Advancing Sustainable Development Goals through Sustainable Energy Solution in India: Pathways and Prospects

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Abstract

India's commitment to Sustainable Development Goals (SDGs) is significantly bolstered by its focus on sustainable energy solutions, reflecting a strategic pathway toward achieving environmental sustainability, economic development, and social inclusiveness. The country's approach includes the ambitious target of installing 450 GW of renewable energy by 2030, underscoring a shift towards cleaner energy sources such as solar and wind power. This transition not only addresses SDG 7 (Affordable and Clean Energy) but also contributes to SDG 13 (Climate Action) by reducing carbon emissions and mitigating climate change impacts. Additionally, by promoting energy access and efficiency, India aims to foster economic growth and job creation, aligning with SDG 8 (Decent Work and Economic Growth). The integration of innovative technologies and policies, such as smart grids and renewable energy incentives, further exemplifies India's holistic approach to sustainable energy. Through these initiatives, India not only targets energy sustainability but also encapsulates the essence of the SDGs by intertwining economic, social, and environmental objectives.

Keywords: Renewable Energy, IPDS, PAT, COP-21, Hydrogen Mission.

Introduction

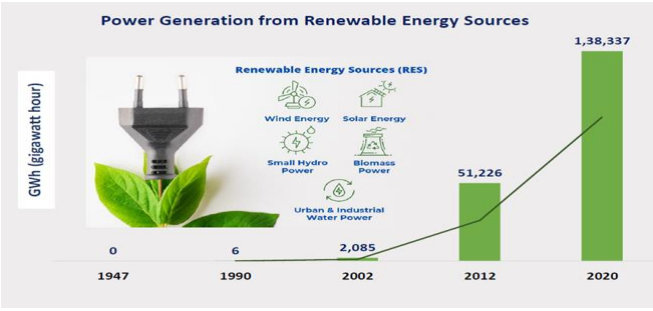
The integration of sustainable energy solutions within the framework of national development agendas is a critical pathway towards achieving the Sustainable Development Goals (SDGs) outlined by the United Nations in 2015. These goals aim to address global challenges including poverty, inequality, climate change, environmental degradation, and access to clean energy. The role of sustainable energy, particularly, is enshrined within SDG 7, which calls for affordable, reliable, sustainable, and modern energy for all. The significance of sustainable energy transcends SDG 7, influencing the achievement of other goals related to health, education, economic growth, and climate action, among others. This interconnectedness underscores the importance of adopting holistic approaches to sustainable development, where energy solutions play a pivotal role.

India, with its vast and diverse population, burgeoning economy, and extensive geographical area, stands at a crucial juncture in its energy transition journey. SDG 7 aims to achieve energy security and efficiency by boosting sustainable energy consumption per capita while simultaneously targeting a decrease in emissions and pollution in alignment with both global and national benchmarks.

Although the global primary energy intensity — the measure of energy consumption per unit of GDP — has seen a 2.3 percent improvement, it still falls short of the anticipated 2.7 percent rate. India has achieved nearly complete electrification of its villages and households, with only a negligible 0.01 percent of households remaining. The focused initiative, Pradhan Mantri Sahaj Bijli Har Ghar Yojana (Saubhagya), is specifically designed to ensure electricity connectivity to these last few households. The forthcoming goal is to guarantee a consistent electricity supply to every household, with ongoing efforts supported by various programs like the Integrated Power Development Scheme (IPDS) and Deendayal Upadhyaya Gram Jyoti Yojana, aimed at enhancing the transmission and distribution infrastructure and services.

Initially, India set a goal to elevate its renewable energy capacity to 175 GW by 2022, including contributions from solar (100 GW), wind (60 GW), biomass (10 GW), and small hydropower (5 GW). In 2018, this ambition was expanded to achieve 225 GW of renewable capacity by 2022 and 275 GW by 2027. India remains dedicated to meeting its Nationally Determined Contribution (NDC) target of achieving a 40 percent share of renewable energy in its total energy mix by 2022. During COP 21, India pledged under its Nationally Determined Contributions (NDCs) to source 40% of its electricity capacity from non-fossil fuels by 2030. This goal was met by November 2021. As of 30 November 2021, India's Renewable Energy (RE) capacity reached 150.54 GW, broken down into solar (48.55 GW), wind (40.03 GW), small hydro power (4.83 GW), bio-power (10.62 GW), and large hydro (46.51 GW), alongside a nuclear energy capacity of 6.78 GW. Consequently, the total non-fossil fuel installed capacity amounted to 157.32 GW, constituting 40.1% of the total electricity capacity of 392.01 GW. Over the past 7.5 years, India has seen unparalleled growth in renewable energy capacity among major economies, with the renewable sector (including large hydro) expanding nearly twice and solar energy growing more than 18-fold.

By harnessing the potential of sustainable energy solutions, India can not only meet its SDG commitments but also position itself as a global leader in sustainable development.



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Sustainable Development Goals and Energy: An Overview

The Sustainable Development Goals (SDGs), adopted by all United Nations Member States in 2015, represent a universal call to action to end poverty, protect the planet, and ensure that all people enjoy peace and prosperity by 2030. This section delves into the critical relationship between sustainable energy and the SDGs, emphasizing the significance of energy in achieving broader development objectives.

A. Energy and the SDGs: An Indispensable Link: SDG 7: Affordable and Clean Energy is explicitly dedicated to ensuring access to affordable, reliable, sustainable, and modern energy for all. It serves as a cornerstone for progress, impacting other SDGs. Access to clean energy is fundamental in alleviating poverty (SDG 1), enhancing health through reduced air pollution (SDG 3), enabling educational opportunities by providing schools with power (SDG 4), and promoting gender equality by reducing women's and girls' labor in collecting fuel (SDG 5). Beyond SDG 7, sustainable energy influences economic growth (SDG 8) by powering industries without harming the environment. It also underpins innovations in sustainable industrialization (SDG 9) and impacts cities and communities (SDG 11), making them more sustainable through integrated energy solutions. Moreover, energy plays a critical role in combating climate change (SDG 13) by transitioning towards low-carbon energy sources and enhancing energy efficiency, thereby contributing to the global efforts against climate change.

B. Renewable Energy and SDG Achievement in India: Renewable energy sources offer a promising pathway to achieving the SDGs in India. Solar and wind energy, in particular, have seen remarkable growth, driven by policy initiatives such as the National Solar Mission and wind energy auctions. These renewable sources not only contribute to SDG 7 by enhancing energy access and reliability but also support SDG 13 by reducing carbon emissions. Additionally, the growth in renewables can stimulate job creation (SDG 8), foster innovation (SDG 9), and promote sustainable cities and communities (SDG 11) through decentralized energy systems. Energy efficiency is another critical aspect. India's Perform, Achieve and Trade (PAT) scheme and standards for appliances aim to reduce energy consumption in industries and households, directly contributing to SDG 12 (Responsible Consumption and Production) and indirectly supporting climate action (SDG 13) by lowering energy demand and emissions.

Despite the potential, transitioning to sustainable energy in India faces several barriers. Financial constraints, technological challenges, grid integration of renewable energy, and the need for capacity building and awareness are significant hurdles.

Sustainable Energy Solutions for India

India's journey toward sustainable energy solutions is critical for its environmental, economic, and social development. As the nation grapples with the challenges of its vast energy

demand, reliance on fossil fuels, and the pressing need to address climate change, sustainable energy solutions emerge as the beacon of hope and progress.

A. Renewable Energy Sources: Harnessing the Elements

Solar Power: India's geographical advantage, with abundant sunshine for most of the year, positions solar energy as a cornerstone of its renewable energy strategy. The National Solar Mission aims to promote the development of solar cities and solar parks, reducing the cost of solar power generation and achieving grid parity. Implementing rooftop solar installations in urban and rural areas can decentralize energy production, ensuring energy security and sustainability.

Wind Energy: With the fourth largest wind power capacity globally, India's wind energy sector has immense potential for growth. Focusing on offshore wind projects and enhancing the efficiency of onshore wind farms through advanced turbines can significantly increase wind energy production. Policies encouraging investments in wind energy infrastructure and technology are pivotal for tapping into this resource.

Hydropower and Biomass: Small-scale hydropower projects can provide clean energy to remote areas, supporting rural development and reducing reliance on diesel generators. Biomass energy, derived from agricultural residues and waste, can offer dual benefits of waste management and energy production, especially in rural India where it can also create employment opportunities.

Geothermal and Tidal Energy: Exploring geothermal energy sources and the potential for tidal energy along India's vast coastline can diversify the renewable energy portfolio. Although these sources are currently underutilized, targeted research and pilot projects could unlock new sustainable energy avenues.

B. Enhancing Energy Efficiency: The First Fuel

Energy efficiency is often termed the "first fuel" for sustainable development, offering significant savings and emissions reductions. India's Perform, Achieve, and Trade (PAT) scheme incentivizes energy-intensive industries to improve their energy use efficiency. Expanding energy efficiency measures to buildings, transportation, and appliances through stricter standards and labeling programs can further reduce energy demand and environmental impact.

C. Innovative Technologies: Paving the Way Forward

Energy Storage: As India increases its renewable energy share, investing in energy storage technologies becomes crucial for managing supply variability. Advanced batteries, pumped hydro storage, and other innovative storage solutions can stabilize the grid and ensure reliable energy supply.

Smart Grids: Implementing smart grid technologies can optimize electricity delivery and use, improving energy efficiency and allowing for the integration of distributed energy resources, including rooftop solar and wind energy.

Electric Vehicles (EVs): Promoting the adoption of EVs through incentives, infrastructure development, and manufacturing support can reduce oil dependence and emissions. Coupled with renewable energy-powered charging stations, EVs can significantly contribute to India's sustainable transport solutions.

D. Policy Frameworks and Financing: The Enablers

Effective policy frameworks and financing mechanisms are essential to accelerate the transition to sustainable energy. Policies that promote renewable energy through subsidies, tax incentives, and feed-in tariffs can attract investments and drive down costs. Additionally, innovative financing models, such as green bonds and public-private partnerships, can mobilize the necessary capital for large-scale renewable energy projects.

E. Capacity Building and Public Participation: Strengthening the Foundation

Building technical and institutional capacity across the energy sector is vital for the adoption of sustainable energy technologies. Training programs for engineers, technicians, policymakers, and the public can foster a knowledgeable ecosystem supportive of renewable energy initiatives. Encouraging public participation through awareness campaigns and community-led renewable energy projects can enhance social acceptance and drive grassroots-level change.

Challenges and Barriers

India's journey towards a sustainable energy future, while marked by significant progress and innovation, faces numerous challenges and barriers. Understanding these challenges is crucial for devising effective strategies to overcome them and achieve India's sustainable energy goals.

A. Technical Challenges

Grid Integration of Renewable Energy: As India increases its renewable energy capacity, integrating these intermittent energy sources into the existing grid poses a significant challenge. The variability of solar and wind energy necessitates advancements in grid management and energy storage solutions to ensure reliability and stability.

Energy Storage: The development of cost-effective, large-scale energy storage technologies is still in its nascent stages. Effective storage solutions are critical for addressing the intermittency of renewable energy sources and for enabling a shift towards a more flexible and resilient energy system.

B. **Financial Barriers**

High Initial Investment Costs: Despite the decreasing costs of renewable energy technologies, the initial capital investment required for renewable energy projects remains substantial. This financial barrier can deter investment, particularly in rural and remote areas where the return on investment is perceived as uncertain.

Access to Finance: Accessing finance for renewable energy projects, especially for small and medium enterprises (SMEs) and community initiatives, is a significant barrier. The lack of tailored financial products and the high perceived risk by financial institutions hinder the flow of capital to sustainable energy projects.

C. Regulatory and Policy Challenges

Policy Inconsistency and Uncertainty: Frequent changes in policies and regulations can create an environment of uncertainty for investors and developers. Inconsistent policies across different levels of government and delays in policy implementation can impede the growth of the renewable energy sector.

Subsidies for Fossil Fuels: Despite the commitment to sustainable energy, subsidies for fossil fuels continue, creating an uneven playing field. These subsidies can distort energy markets and discourage investment in renewable energy sources.

D. Social and Behavioral Barriers

Awareness and Acceptance: Public awareness and acceptance of renewable energy technologies are crucial for their widespread adoption. Misconceptions and lack of information about the benefits and feasibility of sustainable energy solutions can slow down their acceptance and uptake.

Energy Equity: Ensuring equitable access to sustainable energy solutions is a significant challenge. Vulnerable and marginalized communities often face barriers to accessing clean energy, perpetuating energy poverty and inequality.

E. Infrastructure and Market Challenges

Lack of Infrastructure: Adequate infrastructure for renewable energy, such as transmission lines for remote renewable energy installations or charging stations for electric vehicles, is lacking. Developing this infrastructure is essential for the widespread adoption of sustainable energy solutions.

Market Structure and Competition: The dominance of established fossil fuel companies in the energy market can hinder the entry and growth of renewable energy enterprises. Creating a level playing field requires regulatory interventions and market reforms to encourage competition and

innovation.

F. Addressing the Challenges

Overcoming these challenges requires a multifaceted approach that includes technological innovation, financial mechanisms, policy reforms, and public engagement. Developing and deploying advanced technologies for energy storage and grid integration can address technical challenges. Financial innovations, such as green bonds and risk guarantee mechanisms, can alleviate financial barriers.

Policy stability, clear regulatory frameworks, and the gradual phasing out of fossil fuel subsidies can create a conducive environment for renewable energy investments. Public awareness campaigns, capacity-building initiatives, and inclusive policies can ensure wider acceptance and equitable access to sustainable energy.

Collaboration among government, private sector, civil society, and international partners is crucial for overcoming these barriers. By addressing these challenges comprehensively, India can pave the way for a sustainable energy future, contributing significantly to global efforts to combat climate change and achieve the Sustainable Development Goals.

Prospects for the Future

As India navigates through the myriad of challenges in its quest for sustainable energy, the prospects for the future are both promising and transformative. The nation stands on the brink of a renewable energy revolution, with the potential to not only meet its energy demands sustainably but also to emerge as a global leader in green energy innovation. This vision for the future is built on the foundation of technological advancements, policy reforms, international collaboration, and a growing awareness of sustainability among the populace.

A. Technological Innovation and Advancements

The rapid pace of technological innovation in the energy sector presents a bright outlook for India's sustainable energy future. Developments in solar photovoltaic (PV) technology, wind turbine efficiency, energy storage solutions, and smart grid technologies are making renewable energy more reliable, affordable, and scalable. As these technologies advance, they promise to overcome current limitations, especially in energy storage and grid integration, enabling a smoother transition to a renewable-led energy system.

B. Policy Reforms and Government Initiatives

India's commitment to renewable energy is reflected in its ambitious policy frameworks and targets, such as aiming for 450 GW of renewable energy capacity by 2030. Continued policy support,

including incentives for renewable energy projects, streamlined regulatory processes, and support for research and development, are crucial for achieving these targets. Moreover, policies promoting electric vehicles (EVs), energy efficiency, and green buildings are set to further reduce the carbon footprint of India's economy.

C. International Collaboration and Investment

International collaboration and foreign investment are key to accelerating India's sustainable energy transition. Partnerships under platforms like the International Solar Alliance (ISA) not only facilitate knowledge exchange but also mobilize financial resources for renewable energy projects. Increased investment from global financial institutions and countries looking to support green energy initiatives can provide the necessary capital for large-scale renewable energy infrastructure and innovation.

D. Socio-Economic Development and Job Creation

The shift towards sustainable energy is expected to spur socio-economic development and create millions of jobs across the renewable energy sector. From manufacturing and installation to maintenance and operations, renewable energy projects can generate employment opportunities, especially in rural and underserved regions. This economic stimulus can drive broader development goals, improving livelihoods, and reducing poverty.

E. Environmental Benefits and Climate Action

The environmental benefits of transitioning to a sustainable energy system are profound. By reducing dependence on fossil fuels, India can significantly cut its greenhouse gas emissions, contributing to global efforts to combat climate change. Cleaner air, reduced water usage, and conservation of natural habitats are additional environmental benefits that accompany the adoption of renewable energy sources.

F. Energy Access and Equity

Improvements in renewable energy technologies and their decreasing costs hold the promise of universal energy access in India. Decentralized renewable energy solutions, such as solar microgrids and home systems, can provide reliable and affordable energy to the remotest corners of the country, bridging the energy access gap and promoting equity.

G. Public Awareness and Shift in Consumer Behavior

Growing public awareness of environmental issues and the benefits of renewable energy is likely to drive a shift in consumer behavior towards more sustainable practices. Increased demand for clean

energy, sustainable transportation options like EVs, and energy-efficient appliances can propel the market for green technologies and services, further accelerating the energy transition. The future prospects for sustainable energy in India are bright, underpinned by a confluence of technological, policy, economic, and social factors.

H. Advancing Clean Energy and Combating Climate Change

India has successfully pursued economic growth while reducing greenhouse gas emissions. The Indian Railways' commitment to net-zero emissions by 2030 will cut emissions by 60 million tonnes annually. Additionally, the UJALA LED bulb initiative is reducing emissions by 40 million tonnes each year. In support of these efforts, India inaugurated the National Hydrogen Mission in 2013, aiming to become a leading global hydrogen producer. Despite having the world's second-largest population, India maintains per capita CO2 emissions significantly below the global average, with 1.8 tonnes per capita compared to the United States' 14.7 tonnes and China's 7.6 tonnes.

The international power sector is rapidly evolving through technological advancements and the adoption of climate change measures. At the COP-21 Paris meeting in 2015, India vowed to achieve a 40% reliance on non-fossil fuel power generation, a target it reached well before the 2030 deadline. India is committed to leading the charge against climate change, aiming for Net Zero Emissions by 2070 and setting near-term objectives such as increasing renewable energy capacity to 500 GW by 2030, fulfilling 50% of energy needs with renewables, cutting total emissions by one billion tonnes by 2030, and reducing the emissions intensity of its GDP by 45% by 2030. India's journey offers valuable insights for other developing countries striving to fulfill their climate commitments and transition towards a more sustainable energy future.

Hydrogen Mission

In the Independence Day speech on 15.08.2021, Prime Minister announced the launch of National Hydrogen Mission and stated the goal to make India a global hub for Green Hydrogen production and export. The draft National Green Hydrogen Mission document is under inter-ministerial consultations.

One Sun – One World – One Grid (OSOWOG)

A tripartite Memorandum of Understanding (MoU) was signed between the Ministry of New and Renewable Energy (MNRE), the International Solar Alliance (ISA) and the World Bank on 08.09.2020 for a study on the One Sun – One World – One Grid (OSOWOG) initiative. Currently, the implementation plan, road map and institutional framework is being developed by a consultant appointed for this purpose. The inception report has already been submitted by the consultant in September'2021. The complete study is expected to be completed by mid of 2022.

Conclusion

India's ambitious pursuit of sustainable energy is a testament to its commitment to achieving the Sustainable Development Goals and addressing the global challenge of climate change. The transition towards renewable energy sources, bolstered by technological innovations, supportive policies, and international collaboration, offers a pathway to energy security, environmental sustainability, and socio-economic development. While challenges remain, from financial barriers to infrastructure needs, the prospects for a sustainable energy future in India are promising and full of potential. The success stories and case studies across the country illuminate the path forward, showcasing the transformative impact of sustainable energy solutions on communities, economies, and the environment. As India continues to navigate its energy transition, it stands as a beacon of progress and an example for nations worldwide, underscoring the pivotal role of sustainable energy in building a resilient, equitable, and sustainable future for all.

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