 2022, https://doi.org/10.1007/ s10311-022-01468-z.

[5] L. Chen, G. Msigwa, M. Yang, AI. Osman, S. Fawzy, DW. Rooney and P-S Yap, "Strategies to achieve a carbon neutral society: a review," Environ Chem Lett. vol. 20, pp. 2277–2310, April 2022, https://doi.org/10.1007/s10311-022-01435-8.

[6] IEA. (2020, November). IEA. Retrieved March 05, 2022, from https://www.iea.org/reports/renewables-2020: https://www.iea.org/data-and-statistics.

[7] N. L. Panwar, S. C. Kaushik and S. Kothari, "Role of renewable energy sources in environmental protection: A review," Journal of Renewable and Sustainable Energy Reviews, vol. 15, pp. 1513–1524, 2011.

[8] G. E. Williams, "Geological constraints on the Precambrian history of Earth's rotation and the Moon's orbit," Reviews of Geophysics, vol. 38, pp. 37–60, 2000.

[9] C. V. Zabeltitz, "Effective use of renewable energies for greenhouse heating," Renewable Energy, vol. 5, pp. 479-485, 1994.

[10] World Energy Scenarios Composing energy futures to 2050 (2013), World energy Council. https://www.worldenergy.org/wp-content/uploads/2013/09/World-Energy-Scenarios_Composing-energy-futures-to-2050_Full-report.pdf.

[11] M. Blondeel and T. V. de Graaf, "Toward a global coal mining moratorium? A comparative analysis of coal mining policies in the USA, China, India and Australia," Climatic Change, vol. 150(1-2), pp. 89–101, 2018.

[12] G. Schmid, "The development of renewable energy power in India: which policies have been effective?", Energy Policy, vol. 45, pp. 317–326, 2012.

[13] R. Singh, "India's renewable energy targets: How to overcome a $200 billion funding gap", Renewable Energy Focus, vol. 16(4), pp. 60–61, 2015.

[14] V. Khare, S. Nema and P. Bareda, "Status of solar wind renewable energy in India," Renewable and Sustainable Energy Reviews, vol. 27, pp. 1-10, 2013.

[15] United Nations, Department of Economic and Social Affairs, World Population, 2019. WPP2019-Wallchart.pdf (un.org)

[16] Ministry of power, Govt. of India, Annual report 2024-25, https://powermin.gov.in/en/content/annual-report-2024-25 and https://mnre.gov.in/en/annual-report-2024-25/ .

[17] World Energy Scenarios Composing energy futures to 2050 (2013), World energy Council. https://www.worldenergy.org/wp-content/uploads/2013/09/World-Energy-Scenarios_Composing-energy-futures-to-2050_Full-report.pdf.

[18] Canadian environmental sustainability indicators (2017), Global greenhouse gas emissions, http://www.ec.gc.ca/indicateurs-indicators/54C061B5-44F7-4A93-A3EC-5F8B253A7235/GlobalGHGEmissions_EN.pdf.

[19] D. Pappas, "Energy and Industrial Growth in India: The Next Emissions Superpower?" Energy procedia, vol. 105, pp. 3656–3662, 2017.

[20] S. Kumar, "CO2 emission reduction potential assessment using renewable energy in India", Energy, vol. 97, pp. 273–282, 2016.

[21] "India remains major competitor in global hydropower". Archived from the original on 16 April 2016. Retrieved 17 April 2016.

[22] "Executive Summary Power Sector February 2017". report. Central Electricity Authority, Ministry of Power, Govt. of India. 28 February 2017. Archived from the original (pdf) on 17 April 2018. Retrieved 24 April 2017.

[23] History of the Indian Wind Market, Renewable Nation, History of the Indian Wind Market - Renewable Nation.

[24] Annual report 2021-22, Ministry of New and Renewable energy, Govt. of India, https://mnre.gov.in/knowledge-center/publication

[25] C. R. Kumar. J, M. Arunsi. B, Jenova. R and M. A. Majid, "Sustainable waste management through waste to energy technologies in India—opportunities and environmental impacts," International journal of renewable energy research, vol. 9(1), pp. 309-342, 2019.

[26] REMAP, renewable energy prospects for India (2017), The International renewable energy agency (IRENA). Available at https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/May/IRENA_REmap_India_paper_2017.pdf.Accessed 23 Aug 2017.

[27] C. J, Hill, Y, "Energy and policy providing for sustainable rural livelihoods in remote locations – The case of Cuba," Geoforum, vo. 40, pp. 142-158, 2009.

[28] D. Barnes and W. Floor, "Rural Energy in Developing Countries: A Challenge for Economic Development," Annual Review of Energy and Environment, vo. 21, pp. 21-35, 1996.

[29] P. Yadav, P. J. Davies and S. A. Sarkodie, "The prospects of decentralised solar energy home systems in rural communities: User experience, determinants, and impact of free solar power on the energy poverty cycle," Energy Strategy Reviews, vol. 26, pp. 100424, 2019.

[30] P. Malik, M. Awasthi and S. Sinha, "Biomass-based gaseous fuel for hybrid renewable energy systems: an overview and future research opportunities," Int J Energy Res, vol. 45(3), pp. 3464–3494, October, 2020, https://doi.org/10.1002/er.6061.

[31] Renewable energy and Jobs –Annual review 2018. https://irena.org/-/media/Files/IRENA/Agency/Publication/2018/May/IRENA_RE_Jobs_Annual_Review_2018.pdf.

[32] V. Khare, C. J. Khare, S. Nemac and P. Baredar, "Path towards sustainable energy development: Status of renewable energy in Indian subcontinent", Cleaner Energy Systems, vol. 3, 100020, September 2022, https://doi.org/10.1016/j.cles.2022.100020.

[33] India Energy Outlook 2021, World Energy outlook special report, India Energy Outlook 2021 – Analysis - IEA.