



Public Policy and Governance: Analyzing the effectiveness of the National Green Hydrogen Mission (NGHM) in rural development.

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ARTICLE DETAILS	ABSTRACT
Research Paper Received: 25-08-2026 Accepted: 24-09-2026 Published: 20-10-2026 Keywords: <i>climate change, GHG emission, National Green Hydrogen Mission, sustainability, rural development, paradigm shift.</i>	Climate change has been recognized as one of the most critical challenges faced by the global society and economy in the 21st century. It has abruptly increased the frequency and intensity of disasters. India, due to its geographical position and geological conditions, is traditionally vulnerable to natural disasters, such as floods, droughts, and heat waves. Greenhouse gas (GHG) emissions are considered the primary driver of climate change. Environmental protection in India is supported by various environmental laws and judicial interventions; however, their effectiveness is constrained by friction between rapid economic development and ecological conservation. India, despite having more than 17% of the global population, contributes less than 4% of the cumulative global greenhouse gas emissions. However, the country is facing significant climate impacts and continuously bearing the brunt of these effects, which threaten the lives and livelihood, especially in rural areas. India's progress in decoupling economic growth from GHG emissions shows its dedication to sustainable development goals (SDGs); to meet the country's developmental goals, it

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is utmost important to increase energy consumption significantly. Accordingly, in line with achieving Net-Zero by 2070, India launched the National Green Hydrogen Mission (NGHM) in 2023 with the objective of linking sustainability with self-reliance. Rural areas, the backbone of the NGHM, serve as the primary resource base for renewable energy and decentralized production, and face core energy issues, such as unreliability and lack of clean sources. This study aimed to understand the effectiveness of the NGHM, particularly in rural areas vulnerable to floods. A mixed-method of survey research question was used in this study. Data collection and analysis is based on secondary source. The study provides potential impact of NGHM on rural lives & livelihood. The Mission effectively promotes a paradigm shift from traditional energy to a greener, cleaner & more technology driven sustainable energy

1. Introduction

Energy is an essential component for economic growth and development. Presently, the world confronts two significant and interconnected challenges: increasing energy demand and climate change. The energy sector is responsible for approximately 73% of global greenhouse gas emissions, primarily due to its persistent dependence on fossil fuels. As of March 2025, India ranks as the third largest electricity producer globally, with a total installed capacity of 475.2 GW (utility-based). Coal-based power plants remain predominant, contributing approximately 47% of the total installed capacity (India Energy Scenario, Bureau of Energy Efficiency, Ministry of Power, 2025). This represents a reduction from approximately 60% in 2014-15, indicating a concerted effort by the country to transition from fossil fuels to cleaner energy sources. In today's "Glocal" era, the global community is grappling with major energy and climate change challenges due to the overuse of fossil fuels for various developmental metrics. The rapid increase in population, unplanned urbanization, deforestation, and natural calamities have exacerbated these challenges. To address these issues and meet sustainable development goals, a shift towards renewable energy sources like solar, wind power, and green hydrogen is essential. The development of renewable energy and green hydrogen is heavily dependent on the availability of adequate land and water. While renewable energy requires land, green hydrogen production relies on water resources. These limitations affect their potential for generation

and production. Challenges include population density, existing land disputes, disaster-prone areas, land costs, and water availability.

India has set a goal of achieving energy independence by 2047 and net-zero emissions by 2070. Despite various obstacles, renewable energy sources, including solar and wind power, along with green hydrogen, are anticipated to be crucial in reaching this goal. According to the Council on Energy, Environment and Water (CEEW), India will need a solar capacity exceeding ~5,600 GW and a wind capacity of ~1,800 GW to achieve net-zero emissions by 2070 (Chaturvedi and Malyan 2022). Additionally, the demand for green hydrogen in sectors such as fertilizers, refineries, steel, and transportation in India is projected to reach ~30 million tonnes per annum (MTPA) by 2050 (Kowtham, Pranav, and Clay 2022). According to its revised Nationally Determined Contributions (NDC), India aims to cut the emissions intensity of its gross domestic product (GDP) by 45% by 2030 compared to 2005 levels and achieve 50% non-fossil installed capacity by 2030. Green hydrogen presents an opportunity to lessen reliance on imported fossil fuels, particularly in decarbonizing sectors like steel and chemicals that are difficult to abate.

2. Green Hydrogen

Hydrogen is the lightest and most abundant element in the universe. It is rarely found in its elemental form in nature and must always be extracted from other hydrogen-containing compounds. Depending on the nature of the method of its extraction, hydrogen is categorized into three categories, namely, Grey, Blue and Green. Green hydrogen is considered “*the fuel of the future*” and a promising alternative for enabling energy transition. Green hydrogen (GH₂) is produced by electrolysis, in which water is split into hydrogen and oxygen using electricity generated from renewable sources, such as solar, wind, or hydropower. This process results in a clean and emission-free fuel that has immense potential to replace fossil fuels and reduce carbon emissions. Another method of producing green hydrogen is from waste biomass, which involves the gasification of biomass to produce hydrogen. This method provides an additional revenue stream for farmers and local communities. Both these production methods are clean and sustainable, making green hydrogen an attractive option for transitioning to a low-carbon future. The need for green hydrogen is rapidly increasing because of its potential to decarbonize several sectors, including transportation, shipping, and steel. Green hydrogen can replace traditional fossil fuels in transportation, which contributes significantly to greenhouse gas emissions. It can also be used in industry to produce ammonia, methanol, and steel, which are currently heavily reliant on fossil fuels. Additionally, green hydrogen can be used as a backup energy source for renewable energy plants, providing a constant and reliable source of energy. Furthermore, it can be used in micro grids to provide electricity to remote areas and enable energy

independence. In the context of global efforts to mitigate climate change and reduce carbon emissions, green hydrogen has surfaced as a viable substitute for conventional fossil fuels at the local to global levels. It has emerged as a key enabler of traditional energy to sustainable energy transition. Its applications in hard-to-abate sectors offer a pathway to reduce carbon emissions and mitigate climate as well as disaster risk. Recent trends and analysis indicate that, driven by technology advancements, reduction in costs of renewable energy and electrolyzers along with aggressive national strategies, green hydrogen is likely to become cost-competitive in applications across industry, mobility, and other sectors within a short span. Accordingly, India has launched the National Green Hydrogen Mission (NGHM).

2.1. National Green Hydrogen Mission (NGHM)

India currently expends over \$160 billion annually on energy imports, a figure projected to double within the next 15 years without intervention (PIB, Jan 2023). The nation stands at a pivotal point regarding its energy framework, with green hydrogen poised to significantly contribute to achieving self-reliance and energy independence. In response, the Government of India has initiated several measures, including the National Green Hydrogen Mission (NGHM), to facilitate the transition from fossil fuels to green hydrogen. The NGHM aims to produce 5 million tons per annum (MTPA) of green hydrogen by 2030. Additionally, India is projected to establish approximately 30 million tons of green hydrogen production capacity by 2050 (Kowtham, Pranav, and Clay 2022). This initiative involves various activities, such as stakeholder engagement, public awareness campaigns, research and development, infrastructure development, research collaborations, legislation, standards, pilot projects, and international cooperation. By 2030, these efforts are expected to reduce emissions by approximately 50 million metric tons (MMT) and significantly decrease fossil fuel imports. The Green Hydrogen pathway is anticipated to be a crucial enabler for India's goal of developing a low-carbon and self-reliant economy. Currently, India spends over \$160 billion on foreign exchange annually for energy imports. These imports are likely to double in the next 15 years without remedial action. (PIB, Jan 2023).

2.2. National Green Hydrogen Mission (NGHM) outcomes

The Mission will likely result in the following outcomes by 2030:

Methodology

The literature review for this study was conducted using standard databases. Relevant keywords, such as “sustainable development & renewable energy,” “energy crisis & green hydrogen,” and “significance of NGHM in rural development,” were employed to gather pertinent information. The retrieved materials were



categorized into research articles, technical reports, websites, and news articles. Within the research articles category, pertinent research papers were reviewed, while in the technical reports category, relevant reports from government bodies and institutions were consulted. Additionally, data were collected from the websites of various organizations. News articles, particularly those related to India's NGHM, were also examined. To formulate the survey research questions, both quantitative and qualitative methods were utilized in this study. The primary research questions designed to enhance the study are as follows: Research Question (1): Why does India need to implement NGHM? Research Question (2): How does the NGHM contribute to achieving India's target of energy independence by 2047 and net-zero by 2070? Research Question (3): What is the significance of NGHM in rural development? Research Question (4): What is the effectiveness of the NGHM in India?

3. Significance of NGHM in Rural Development

Energy is integral to rural development. The absence of affordable energy access significantly contributes to the substandard quality of life in rural regions of developing nations, such as India. India, as a developing country, is the most populous nation globally and exhibits considerable socio-economic and geographical diversity. Approximately 65% of India's population resides in rural areas, with 47% relying on agriculture and related sectors for their livelihood (Economic Survey, 2021). Consequently, the government's emphasis on rural development is essential, necessitating affordable access to adequate energy. Although India has achieved notable progress in electrification, rural areas continue to encounter two primary energy challenges: unreliability and a scarcity of clean energy sources. Extending the grid to remote areas, particularly those prone to flooding, is often financially impractical. Diesel generators, frequently used as backups, are both expensive and polluting. While solar power is gaining traction, it faces issues of intermittency and storage. To address these challenges, green hydrogen is emerging as a decentralized and transformative energy solution for rural development in India.

4. A case study

4.1. Energy, floods and rural lives:

Bihar is the most flood-prone state in India, with 76% of the population in North Bihar consistently facing the threat of flood devastation. Among the 38 districts, 28 experience flooding, with 15 being severely affected, resulting in significant losses of property, lives, farmland, and infrastructure. The Kosi River basin is particularly susceptible to flooding, with the Kosi River, often referred to as the "Sorrow of Bihar," causing recurrent floods in the Saharsa, Madhepura, and Supaul districts of North Bihar. The primary victims of these frequent floods are individuals residing between the Kosi River embankments, who endure



a combination of challenges, including regular flooding, a lack of basic amenities, and loss of livelihood. These frequent and severe floods result in substantial economic and human losses. Flood inundation significantly influences flood risk in a given area. This study investigates the flood inundation of the Kosi embankment area in the Sahasra district, Bihar. Secondary data were sourced from various entities, including the Bihar Economic Survey, Census 2011, FMISC, Department of Disaster Management, Bihar State Disaster Management Authority (BSDMA), Energy Department, and other pertinent open-source data. The study areas within the embankment receive discharge from the upstream region via the Kamla-Balan and Adhwara Rivers and experience backflow from the Kosi River during the monsoon season. Consequently, water persists in the area for extended periods, resulting in the formation of marshes, swamps, and ponds, and is characterized by inadequate drainage systems (Jain and Sinha, 2005). A segment of the population with limited socio-economic potential is disproportionately affected by natural disasters (Kahn, 2005). Residents have adopted various strategies to cope with the Kosi River's shifting courses, flooding, waterlogging, and sand deposition. The recurrent floods perpetuate a cycle of stress, leading to distress-induced seasonal migration. The region has become a hub for seasonal migration and faces various social stigmas. Among the challenges, insufficient electricity supply remains a core issue. Grid extension and electricity provision, particularly during the monsoon, are often operationally unfeasible and challenging. Diesel generators, commonly used as backups, are costly and polluting. Although solar power is gaining popularity, it faces issues of intermittency and storage. Addressing these challenges necessitates the development of a clean, reliable, and scalable energy solution capable of operating locally and independently from the central grid. Green hydrogen technology provides such a solution. It facilitates long-duration energy storage, thereby mitigating the intermittency issues related to renewable energy sources like solar power. Furthermore, it has the potential to supply energy not only to residential areas but also to water pumps, small-scale industries (e.g., flour mills), & local transportation systems (e.g., boats).

4.2. Energy Transition in Bihar

Bihar has faced numerous challenges within its energy sector, including limited power generation capacity, significant transmission and distribution (T&D) losses, and a heavy reliance on thermal power. To address the increasing demands of its population and economy, the energy sector in Bihar has experienced substantial transformation. Historically dependent on traditional energy sources, the state has diversified its energy mix to incorporate renewable sources, modernized its infrastructure, and enhanced its power generation capacity. In recent years, concerted efforts have been directed towards overcoming these constraints & advancing renewable energy development. The expansion of renewable energy, particularly solar power, has become a fundamental component of Bihar's energy strategy. The Bihar Renewable Energy



Development Agency (BREDA) has spearheaded numerous initiatives to increase solar generation through the establishment of large solar parks, rooftop systems, and off-grid solutions aimed at rural electrification.

4.3. Promotion of Green Hydrogen Production

Green hydrogen offers a viable solution to address Bihar's energy and environmental challenges. By utilizing its renewable energy potential and establishing a comprehensive green hydrogen infrastructure, Bihar can attain energy security, foster economic growth, and ensure environmental sustainability. Policies and initiatives, including the National Hydrogen Mission initiated by the Government of India, are designed to facilitate the development of a green hydrogen ecosystem. Bihar can capitalize on these national initiatives and align its state policies to encourage the adoption of green hydrogen.

4.4. Integrate Climate Resilience into Energy Policies

Renewable energy infrastructure must be designed and constructed to endure the effects of climate change, including extreme weather events and flooding. Such measures will improve the resilience and reliability of energy systems. Furthermore, disaster risk management should be incorporated into energy planning to reduce the impacts of climate-related disasters on renewable energy projects.

4.5. Impacts of NGHM in the context of the study area

4.5.1. Environmental impact

The National Green Hydrogen Mission (NGHM) aims to reduce greenhouse gas emissions by employing green hydrogen as an energy carrier across various sectors, including transportation, electricity generation, and industrial processes. This initiative aligns with global efforts to mitigate climate change and decrease air pollution. Additionally, green hydrogen addresses the energy storage challenges associated with renewable energy sources, such as solar power, by ensuring a consistent and reliable energy supply during peak generation periods. This approach promotes the adoption of cleaner technologies, reduces emissions, enhances energy storage capacity, and supports sustainable energy practices. By embracing green hydrogen, India contributes to international efforts to combat climate change. The study area presents potential for further exploration of the NGHM.

4.5.2. Economic impact

The National Green Hydrogen Mission (NGHM) aims to decarbonize essential industries and achieve national energy independence by promoting the production and utilization of green hydrogen. To facilitate India's transition to a low-carbon economy, initiatives such as the NGHM and the Green Hydrogen Policy



have been implemented to encourage innovation, attract investment, and generate employment within the green hydrogen sector (Athia et al., 2025; Raman et al., 2022). The availability of numerous job opportunities through the NGHM in the study area can mitigate issues related to stress migration and the excessive burden on urban centers.

4.5.3. Technological impact

The objective of the NGHM is to reduce production costs and enhance the economic feasibility of green hydrogen. Green hydrogen serves as a fuel for FCEVs, facilitates the decarbonisation of processes, and generates electricity without greenhouse gas emissions. It is applicable in transportation, industry, and power generation sectors. The mission also seeks to increase awareness and demand for green hydrogen through financial incentives and pilot projects. The initiative within the study area is pivotal for skill development among youth, particularly females. With investment in research, academic collaboration, and government support, India has the potential to become a global leader in green hydrogen technology (Athia et al., 2024c). Achieving this potential necessitates addressing the needs of rural areas through need assessments.

4.5.4. Social impact

The National Green Hydrogen Mission (NGHM) holds the potential to substantially influence social issues, particularly in the realms of women's empowerment and gender equality. Green hydrogen energy, derived from renewable sources, offers marginalized populations a clean and sustainable alternative to conventional fuels, thereby empowering these communities. Decentralized green hydrogen initiatives can enhance women's socioeconomic status and expand gender opportunities. Research conducted in remote communities has illustrated that the involvement of local women in energy production and management decisions contributes to broader social development objectives, such as increased income, improved hygiene and health conditions, and enhanced educational outcomes, especially for girls (Brahmi et al., 2023; Di et al., 2022).

4.5.5. Promote Public–Private Partnerships (PPPs)

The National Green Hydrogen Mission (NGHM) in India seeks to enhance industry engagement in green hydrogen initiatives through the establishment of a Strategic Hydrogen Innovation Partnership (SHIP) framework. This framework facilitates public–private partnerships (PPPs) for research and development (R&D) within the hydrogen sector. The partnership's objective is to expedite the development and implementation of green hydrogen solutions by integrating efforts from government agencies and industry

stakeholders. The mission allocates significant financial resources for supply-side incentives related to green hydrogen production and electrolyser technology, thereby fostering a conducive investment climate. These incentives are designed to promote the establishment of specialized manufacturing facilities in India, thereby supporting domestic manufacturing and enhancing economies of scale by lowering production costs and project timelines. Incentives for green hydrogen production motivate project developers to pursue ambitious initiatives. The primary goals of the mission are to increase industry participation and to cultivate an investment-friendly environment for green hydrogen projects (Singh et al., 2024).

5. Conclusion

The National Green Hydrogen Mission (NGHM) is anticipated to substantially enhance India's energy landscape, economy, and environmental conditions. Its objectives include reducing carbon emissions, enhancing energy security, generating employment opportunities, and fostering innovation within the renewable energy sector by promoting the production and utilization of green hydrogen. Overall, the NGHM holds significant potential in facilitating India's transition towards a low-carbon future and advancing sustainability. Despite the considerable progress made by the NGHM, substantial efforts are still required to achieve its ambitious targets.

6. The principal findings of this study indicate that

- The NGHM will positively impact the entire economy, with particular benefits for rural areas. This will be achieved through the decarbonisation of the energy, transportation, and industrial sectors, which will reduce national dependence on imported fossil fuels. Additionally, the initiative will enhance domestic manufacturing capacity, create employment opportunities, and facilitate skill development at the local level. Furthermore, it will support the advancement of manufacturing techniques and the establishment of an innovation ecosystem within the nation.
- The NGHM has the potential to transform the nation's energy sector and further its decarbonisation goals. To guarantee the mission's sustained success, it is essential to address the fundamental causes of challenges and issues at the local level.

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