# Sub-national drivers of India's green hydrogen development

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## Abstract

India's national government has offered strong support for the development of green hydrogen as part of the country's clean energy transition. However, much of the actual progress in this transition will depend not on national but subnational governments. This paper argues that India's subnational governments have significant potential to capitalise on diverse natural resource endowments while creating jobs and growing the local economy when promoting green hydrogen. At the same time, the national government will need to offer direct and indirect support to address technological, financial, and institutional constraints when promoting green hydrogen at the subnational level. The paper conducts case studies of three Indian states, namely Gujarat, Jharkhand, and Kerala, to examine developments in the hydrogen sector at the sub-national level. The paper then recommends a six-point plan to strengthen the multi-level collaboration needed to capture the full benefits of green hydrogen. The plan consists of the following: 1) tailoring skill development programme to support the green hydrogen ecosystem; 2) closing infrastructure gaps; 3) incentivising off-takers; 4) attracting investment and enabling public-private partnerships; 5) encouraging research and development (R&D); and 6) promoting co-innovation. These six points can help India realise its potential while addressing the attendant limitations of a green hydrogen transition.

## Introduction

India's National Green Hydrogen Mission (MNRE, 2023) is strategically important to the country's clean energy transition. The mission is rooted in the realization that hydrogen has considerable potential to decarbonise hard-to-abate sectors like industry, transport, and power generation. It further reflects the need to invest significantly in becoming a global hub for green hydrogen production, usage, and export (Government of India, 2023b); this financial commitment is apparent in the initial outlay of $2.3 billion in 2023 for the Green Hydrogen Mission (PIB, 2023)—a figure that is expected to increase more than 100% by 2024 (ET, 2024). At the same time, the mission also underlines that green hydrogen cannot only contribute to international decarbonisation efforts but foster economic growth and innovation.

Though there are several reasons that the mission is viewed as important, questions are often raised about the capacity of the green hydrogen industry to grow at not simply the national but sub-national levels. More concretely, many subnational governments are keen to develop a green hydrogen ecosystem. However, they may also lack the infrastructure and market support to contribute to those efforts. It is against this backdrop, that this paper argues that India's subnational state governments can tailor green hydrogen plans to suit local conditions and resources. The paper also contends that it will be critical to recognise that some states may need financial, institutional, and technological support from the national government. A mix of direct resource transfers (i.e. block grants) and indirect enabling reforms (i.e. tax incentives), along with overseas technology support, will be critical in this regard. Pulling off this delicate balancing act will require viewing the transition through a multilevel lens.

## Toward a multilevel perspective

This paper will use a multilevel perspective to understand factors contributing to the green hydrogen transition, drawing on ideas from sustainability transitions and multilevel governance

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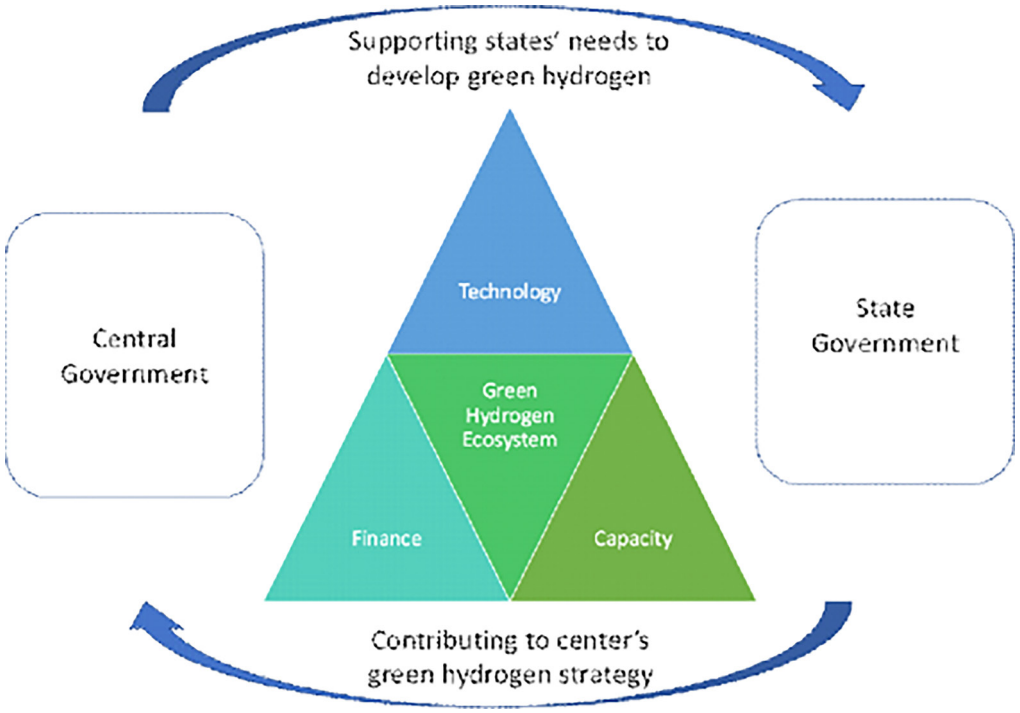


**Figure 1:** Multilevel governance for green hydrogen ecosystem

Source: Authors

(Betsill and Bulkeley, 2006; Geels and Schot, 2007; Bulkeley and Betsill, 2013; Markard, Geels, and Raven, 2020). A core insight of this work literature is that delivering public goods requires leveraging the skills and assets of central, state, and lower level governments-as evidenced by other public goods such as health and education (Moeko Saito-Jensen, 2015). In short, it necessitates cooperative power-sharing arrangements among all levels of government (NITI Aayog, 2018; Kandpal and Okitasari, 2023).

Research has shown that a top-down climate agreement is unlikely to trigger the systemic changes for a 1.5° C degree future (Osofsky, 2010), but subnational governments can initiate these transformative changes (C40 Cities, Sustainia and Realdania, 2017). This is because subnational authorities often possess local knowledge and motivation needed for their climate solutions (C40 Cities, 2015), linking these solutions to development benefits like jobs and industries (Rabe, 2007; Puppim de Oliveira *et al.*, 2013). However, subnational governments may lack the capacity to effectively implement and scale up these climate solutions (Burch, 2010; Corfee-Morlot *et al.*, 2009).

For simplicity, this paper emphasises the collaboration between national and subnational governments, granting subnational governments autonomy for innovative and locally appropriate solutions, and national support for implementation and scaling (Corfee-Morlot *et al.*, 2009). India's green hydrogen ecosystem will require crafting an effective multilevel power-sharing agreement (Figure 1), leveraging states' natural resources while also addressing technological and financial gaps (Gupta, Kumar and Kumar, 2023; Abhyankar *et al.*, 2023). A successful green hydrogen transition will require collaboration and cooperation among all levels of government, (Dutt, 2023), strengthening both stake and national development targets.

## Tracking green hydrogen development plans by the Indian states

The Indian government's initiatives for clean energy prompted the hydrogen market to grow. The country's renewable energy plans are driving investment in the hydrogen sector, particularly in the transportation sector as fuel cell vehicles and hydrogen-powered buses are becoming more promising. States like Kerala, for example, are using hydrogen for water transport. Public-private partnerships are also fostering innovation and expanding the hydrogen energy landscape. Despite challenges like infrastructure development and cost, some states are emerging as major players in the hydrogen economy.

This section examines subnational initiatives and their alignment with India's National Hydrogen Mission, focusing on Gujarat, Jharkhand, and Kerala. In Gujarat, invaluable insights, focusing on policy impacts and business environment, came from Gujarat Energy Research and Management Institute, Indian Institute of Technology (IIT) Gandhinagar, and representatives from industry and the state government. In Jharkhand, discussions with the Jharkhand Renewable Energy Development Authority and the Central University of Jharkhand centred around state policies and capacity. In Kerala, interviews with policymakers, power utilities, and developers helped understand the ambitious green hydrogen goals and challenges.

The assessment was structured into three key subsections: estimated potential, challenges, and strategies. The estimated potential section evaluates each policy, financial resources, technology, and human resources. The challenges section showcases the limitations like renewable energy constraints, technological gaps, and financial hurdles. The strategies section reviews the state's long- and short-term policies for hydrogen development. Together, these sections provide a comprehensive overview of green hydrogen evolution across the studied states.

## Case study 1: Overview of state-level developments in green hydrogen in Gujarat

Gujarat, India's third most industrialised state, aims to produce 3 Million Tonnes per Annum (mtpa) of green hydrogen by 2030 and 8 mtpa by 2035 (Government of Gujarat, 2023a). Gujarat, known as the petroleum capital of India, is committed to achieving its net zero target.

### Estimated potential

Gujarat has significant green hydrogen potential, thanks to its renewable energy resources, industrial base, and the potential for economic growth. As of March 2023, the state has 21.6 GW of installed renewable energy capacity, with a target of reaching 100 GW by 2030 (Government of Gujarat, 2023b).

The private sector, like Reliance Industries Limited and Adani Group, is involved in setting up green hydrogen production infrastructure in Gujarat, aiming for 99.8 GW of renewable power and 4 million metric tonnes of green hydrogen production annually by 2030. Another company, L&T, is aiming to generate high-purity green hydrogen (99.99%) planning for 15% hydrogen blending with natural gas (LiveMint, 2023). The state government also signed agreements with Ocior Energy in February 2023 to build a facility in Kutch to generate 1 million tonnes of green hydrogen and ammonia per annum.

Gujarat is actively involving industry and implementing strategies to support green hydrogen development, including land allocation and stakeholder consultations. The state aims to create new revenue streams by exporting green hydrogen, which will also strengthen its role in the global hydrogen market.

### Challenges

Gujarat faces multiple challenges in developing a hydrogen economy, particularly the lack of adequate and modern electrolysis capacity. It is also crucial to expedite the installation of more renewable energy infrastructure and storage facilities. Despite these challenges, developer's interest in green hydrogen is growing as the government is encouraging public-private partnerships. This optimistic outlook promises future developments and benefits for off-takers.

A critical challenge for the state is the lack of capacity and skilled human resources in the green hydrogen sector. Our research highlights the need for regulators, industrialists, developers, researchers, academicians, original equipment manufacturers (OEMs), and other industry participants to discuss and explore the obstacles, technology readiness level, cost optimisation, and the gap in the existing landscape.

An interviewee from a government organisation estimated around INR 8-10 lakh crore (roughly 100-120 billion USD) investment in the green hydrogen sector over the next 15 years in the state's green hydrogen sector. Yet, more investments are needed in this ecosystem including industry, academia, and research. Furthermore, R&D of storage technologies receives less attention since tenders favour high-readiness projects. More focus is needed on infrastructure, demand creation, R&D, and capacity-building programs.

### Strategies

The state government aims to create an ecosystem for small and medium enterprises (SMEs) in the green hydrogen value chains by providing incentives such as capital subsidies and stamp duty waivers. Industry and academic insights assert continuous government support for the green hydrogen industry.

A key measure is the state government's readiness to allocate land for setting up renewable energy for green hydrogen production. The Gujarat Power Corporation Limited has already allotted 1,99,000 hectares of land in the Kutch-Banaskantha border areas for green hydrogen production to several companies including Reliance, Adani, Torrent Power, ArcelorMittal Nippon Steel India and Welspun Group.

The plan for developing a green hydrogen hub is an important milestone. The government has identified key players in the production, storage, transportation, and end use, including plans for electrolyser plants and storage facilities. It is expected that the industrial sectors like steel, fertilisers, and refineries will be primary consumers, aligning perfectly with the national targets.

## Case study 2: State-level developments in green hydrogen in Jharkhand

Jharkhand hosts several major industries, like iron and steel, cement, mining, transport vehicles, and fertilisers, which can be potential consumers and producers of green hydrogen. Committed to promoting green hydrogen. The state has formed a task force and signed agreements for green hydrogen projects. The task force evaluates global best practices in hydrogen utilization and intends to develop a roadmap for (Bisoee, 2023), to develop 5,000 MW solar power capacity, incentivising land leasing for solar farms' green power generation (Deogharia, 2021).

### Estimated potential

Two key drivers underpinning Jharkhand's strategic promotion of green hydrogen are deployment and manufacturing. The deployment driver aims to stimulate green hydrogen demand across sectors, including transport, industry, power, and agriculture. Concurrently, the manufacturing driver seeks to position Jharkhand as a hub for green hydrogen production and supply chains (The Pioneer, 2023). This dual focus stimulates demand and aligns with the state's broader economic goals. Jharkhand, with substantial reserves of critical minerals such as graphite, is poised to emerge as a promising manufacturing

hub. Graphite, essential for batteries, fuel cells, and high-tech applications, complements the green hydrogen industry, supporting livelihoods, and job creation, and leveraging the state's renewable energy potential and industrial base.

The Jharkhand Task Force on the Green Hydrogen Mission oversees state-level initiatives, comprising officials from the Energy and Forest departments, NTPC, CCL, and Tata Steel, with technical support from CEED (Centre for Energy and Environment Development). This collaboration guides policy execution, ensures departmental coordination, and enhances industry partnership (CEED, 2023). The Departments of Mines and Geology, and Industries engage stakeholders to develop Jharkhand's green hydrogen ecosystem. Simultaneously, the Department of Energy serves as the nodal agency for state-level renewable energy projects.

Jharkhand actively engages with industries to shape strategies for green hydrogen production and utilisation. A significant milestone is the formal approval of the *"Hydrogen Fuel Project "* in Jamshedpur, marking the launch of production of over 4,000 hydrogen internal combustion engines and 10,000 battery systems. Subsequent phases of the project will expand into advanced chemistry batteries, hydrogen fuel cells, and hydrogen fuel delivery systems in collaboration with TCPL Green Energy Solutions Private Ltd. (Ray, 2023).

Additionally, Tata Steel's trial of injecting hydrogen into the 'E' Blast Furnace at its Jamshedpur Works is another milestone in sustainable steelmaking in India (Tata Steel, 2023). The trial explores the viability of hydrogen as a fuel source, providing crucial insights for future green hydrogen initiatives.

Jharkhand's green hydrogen initiatives present possibilities for remarkable growth, supported by several projects such as Tata Steel's trial and collaboration with TCPL Green Energy Solutions. The state also aims to attract developers by leveraging its industrial strength offering a business-friendly environment with transparent rules and streamlined processes for green hydrogen projects.

## Challenges

Jharkhand faces challenges inherent in the nascent stage of entering the green hydrogen sector. Creating a comprehensive and supportive ecosystem tailored to the state's unique context is crucial, coupled with the need for developing robust renewable energy sources to power electrolysis. Ensuring access to cutting-edge electrolyser technology and fostering local manufacturing capabilities are key priorities for Jharkhand's green hydrogen journey.

Developing effective storage solutions for intermittent renewable energy sources and building an efficient hydrogen transportation network presents a complex task. Balancing innovation, safety, and environmental sustainability is essential for a conducive environment. The state also emphasises the importance of R&D plans to fund R&D initiatives that address the specific challenges in green hydrogen production.

## Strategies

The green hydrogen task force envisions a pivotal role in Jharkhand's future administrative landscape by fostering stakeholder collaboration. However, administrative frameworks must adapt to the evolving green hydrogen landscape, integrating industry, academia, and governmental insights for effective policy implementation in the future.

Jharkhand can also leverage the Eastern Zonal Council in Ranchi to become a hub for green hydrogen trading. This involves creating a coordinating body within the Council to promote inter-state collaboration, joint projects, shared infrastructure, and standardised regulations. Reinforcing the state's leadership in setting standards and ensuring fair trade practices.

With the capital-intensive nature of green hydrogen initiatives, Jharkhand is committed to providing adequate financial resources. The agreement Jharkhand signed with TCPL Green Energy Solutions Private Ltd (TCPL GES) to set up India's first Hydrogen Fuel Project in Jamshedpur (ET Online, 2023) signifies the state's initial foray into this domain, paving the way for scaled-up operations in hydrogen combustion engines, advanced chemistry batteries, fuel cells and delivery systems.

Jharkhand's commitment to green hydrogen is evident in its "Solar Energy Policy 2022," aiming to achieve a cumulative solar power capacity of 4 GW by 2027 (Government of Jharkhand, 2021). The policy includes plans for 3 GW of utility-scale solar projects, comprising solar and non-solar parks, floating solar, and canal top solar projects (Government of Jharkhand, 2021), aiming to encourage private investors and integrate solar power advancements into its green hydrogen landscape.

## Case study 3: Kerala's green hydrogen development strategy and progress

The Kerala government views green hydrogen as crucial to achieving its target of 100% renewable energy by 2040 and net-zero status by 2050 (Government of Kerala, 2023a). The state envisions green hydrogen replacing grey hydrogen in refineries and the fertiliser industries, powering heavy transports and boats, blending with natural gas for heating, and enabling sustainable aviation fuel. The state aims to leverage its abundant natural resources, renewable energy potential, freshwater, and access to ports to become a green hydrogen production centre.

## Estimated potential

Kerala plans to tap domestic and export markets for green hydrogen. Although the state has a small industrial base, it has several refinery and fertiliser units like Fertilisers and Chemicals Travancore Limited (FACT) and Bharat Petroleum Corporation Limited (BPCL) Kochi Refinery, with substantial demand for hydrogen (NITI Aayog, 2022). Kerala focuses on early-stage deployments in heavy transport and is also exploring other sectors, like energy storage, on an experimental basis.

Kochi, with its industrial base and access to the Cochin Port, has significant potential to become a green hydrogen hub. The state government has partnered with India Hydrogen Alliance (IH2A), to evaluate the Kochi Green Hydrogen Hub (KGH2), including building a green hydrogen plant

and zero-emission transport options (IH2A, 2022). This project has been selected for funding support under the Hydrogen Valley Innovation Cluster of the union government (Kondul, 2024).

The export market offers tremendous opportunities, particularly with EU countries setting ambitious green ammonia targets. India's cheap renewables and the fully integrated national grid offer significant competitive advantages for domestically produced ammonia, and some Indian firms are already securing supply contracts. Most large-scale projects target external markets. The Vizhinjam port, India's first trans-shipment port, has the potential as an export-oriented green ammonia hub, with infrastructure development plans underway. Kerala has already received significant proposals for setting up export-oriented green Hydrogen and green ammonia production plants (Arushi Koundal, 2023).

Electricity costs, which account for more than 60% of the final cost of green hydrogen, make cheap renewable electricity vital for attracting investments. Kerala aims to ramp up its renewable energy capacity through floating solar plants and pumped hydro storage, taking advantage of its vast reservoirs and unproductive lands. The potential for floating solar and pumped hydro stands at 6,500 MW and 11,000 MW respectively, supported by small hydro projects and vast freshwater resources.

## Challenges

As green ammonia is three times costlier than grey ammonia, fertiliser companies are unlikely to absorb costs without explicit government support. While fertiliser and refinery industries are crucial for green hydrogen scale-up (Kowtham Raj, Pranav Lakhina, 2022; Challa *et al.*, 2023), they face subsidy-related constraints. Refineries also depend on government push as public sector undertakings dominate the sector. Bharat Petroleum Corporation Limited (BPCL) has shown interest in establishing green hydrogen production at the Kochi refinery, but no projects have yet been finalised. Developers emphasised the need for hydrogen purchase obligations (HPO) to accelerate the green hydrogen market.

In the transport sector, Kerala focuses on hydrogen internal combustion vehicles due to the lower retrofitting costs. However, their efficiency is much lower than fuel cells. Further, Green hydrogen's role in heavy transport and energy storage remains unclear there are cheaper alternatives like battery storage.

Another key issue is the lack of testing and certification facilities. This is an area where modest government investment can have a significant impact by reducing project risks and costs and by accelerating local manufacturing of components.

The state also faces challenges in harnessing its renewable resources. Kerala currently imports about 76% of its electricity and has low renewable penetration. Much of Kerala's renewable potential lies within forest reserves, but developing these areas poses environmental implications.

According to the interviewees, risk perception of green hydrogen projects among financiers has decreased significantly in recent years but remains a challenge for projects without secured purchase agreements.

## Strategies

Kerala is in the final stages of announcing a green hydrogen policy targeting 30% green hydrogen blending by 2027 reducing Green Hydrogen costs to USD 1/kg, and achieving 100% Green Hydrogen/Ammonia in all hydrogen applications by 2040 (Government of Kerala, 2023b). The state's strategy for scaling up Green Hydrogen includes developing Hydrogen hubs and small-scale projects dispersed across the state, including Green Hydrogen Valleys in Kochi and Thiruvananthapuram, aiming for private-investment-led growth. Kerala allocated INR 200 crores (USD 24 Million) for green hydrogen development in 2023-24 through Viability Gap Funding (VGF), equity, and loans, with other potential incentives like electricity duty concessions and priority project clearances (RenewableWatch, 2023).

A high-level steering committee, with the Agency for New and Renewable Energy Research and Technology (ANERT) as the nodal agency, oversees Kerala's green hydrogen scheme. ANERT has constituted a project management unit to promote investment and support implementation, aiming at large-scale projects and aggregating demands for scale economies (Government of Kerala, 2016). The state plans to implement a few pilots using the union government's PLI scheme and will create sector-specific roadmaps and strategic investment to expedite renewable energy project deployments and forge partnerships.

## The States' role in accelerating a green hydrogen transition

The case studies of Gujarat, Jharkhand, and Kerala underscore the pivotal role that Indian states play in advancing the national hydrogen industry. These cases demonstrate the various approaches the states may consider as part of the green hydrogen policies.

The cases further demonstrate that the states align with India's national hydrogen targets and develop comprehensive policies for the hydrogen sector's growth. Effective implementation, rigorous monitoring and enforcement, and addressing the challenges in production, technology, infrastructure, and investment will be critical to meet these targets.

Gujarat emphasises electrolysis-driven hydrogen, Jharkhand on manufacturing, and Kerala on ambitious green hydrogen targets, all aligning with the national objective of transitioning to a low-carbon economy. However, challenges include developing efficient and cost-effective production, and technological and infrastructural barriers. Additionally, considerable R&D investments will be necessary to remain technologically competitive.

With regard to the challenges associated with developing hydrogen, there could be some concerns. Kerala's State Electricity Board notes that inadequate distribution networks and outdated transmission infrastructure are major hurdles (KSEB, 2019), underscoring the need for improved energy infrastructure and grid expansion to support the hydrogen industry.

**Table 1:** Shared potential, common challenges, and strategies

| Potential | Challenges | Strategies |
|---|---|---|
| ▪ Many Indian states have huge RE potential.<br>▪ Existing industrial bases in many states can help advance hydrogen production and create demand.<br>▪ The presence of industries will help states develop domestic and overseas partnerships.<br>▪ States in the coastal region could benefit from overseas export opportunities.<br>▪ Evolving policy and governance apparatus will help accelerate the hydrogen sector.<br>▪ States will need to work together to develop the hydrogen industry as they have specific competitive advantages in terms of resources – land, RE potential, water as well as technology and finance access. | ▪ Accessibility and affordability of advanced technology remain the key hurdles to states.<br>▪ The lack of testing and certification facilities is a common challenge across states.<br>▪ Need centre-state coordinated efforts to rope in off-takers.<br>▪ Production cost remains a key hurdle in attracting off-takers.<br>▪ Land acquisition for RE projects remains another major concern in many states. However, states like Gujarat have already shown significant progress.<br>▪ Clean water availability can be a concern in certain regions. | ▪ There is an emphasis on public-private partnerships.<br>▪ Financial incentives continue to be the common element in strategies to attract investments.<br>▪ Many states are progressing on green hydrogen policies and building nodal agencies/ institutions.<br>▪ Efforts are seen to align policies with industries to develop a hydrogen ecosystem.<br>▪ States with geographic advantage and proximity to ports focus on becoming green hydrogen hubs. |

*Source: Based on assessment done by IISD and WRI researcher teams*

All three states are exploring various funding mechanisms, including international investments, public-private partnerships, and multilateral lending agencies, aligning with the national objective for green hydrogen projects. However, convincing financiers, especially those without secured purchases, remains challenging. Clear and robust mechanisms to attract and retain investments are crucial.

The diversification of end-use sectors, as recognised by Gujarat, Jharkhand, and Kerala, aligns with India's national strategy. However, harnessing the market potential, especially for sectors with low hydrogen demand is challenging. States need innovative solutions to aggregate demands and secure off-takers to achieve economies of scale and meet India's national hydrogen industry targets.

International collaboration is also crucial for achieving these targets. States can facilitate collaborations by acting as intermediaries in the country to accelerate collaboration on three fronts, such as technology, finance, and capacity development. Possible areas include sharing electrolyser technology, advancements in transport and storage solutions, and securing financial support. In this context, the agreements with the EU and Japan can be of potential benefit to India's hydrogen sector development. Japan, with its focus on hydrogen and climate strategies and numerous patents for hydrogen technology (Ungria, Rodriguez, and Burattini, 2023) can be a good option for Indian exports and a source of technology access. India's agreement with Germany to establish a hydrogen task force aims to foster cooperation in the production, utilisation storage, and trade of green hydrogen (Shetty, 2022). Green hydrogen from India could cater to the growing demand for green hydrogen in the European countries that adopted a hydrogen strategy.

Developing the hydrogen ecosystem in Indian states also demands collaboration with overseas investors and technology leaders. Co-innovation (Janardhanan, 2020)–collaborative development of technologies- can be an effective approach, particularly with states that lack adequate technical know-how but possess the potential to generate investment. Although the central government controls foreign policy, there is a growing emphasis placed on para-diplomacy–involving subnational entities in foreign policy. This can enhance technology, finance, and capacity development. Utilising mechanisms such as sister city partnerships and Exclusive Economic Zone (EEZ) ties can expedite these efforts.

## Conclusion and recommendations

The case studies highlight the importance of sub-national governments in supporting the national green hydrogen mission. To achieve this, a comprehensive strategy strengthening the state's capacity to develop a hydrogen ecosystem is required. A set of six recommendations outlining specific actions to support 'capacity development, strengthening hard and soft infrastructure, incentivising off-takers, inviting more investment, strengthening

technology and promoting international collaboration' is listed below:

1. ***Tailor skill development programme to suit the hydrogen ecosystem***: To strengthen the hydrogen ecosystem, a skilled workforce plays a key role. Programmes need to be in place to ensure that the workforce is capable of contributing to the design, operation, and maintenance of the green hydrogen ecosystem. For this, the support of the national government will be important for the state governments.
2. ***Close the infrastructure gap***: As renewable energy production expands; transmission and distribution infrastructure must be strengthened. For example, the aggregate technical and commercial loss in power systems is about 44% of the generation in Jharkhand, about 15% in Gujarat, and 16% in Kerala (Government of India, 2023a). States must also focus on strengthening the governance mechanism to support this transformation and ensure the readiness of domestic technologies. Centre-state collaboration as well as engagement with overseas technology partners will be crucial.
3. ***Incentivise off-takers***: Implementing adequate financial mechanisms to incentivise off-takers will encourage the hydrogen industry's growth. Subsidies and tax credits along with mechanisms similar to Renewable Purchase Obligations (RPO) (MNRE, 2010) to mandate hydrogen purchases for high-consuming sectors can help in this regard.
4. ***Attract investment, and encourage PPP***: States need to attract and facilitate investment from stakeholders in the hydrogen sector. This demands policies to encourage public-private partnerships and legal and governance structures.
5. ***Encourage R&D***: Lack of access to affordable technologies, in the production, transportation, and storage of hydrogen, has been critical in many states. This demands specific initiatives to support R&D to support the technology-intensive green hydrogen industry.
6. ***Promote co-innovation***: Co-innovation and co-production with overseas partners need institutional support for joint research, manufacturing, and scaling up technologies. The central government may promote para-diplomatic engagement between Indian states and overseas counterparts through sister-city initiatives to bridge the technology gap.

By focusing on these elements, national and state governments together can overcome challenges and foster a vibrant green hydrogen ecosystem in India.

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**Note**: This paper is based on the IGES Discussion paper (2024) titled 'The Role of Sub-National Governments in India's Green Hydrogen Transition: A multilevel perspective'. This paper largely confines its analysis to the information available until December 2023.

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