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Accelerating India's Energy Transition through Industrial Clusters

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Introduction

Industrial clusters are geographic hubs of co-located businesses and public institutions that act as engines of economic growth, fostering collaboration, resource-sharing, access to skilled labour and innovation, thereby enhancing competitiveness and regional economic resilience.

The World Economic Forum's [Transitioning Industrial Clusters initiative](#), in collaboration with Accenture, is driving collaboration and shared action to foster economic growth, protect and create jobs, and reduce CO₂e emissions in industrial clusters. With 33 clusters¹ across 16 countries, this initiative represents \$492 billion in GDP contribution and 4.3 million jobs, while targeting 832 million tonnes of CO₂e reduction – equivalent to Saudi Arabia's annual emissions.²

By fostering public-private partnerships, supporting policy frameworks, and enabling access to finance and technology, the initiative provides a structured pathway for industrial hubs to transition while enhancing global competitiveness. Key areas of

focus include scaling clean energy adoption, integrating circular economy principles, and leveraging breakthrough technologies like hydrogen and carbon capture solutions.

In India, the initiative has been collaborating with five key industrial clusters in five states, including the Mumbai Green Hydrogen Cluster in Maharashtra, Mundra Cluster in Gujarat, Kerala Green Hydrogen Valley in Kerala, Gopalpur Industrial Park Cluster in Odisha, and Kakinada Cluster in Andhra Pradesh. These clusters demonstrate India's commitment to the energy transition through innovation and collaboration. Together, they are projected to generate tens of thousands of jobs, significantly reduce CO₂e emissions, and contribute billions to India's GDP.

This briefing paper explores India's evolving energy landscape, identifies key challenges and examines how the country's industrial clusters can accelerate the energy transition and broader industrial transformation, while also contributing to economic growth and social development.

Balancing energy demand and energy transition goals

As the world's third-largest energy consumer with a rapidly growing economy, India faces the dual challenge of meeting an expected 35% increase in energy demand by 2030³ while advancing its commitment to achieve net-zero emissions by 2070.⁴ This task demands bold, transformative strategies that balance equitable economic growth, energy security and sustainability. India's energy transition and decarbonization efforts are not just essential for global climate goals, but also for ensuring energy security, improving air quality, fostering economic growth and promoting equitable social impact. By driving clean energy investments, India can create green jobs, expand energy access and foster inclusive growth, ensuring that this transition benefits all.

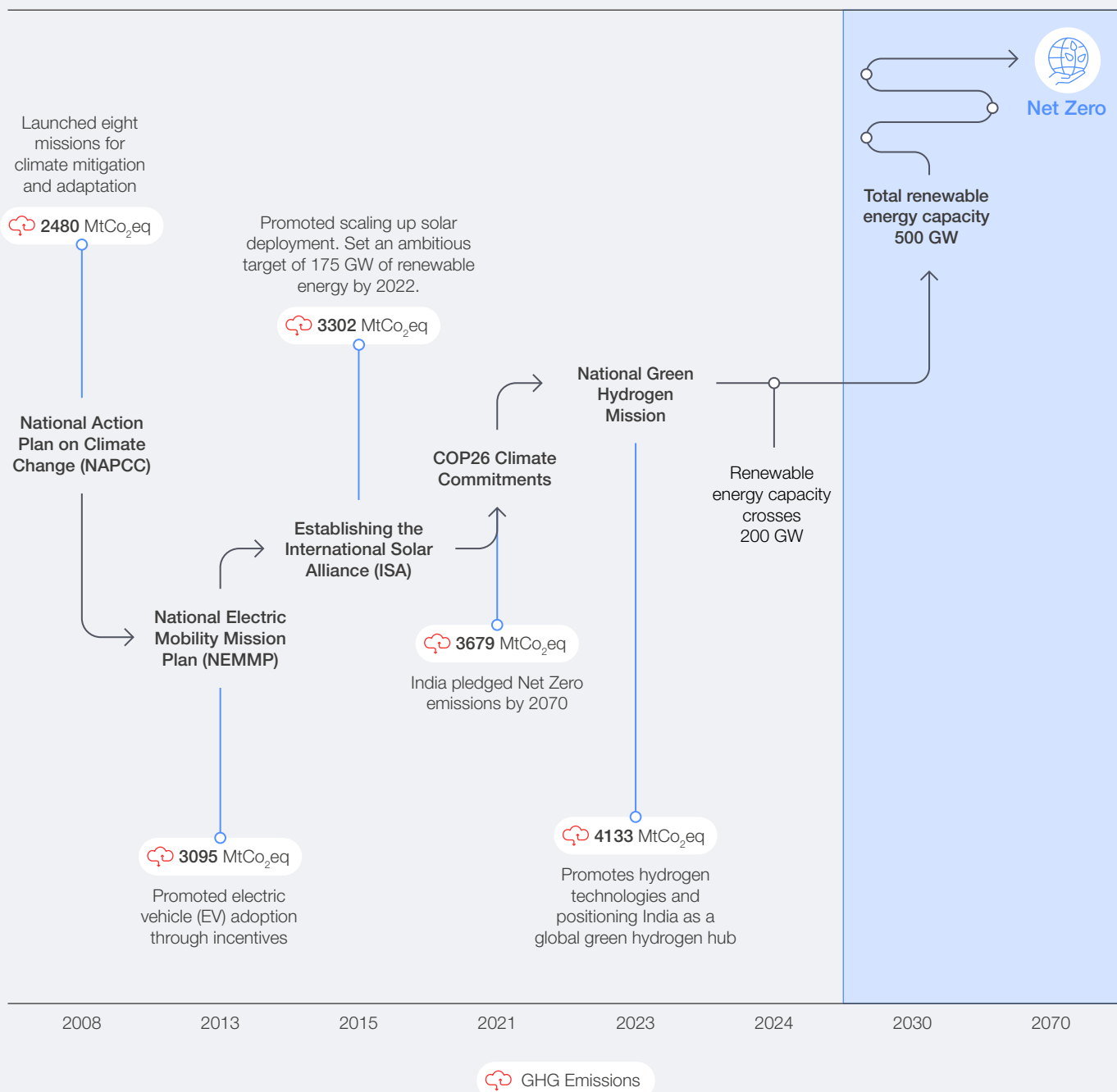
Coal is the dominant source in India's energy mix, accounting for nearly 70% of electricity generation,⁵ which means the transition to renewable energy will need careful planning. The industrial sector, which contributes to over 30% of GDP⁶, is also responsible for 24%⁷ of total emissions, making industrial transformation vital for India to achieve its net-zero goal by 2070. For industries navigating the dual challenge of maintaining profitability and reducing emissions, industrial clusters offer a scalable model to accelerate transition at speed and scale, supporting an inclusive and resilient economic growth.

The country is rapidly transforming its energy landscape, with significant progress in clean energy adoption, industrial decarbonization and the emergence of industrial clusters supporting low-carbon development. India's energy transition has gained momentum in the last decade since aligning with the Paris Agreement commitments.^{8,9} At the COP26 climate change summit in 2021,¹⁰ India announced its aims to increase its non-fossil energy capacity to 500 GW by 2030,¹¹ which is enough power to supply electricity to around 400 million homes and set a target to achieve net-zero carbon emissions by 2070.¹² India has implemented multiple missions under the National Action Plan on Climate Change and introduced strategic policies to accelerate its energy transition. One such example is the launch of the National Green Hydrogen Mission in 2020, aimed at driving green hydrogen development and positioning India as a global hub for green hydrogen production.

India has demonstrated a commendable ability to attract green finance with a 150% increase¹³ in 2019-2020 from 2017-2018. India's major corporations like Tata Power and Reliance Industries¹⁴ are investing heavily in renewable energy, transforming the country's energy landscape. Backed by government policies, these investments are fast-tracking India's industrial shift towards emission reduction. The nation has already crossed a significant milestone in its clean energy transition, with total renewable energy capacity exceeding 200 GW.¹⁵

India's 2030 500 GW renewable energy target requires substantial investments in emerging technologies, estimated at \$385 billion by Moody's.¹⁶

FIGURE 1 India's Energy Transition Journey



Source: India Energy Transition Journey^{17,18,19,20,21,22,23}

Challenges in transitioning India's industrial clusters

India's transition to a low-carbon economy faces significant technological, financial, policy and social challenges that must be addressed to ensure a smooth and inclusive shift. If left unaddressed, these challenges will hinder the deployment of clean energy solutions and delay India's energy transition ambitions.



Solar photovoltaic (PV) supply chain:

India relies heavily on imports for its solar energy infrastructure. In 2023-2024, the country imported \$7 billion of solar equipment, with nearly 63% sourced from China.²⁴ Despite expanding domestic manufacturing supported by the Production-Linked Incentive scheme, the country still lacks production capabilities for polysilicon, wafers and ingots,^{25, 26, 27} which are essential for solar panel manufacturing.

Technological challenges

While some technological barriers, such as battery supply chain constraints, solar power intermittency, and hydrogen storage and transport limitations, are global, India's transition is further complicated by its unique infrastructure, energy security concerns and other constraints:



Battery storage and electric vehicle (EV) components:

Battery storage is a key enabler of India's clean energy transition and relies on imports to meet its lithium-ion battery requirements. In the fiscal year 2023, the nation imported nearly all its 15 GWh²⁸ battery demand.²⁹ India's local battery manufacturing, such as lithium-ion batteries (LIBs), is still in its early stages and should address raw material dependency.³⁰ Moreover, the charging infrastructure is limited and concentrated in metro cities, leaving rural and semi-urban areas underserved.³¹



Grid modernization and energy storage:

India's power grid faces high transmission and distribution³² losses due to outdated infrastructure and technical inefficiencies. As India expands its renewable capacity, grid modernization and Battery Energy Storage System (BESS) and Pumped Storage Plant (PSP) assets are crucial to integrating variable solar and wind power successfully into the grid.³³



Green hydrogen infrastructure:

India aims to become a global leader in green hydrogen but needs to boost electrolyser manufacturing.³⁴ Government-led initiatives, such as the National Green Hydrogen Mission, are promoting local production, with significant investment and R&D needed to establish a fully self-reliant hydrogen ecosystem.



India's renewable energy transition will require a strategic mix of domestic capacity expansion and targeted imports. Strengthening domestic manufacturing, securing supply chains for critical minerals, and investing in R&D will be essential to reducing dependency and achieving long-term energy independence.

Financial challenges

India's goal of achieving net-zero emissions by 2070 will require a staggering \$10.1 trillion in cumulative investment,³⁵ according to the Council on Energy, Environment and Water. However, funding sources are projected to cover only \$6.6 trillion, leaving a substantial gap of \$3.5 trillion³⁶, equivalent to India's GDP.³⁷

High upfront costs for renewable energy infrastructure and emerging technologies such as green hydrogen, sustainable

aviation fuel (SAF), and carbon capture utilization and storage (CCUS) necessitate the exploration of innovative and non-traditional financing approaches, strong financial incentives and policy support. While these solutions offer long-term cost savings and emissions reductions, their high initial capital requirements make it a challenge to finance and commit to decarbonization efforts.^{38, 39} Compounding this issue is the lack of sufficient financing mechanisms,⁴⁰ as traditional lending structures are often ill-equipped to support green projects with long payback periods and low confidence in expected returns.

Policy challenges

India has introduced various policies to improve energy efficiency in energy-intensive industries, promote electric mobility and integrate renewable energy into the national power grid, and also several federal policies targeting solar, wind, biomass and small hydro. The country is also developing a National Framework for the Indian Carbon Market⁴¹ to complement and support various entities through carbon pricing.

Complementing these efforts are advanced policies introduced by individual states to leverage available resources to meet local demand and needs. Each state offers various benefits and incentives to developers and consumers, such as financial/capital subsidies. Furthermore, some states offer non-financial incentives like procuring power at a pre-fixed levelized tariff for Power Purchase Agreements (PPA), tax or duty exemptions, and fast-tracked approvals.

Incidentally, the coastal locations of Gujarat, Odisha, Maharashtra, Andhra Pradesh, Kerala and Tamil Nadu strategically place them near key shipping hubs and seaports. Below is a brief overview of the six individual states in India with progressive policies in the areas of renewable energy, hydrogen and green mobility.

At the national level, the task of coordinating the policies and efforts of various government agencies, ministries and stakeholders is enormous, and a holistic and integrated approach to energy policy formulation and implementation is necessary.

Social and employment challenges

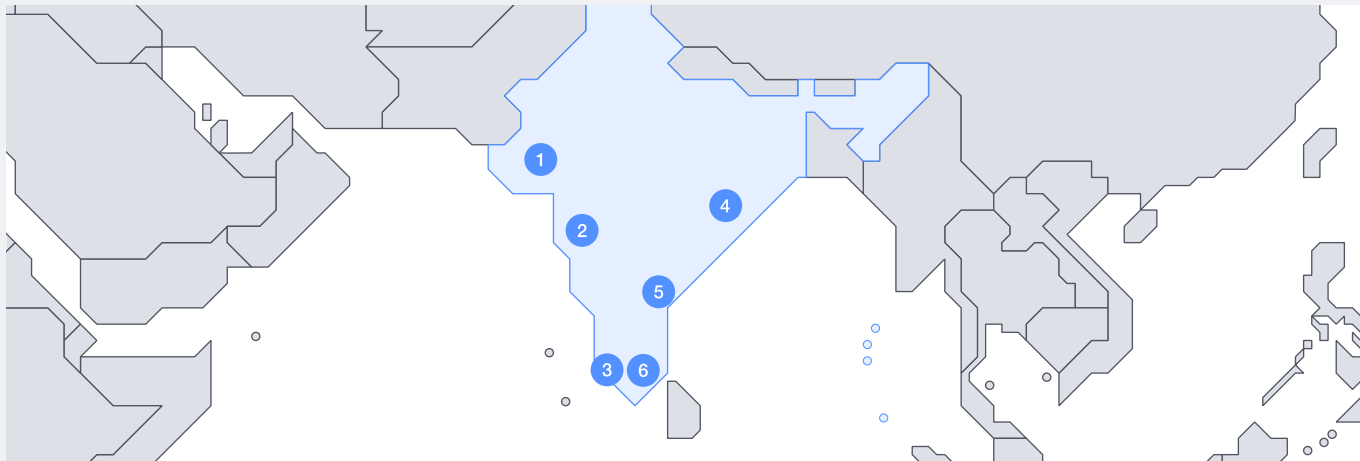
In 2023, the fossil fuel sector employed over three million workers, with coal supply supporting 1.6 million jobs.⁴² The oil and gas industry provided over 800,000 jobs, primarily in midstream and refining. Several million more depend on indirect employment by the fossil fuel sector. A just transition aims to ensure jobs in renewables, electric mobility and sustainable industries offset losses in traditional sectors. However, India's largely informal, low-skilled energy workforce needs extensive reskilling to transition to clean energy jobs.

There is currently a skills gap of approximately 1.2 million workers,⁴³ with demand projected to increase to 1.7 million by 2027. Government initiatives such as the Production-Linked Incentive (PLI) scheme have encouraged local manufacturing, but companies struggle to fill key technical roles.





Regional disparities add complexity to the transition, as some areas are more vulnerable to fossil fuel phase-outs while others stand to gain from renewable energy growth. Ensuring an equitable transition will be essential to balancing job losses with new employment opportunities.







FIGURE 2 State Wise Policy Overview







1 Gujarat

-  **RE:** Target of 100 GW RE capacity by 2030. Subsidies for consumers and providers.
-  **GH2:** Aligns with the NGHM. with a target of 3 million metric tonnes by 2030. Capital subsidies, waivers, and exemptions available.
-  **EV:** Deploy 200k EVs by 2025. Subsidies and financial incentives available.
-  **WtE:** Use of MSW for electricity generation. Incentives include subsidies, land allocation, and various exemptions.





2 Maharashtra

-  **RE:** Target of 17,360 MW RE projects by 2025. Personnel support for large-scale projects and rural electrification provided.
-  **GH2:** Production capacity of 500k TPA by 2030. Financial incentives include capital subsidies, concessions, exemptions and direct funding.
-  **EV:** Accelerate adoption across various segments. Financial incentives available for consumers and suppliers.
-  **WtE:** Target of 200 MW capacity. Subsidized rates, reimbursements, and exemptions available.





3 Kerala

-  **RE:** Aim to be 100% RE-based by 2040 and net-carbon neutral by 2050. Guidelines for FSPV projects approved, 3GW capacity targeted.
-  **GH2:** 10% (by vol.) GH2 blending by 2030 and reduce cost to ₹200/kg by 2030. Subsidies to establish hubs and promotion for transport sector. (in draft)
-  **EV:** Increase EV adoption and electrification of public transport. Incentives include subsidies, preferential interest rates, and buyback programme.
-  **WtE:** Significant strides in implementing the Solid Waste Management Rules of 2016.





4 Odisha

-  **RE:** Achieve at least 42% share of RE by 2030. Incentives include a RE Fund, exemptions from electricity duty, and waived power charges.
-  **GH2:** Policy to develop GH2 and GNH3 hubs released in 2022. Currently developing policy to develop GH2 ecosystem.
-  **EV:** Accelerate adoption of EVs and battery EVs. Subsidies for consumers, manufacturers, and charging stations available.
-  **WtE:** Promote use of biodegradable waste for electricity generation. Priority land allocation and electricity duty exemptions available.

5 Andhra Pradesh

-  **RE:** Target 160 GW RE capacity by 2030 with investment potential of approx. ₹10 lakh crore (\$119 billion). Capital subsidies, concessional lease rates, and exemptions available.
-  **GH2:** Production of 0.5 MTPA within 5 years with 12,000 jobs created. Reimbursements and electricity duty exemption available.
-  **EV:** Carbon neutrality in transport sector by 2047. Financial subsidies for manufacturers, charging stations, and consumers.
-  **WtE:** Promote use of MSW and other biodegradable waste for clean energy production. Various exemptions and favorable land purchase agreements.

6 Tamil Nadu

-  **RE:** Targets to derive 50% of its total energy consumption from RE and 70% carbon emissions reduction by 2030.
-  **GH2:** Conducted a study on electrolyser manufacturing in Tamil Nadu.
-  **EV:** 30% electrification of buses and electric conversion of shared mobility fleet by 2030. Tax exemptions, reduced registration fees, and subsidies available.
-  **WtE:** Significant strides in implementing the Solid Waste Management Rules of 2016.

Notes: RE: renewable energy, GH₂: green hydrogen, EV: electric vehicles, WtE: waste to energy

Sources: State-Wise Policy Overview: ET (Gujarat Aims for 100 GW RE); TOI (Gujarat GH₂ Target); Govt of Gujarat (RE Policy 2023; EV Policy 2021; Environmental Clearance Notification); Gujarat Energy Development Agency (GH₂ Policy); Maharashtra Energy Development Agency (RE Policy 2020; W2E Policy; Bio Energy Overview); Govt of Maharashtra (EV Policy 2021); MK Research (Maharashtra GH₂ Policy 2023); Earth Journalism Network (Maharashtra RE MoUs News); Govt of AP (Integrated Clean Energy Policy 2024; GH₂ & GNH₃ Policy 2023; EV Policy 4.0 (2024–2029)); JMK Research (AP Integrated Clean Energy Policy 2024); Sunsire Energy (ICE Policy News Article 2024); Govt of Odisha (RE Policy 2022; EV Policy 2021 – Amended 2023); Outlook Business (Kerala GH₂ Pilot News); ANERT (GH₂ Vision – Kerala); KSEB (EV Policy 2023: Recommendations); Kerala Solid Waste Management Project (State Implementation Overview); Invest Kerala (RE Avenue); Renewable Watch (2024, Kerala & Maharashtra GH₂ Plans); MNRE (Draft Repowering & Life Extension Policy for Wind Electric Generators 2024); The Indian Express (TN GH₂ Policy Intent); Govt of TN (Solar Energy Policy 2019; EV Policy 2019 & 2023); CPCB (Solid Waste Management Rules, 2016).

Key insights from India's industrial clusters

India's industrial clusters are addressing the full spectrum of energy transition challenges: technology, finance, policy and workforce through integrated, localized strategies. Kerala Green Hydrogen Valley is building a collaborative, multisectoral green hydrogen ecosystem; Gopalpur Industrial Park is investing in infrastructure and workforce development;

Mumbai Green Hydrogen Cluster is advancing policy-backed urban decarbonization; and Kakinada Cluster is scaling mature technologies through global partnerships. These clusters demonstrate how targeted action across technology, finance, policy, skills and collaboration can drive India's industrial energy transition.

CASE STUDY 1

Kerala Green Hydrogen Valley

Kerala's Green Hydrogen Valley, led by the Agency for New and Renewable Energy Research and Technology (ANERT), is aimed at establishing Kerala as a major player in the global green hydrogen supply chain.

- **Collaborative ecosystem and strategic partnership:** Collaboration lies at the heart of the cluster's approach. ANERT has built a network of stakeholders, including government entities, private companies and academic institutions, and has partnered with GIZ, the German development agency, and MEC Intelligence to create a roadmap for green hydrogen and ammonia adoption in the state. Additionally, strategic collaborations with state and federal entities, including Kerala Waterways, Kerala State Road Transport Corporation, Travancore Cochin Chemicals, Cochin Shipyard Limited and Cochin Port, are enabling the deployment of hydrogen solutions across multiple sectors.
- **Workforce development:** Recognizing the critical need for a skilled workforce, ANERT is investing in capacity building. Collaborations with state universities and international partners from Australia and the Netherlands are helping to develop the skills required for the rapidly evolving hydrogen economy. This effort ensures that Kerala's green hydrogen ecosystem is

supported by a knowledgeable and capable talent pool, ready to meet future industry demands.

- **Funding and financial support:** The cluster has also tapped into various funding sources, which are crucial for its success, including:
 - National Green Hydrogen Mission funds for transport and green hydrogen production projects.
 - ₹200 crores (\$23 million) allocated by the Kerala state government for hydrogen initiatives.
 - Financial support from international agencies like KfW and GIZ is being explored.

Moreover, to address challenges like high production costs, ANERT is launching a Green Hydrogen Policy, offering capital expenditure subsidy for electrolysers, subject to a maximum of INR 1.5 Cr. per MW for private developers and other financial support for state entities to accommodate the high cost of green hydrogen.

This approach, supported by strategic collaboration, structured financing and workforce development, illustrates how coordinated action can help advance the adoption of green hydrogen.



Source: [HVIC Kerala Project](#)

CASE STUDY 2

Gopalpur Industrial Park (GIP)

Gopalpur Industrial Park (GIP), developed by Tata Steel Special Economic Zone Limited, is emerging as a centre for green hydrogen and clean energy in India. Strategically located in Odisha, GIP offers modern infrastructure and strong connectivity, attracting renewable energy investors. Its proximity to Gopalpur Port, enhanced by a dedicated utility corridor, ensures efficient export operations, a critical advantage for industries focused on green hydrogen production and distribution. GIP has built an ecosystem to support green hydrogen production and export through:

- **Infrastructure development:** GIP's infrastructure development is necessary for establishing a green hydrogen hub and a renewable ecosystem. By facilitating and collaborating with key stakeholders for a power supply and efficient water resources, GIP aims to eliminate critical operational bottlenecks for green hydrogen production. GIP also plans to integrate green hydrogen pipelines and Common Effluent Treatment Plants (CETPs). GIP collaborated with the Odisha government (IDCO) to connect to the Gopalpur Port via a direct route, a dedicated utility corridor, which will reduce the distance from GIP to Gopalpur Port from 14 km to 3 km, streamlining exports/imports.
- **Strategic policy collaboration:** GIP's collaboration with central and state entities has effectively attracted investments, driving Odisha's vision to become a leader in green hydrogen production. The State Government's Industrial Policy Resolution (IPR) 2022, providing a 30% capital subsidy post-production and attractive Goods and Services Tax (GST) incentives, helps attract investors. Additionally, GIP's proactive engagement with the Odisha government to extend IPR 2022 benefits from Domestic Tariff Areas (DTA) to Special Economic Zones (SEZ) significantly strengthens its value proposition.

- **Workforce development:** GIP is building a skilled workforce to support the rapid growth of the green hydrogen and renewable energy ecosystem. The J N Tata Technical Education Centre (JNTTEC), located within the park and established by Tata Steel in collaboration with the Netur Technical Training Foundation (NTTF), currently has a capacity for 600 students. JNTTEC offers a three-year diploma programme in Mechatronics Engineering and Smart Factory, with the potential to develop tailored, industry-specific courses. This initiative not only addresses the industry's demand for specialized skills, but also promotes socioeconomic growth in the region. Moreover, GIP intends to collaborate with the Ministry of Skill Development, through the Skill Council for Green Jobs (SCGJ), to ensure that workforce training is aligned with the emerging needs of the green energy sector.
- **Sustainability initiatives:** GIP invests in innovative technologies to strengthen its commitment to environmental responsibility. As part of its efforts, the industrial cluster operates on a zero-liquid discharge system, ensuring the recovery and recycling of all water by-products to eliminate wastewater. Additionally, GIP is planning to develop a reverse osmosis-based desalination plant to secure a sustainable and reliable water supply.

GIP is emerging as an industrial hub aligned with India's clean energy transition, supported by infrastructure development, enabling policies and sustainability initiatives. The cluster has secured early investments in green hydrogen and solar cell and module manufacturing, with further projects under review. Ongoing collaboration among stakeholders highlights the region's growing role in advancing sustainable industrial development.



Source: Courtesy of the cluster



CASE STUDY 3

Mumbai Green Hydrogen Cluster

To support sustainable energy solutions, the Energy Department (Government of Maharashtra), in coordination with Maharashtra Institution for Transformation (MITRA), is developing a green hydrogen cluster in the Mumbai Metropolitan Region (MMR). This initiative focuses on decarbonizing Mumbai's dense urban-industrial landscape while creating green jobs, aligning with the state's vision of 52% green and renewable energy by 2030, as well as Maharashtra's policy framework to produce 5 million metric tons of green hydrogen annually by 2030.

- **Project details:** The MMR covers South and North Mumbai, including the Trombay area with its concentration of petrochemical, petroleum, hydroelectric and chemical industries – an ideal setting for green hydrogen production. The cluster aims to establish a 10 Kilo Tons Per Annum (KTPA) plant in two phases:
 - **Phase 1:** 5 KTPA facility
 - **Phase 2:** Expansion to 10 KTPA

Bharat Petroleum (BPCL) and Hindustan Petroleum (HPCL) have each committed to offtake 5 KTPA, ensuring project viability and market demand.

- **Policy framework and incentives:** The Maharashtra Energy Department's 2023 Green Hydrogen Policy, facilitated by Maharashtra Energy Development Agency (MEDA), originally set a target of 50 KTPA. However, recognizing the high capital costs and the nascent stage of green hydrogen technology, and with coordination with MITRA, the policy was adjusted to 10 KTPA to enable a phased, scalable approach. This allows for more manageable implementation while fostering learning and innovation in small-scale urban projects. Key policy incentives include:
 - **Capital expenditure subsidies:** 15% subsidy for the first three anchor units up to 10 KTPA
 - **Offtaker support:** 15% subsidy to facilitate scaling from 10 KTPA to 50 KTPA
- **Financial collaboration:** MITRA has collaborated with international organizations, including the Asian Infrastructure Investment Bank (AIIB) and Agence Française de Développement (AFD), to secure funding for energy transition projects.

While urban decarbonization presents significant challenges, MITRA's green hydrogen initiative in Mumbai highlights a feasible approach that supports sustainable development and promotes technological advancement.

CASE STUDY 4

Kakinada Cluster

The AM Green Kakinada Cluster, located in Andhra Pradesh, India, is being developed as a green industrial cluster delivering industrial decarbonization solutions globally with a planned investment of \$3 billion and \$15 billion on upstream investment.⁴⁴ It seeks to establish a resilient green hydrogen ecosystem by integrating mature and commercially viable technologies to ensure effective, fast-paced execution and scalability.

- **Project details:** The project involves the production of green ammonia with a 1-million-ton production capacity powered by round-the-clock renewable electricity. The green ammonia project benefits from faster permitting and approval processes from key regulatory and statutory bodies to facilitate a faster Commercial Operational Date (CoD), which significantly accelerates execution timelines. The cluster complies with the EU Renewable Energy Directive and RFNBO regulations, meeting the strictest standards required for exporting green ammonia to European markets. The cluster will also house a 2 GW electrolyser manufacturing facility and multiple green chemicals production.
- **Partnerships:** The Kakinada Cluster involves several key partnerships to achieve its objectives. Integrated energy partners like NTPC are supplying renewable energy from solar and wind to firm up by AM Green's

pump storage assets to power ammonia facilities. AM Green has partnered with John Cockerill to develop electrolysers through joint ventures, leveraging John Cockerill's global supply chain and local manufacturing capabilities. Additionally, AM Green is working with DP World to establish a global supply chain ecosystem for green ammonia shipping, thereby expanding ammonia's use beyond fertilizers to various industrial applications. Finally, offtake agreements with industry leaders such as Uniper and Yara have established a comprehensive industrial network, ensuring end-to-end value chain integration and project success.

- **Finance and technology:** Funding for the project is being secured through strategic equity investments, debt financing and production-linked incentives from the Indian government for electrolyser manufacturing. The 1 MTPA green ammonia project has already achieved Final Investment Decision (FID) and is under active project execution stage.

The Kakinada Cluster represents a scalable, pioneering industrial decarbonization initiative, leveraging existing infrastructure, established supply chains and strategic partnerships. By aiming to deliver cost-competitive green ammonia at scale, the cluster accelerates the energy transition while creating economic value for off-takers and investors alike.



Source: Courtesy of the cluster

Scaling India's industrial transformation model

India's industrial clusters provide a scalable and replicable framework for industry transformation, aligning with national and global sustainability goals. By addressing technological, financial and policy-related challenges, these clusters are enabling a just

and resilient energy transition. Strengthening partnerships, policy frameworks, technology integration and financing mechanisms will be key to accelerating India's industrial decarbonization and ensuring long-term economic and environmental sustainability.

Call to action



Invest in clean technologies, mobilize green capital and create jobs that align economic progress with sustainability



Scale public-private partnerships to enhance knowledge-sharing and cross-sector collaboration



Strengthen policy incentives and regulatory clarity to attract further investments



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