



*Accelerating Smart Power and
Renewable Energy in India (ASPIRE) Programme*

*Unlocking A \$10-15bn.
Green Hydrogen Investment Opportunity in Andhra Pradesh*



New & Renewable Energy Devt. Corp. Of Andhra Pradesh Ltd.
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DOCUMENT INFORMATION

General

Document Name	Whitepaper on Unlocking a \$10-15Bn. Green Hydrogen Investment Opportunity in Andhra Pradesh
Purpose	The document highlights existing conducive ecosystem for businesses and a positive environment for investors for setting up green hydrogen projects in the state of Andhra Pradesh, India. It presents a holistic view on readiness of the state with respect to various elements such as renewable energy potential and other enabling infrastructure to foster green hydrogen project development activities. The white paper also highlights the potential capacities and investments required across the green hydrogen value chain. The document also captures the socio-economic benefits such as green jobs.
How the document will be used?	The white paper is developed for New & Renewable Energy Development Corporation of Andhra Pradesh (NREDCAP). The white paper provides an overview to the various stakeholders interested in green hydrogen, on how the state of Andhra Pradesh is uniquely placed to capture the Green Hydrogen opportunity.
Audience	New & Renewable Energy Development Corporation of Andhra Pradesh (NREDCAP)

Foreword



S Ramana Reddy, IRPS
*Managing Director,
New and Renewable
Energy Development
Corporation of Andhra
Pradesh Ltd.
(NREDCAP)*

As the world is moving towards Net Zero targets to fight climate change, efforts are being deployed to decarbonise the energy sector, which is the biggest contributor to carbon emissions. A lot has been achieved in creation of renewable energy capacity to meet electricity requirements. To further meet the clean energy requirements of global economies, reliance is being placed on hydrogen as an alternative, which on combustion does not produce greenhouse gas.

India has taken steps to move its economy towards Net Zero by 2070 and has articulated more near-term targets under its Nationally Determined Contribution (NDC), including reducing the carbon intensity of India's economy by 45%. Adoption of green hydrogen within the economy will help India in achieving this key objective. To help drive this process, India has launched the 'National Green Hydrogen Mission' with a target of 5 MPTA by 2030.

Andhra Pradesh is well poised to leverage this opportunity and create a green hydrogen economy in the state. Andhra Pradesh has a domestic hydrogen demand of ~400 Kilo Ton Per Annum (KTPA), nearly 8% of India's industrial hydrogen demand growing at estimated CAGR of 31 % year on year. The state is also aiming to decarbonize its fossil fuel use as much as possible, with the target for production of at least 500 KTPA of green hydrogen by 2030 under Andhra Pradesh Green Hydrogen and Green Ammonia Policy 2023.

Considering the immense potential in Andhra Pradesh, a whitepaper on 'Unlocking a \$10-15 bn. Green Hydrogen Investment Opportunity in Andhra Pradesh' is prepared with the support of Foreign, Commonwealth and Development Office ("FCDO") under Accelerating Smart Power and Renewable Energy in India ("ASPIRE") programme.

The whitepaper highlights existing conducive ecosystem for businesses and a positive environment for investors for setting up green hydrogen projects in the state of Andhra Pradesh. It presents a holistic view on readiness of the state with respect to various elements such as renewable energy potential and other enabling infrastructure to foster green hydrogen project development activities. The white paper also highlights the potential capacities and investments required across the green hydrogen value chain. The document also captures the socioeconomic benefits such as green jobs.

I congratulate the entire NREDCAP team, FCDO, KPMG and all the stakeholders involved for their work and support, and I hope it becomes a valuable reference document for all the stakeholders across the green hydrogen value chain.

DISCLAIMER

- 1 This report has been prepared under Accelerating Smart Power and Renewable Energy in India ("ASPIRE") programme with Foreign, Commonwealth and Development Office ("FCDO"). KPMG is the lead implementing partner of this program.
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EXECUTIVE SUMMARY

Green Hydrogen in Andhra Pradesh: Presenting an opportunity for \$10-15 bn investment

India is on track for economic progression, but these developments result in carbon emissions as well. For sustainable development, the country is adopting strategies at a fast pace against its Nationally Determined Contributions (NDC). The country is focusing on 5 primary targets of a) 500 GW non-fossil fuel energy by 2030, b) 50% of energy mix from RE by 2030, c) reduction of 1 billion tons of total projected carbon emissions by 2030, d) reduction of carbon intensity of its economy by less than 45% and e) achieving net zero by 2070.

With 1000+ GW renewable energy potential, the country has already achieved 125 GW of installed power capacity as of March 2023. As per IRENA 2022 statistics, India ranks 4th globally for total renewable power capacity additions and has witnessed an aggressive growth of ~ 4 times since last 9 years. Renewable energy accounts for ~43% of the total installed power generation capacity in the country primarily due to solar and wind power with ~105 GW followed by small hydro and biomass/co-generation (Invest India, 2023).

Andhra Pradesh (AP) is blessed with 82.5 GW of RE potential, with wind (44 GW) and solar (38.5 GW) (MNRE, 2019). The state has been at the forefront of RE capacity additions in the country, with current installed capacity of ~9 GW (NREDCAP). Additionally, AP has immense potential for Pumped Hydro Storage (34 GW) (EDB AP, 2021) which can be integrated with renewable energy projects to provide round the clock clean energy supply.

While renewable power, which has been one of the key focus areas of national and state policy measures, provides a source for zero-carbon energy, it does not always provide complete industrial decarbonization solutions especially for 'hard to abate' sectors such as steel, fertilizers, refineries, and heavy/long haul transport. There is, therefore, a need for alternative solutions such as green hydrogen (GH), along with its derivatives, that could leverage the substantial renewable energy potential and be used in applications as fuel or feedstock in such sectors to displace the current fossil fuels usage.

India is attractively positioned for fostering green hydrogen growth and adoption. The country announced the National Green Hydrogen Mission in January 2023, targeting at least 5 MTPA (Million Metric Ton per Annum) by 2030 (MNRE, 2023). The mission will enable India to become a global hub for green hydrogen (and derivatives) production and exports and will assist in achieving an annual reduction of 50 MMT of greenhouse gas emissions with domestic fossil fuel substitution in target sectors. Given India's major dependence on energy imports, growth of a green hydrogen economy would also boost energy security by potentially displacing oil and gas usage in various sectors.

Andhra Pradesh is well poised to leverage this opportunity and create a green hydrogen economy in the state. Andhra Pradesh has a **domestic hydrogen demand of ~400 Kilo Ton Per Annum (KTPA), nearly 8% of India's industrial hydrogen demand** growing at estimated CAGR of 3¹ % year on year. The state

is also aiming to decarbonize its fossil fuel use as much as possible, with the target for production of at least **500 KTPA of green hydrogen by 2030** under Andhra Pradesh Green Hydrogen and Green Ammonia Policy 2023. Further, Andhra Pradesh can rapidly develop the supply capabilities for green hydrogen. The state is equipped with **critical resources such as installed RE capacity (~9 GW) and has an immense RE potential (~82.5 GW)**. **The state also has requisite resources such as abundant water, skilled manpower, dedicated T&D corridor, and land parcels for setting up RE parks.**

Another advantage of AP is its existing business ecosystem prowess and conducive policies. The state has announced investment friendly policies aiming for large scale adoption of clean and emerging technologies including wind, solar, pumped hydro, etc. Andhra Pradesh was **Ranked 1st in EODB since last three years** (EDB AP) and is equipped with multi-faceted central business capability to provide hand holding support to upcoming and existing business units.

Parameters	Andhra Pradesh's readiness
High potential for RE	<ul style="list-style-type: none"> ~82.5 GW of wind and solar potential with dedicated land parcels ~ 34 GW of pumped hydro potential which can be leveraged for providing RE RTC supply and enhancing utilization of electrolysers ~ Electricity costs around 75-80% of the green hydrogen cost. Availability of low cost RE is a distinguishing factor in the state
Hydrogen demand	<ul style="list-style-type: none"> ~400 KTPA with nearly 83% attributed to ammonia production for fertilizers and remaining for oil refineries
GH project outlook	<ul style="list-style-type: none"> With three mega announcements already covering, GH/GA production, off take agreements of GH/GA, electrolyser manufacturing and microgrid applications, state is already in a leading position in India
Favorable GH policy regime	<ul style="list-style-type: none"> National Hydrogen Mission forms the backbone of India's GH ecosystem, AP's intention to cater 10% of the production target of 5 MMT will be critical for GH penetration in the state Conducive state policy dedicated for green hydrogen and green ammonia
Industrial Expertise	<ul style="list-style-type: none"> Corridor and Port-led Industrial Development- Only state in India to have 3 National Industrial Corridors, across 48,352 Areas of land bank
Infrastructure experience	<ul style="list-style-type: none"> Blessed with abundant land ~5 lakh acre identified for RE projects, dedicated T&D corridor, 6 operational ports and 6 airports, 39 Trillion of stored water, 1,32,415 km of road, ~7000 km of rail network.

Figure 1: AP's readiness based on critical parameters

¹ Hydrogen demand growth from 2022 to 2032



With primary targets to support and boost state's employment and infrastructure development, Andhra Pradesh is well positioned to attract investments across green hydrogen value chain. To achieve 500 KTPA targets, the state may require a total investment of **~\$ 10-15 bn by 2030²**.

Andhra Pradesh (AP), being **one of the leading industrial states**, had emissions of 169 MTCO₂e [$\sim 6.5\%$ of India's share, ~ 2 ton/capita emissions] in 2018. However, the state has reduced its carbon footprint through various measures such as energy efficiency, creation of carbon sinks and effective waste management

and recycling. Green hydrogen can play a significant role in reducing carbon emissions by replacing grey hydrogen, which is widely utilized across refineries, fertilizers, and other chemical industries both as a feedstock and fuel. Green hydrogen and its derivatives can also reduce fossil fuel use in sectors such as transport, steel, shipping etc. Grey hydrogen emits $\sim 10-11$ KG of CO₂ for every kg of hydrogen produced when compared with green hydrogen which emits zero emissions. With ~ 400 KTPA current demand of hydrogen, Andhra Pradesh has the potential to reduce 4-4.5 MTPA³ of CO₂ with 100% shift to green hydrogen.

² KPMG analysis

³ Million Ton Per Annum



India has experienced an increase in carbon emissions from 2010 levels. This calls for vital interventions across various levels to address the increase in carbon emissions.

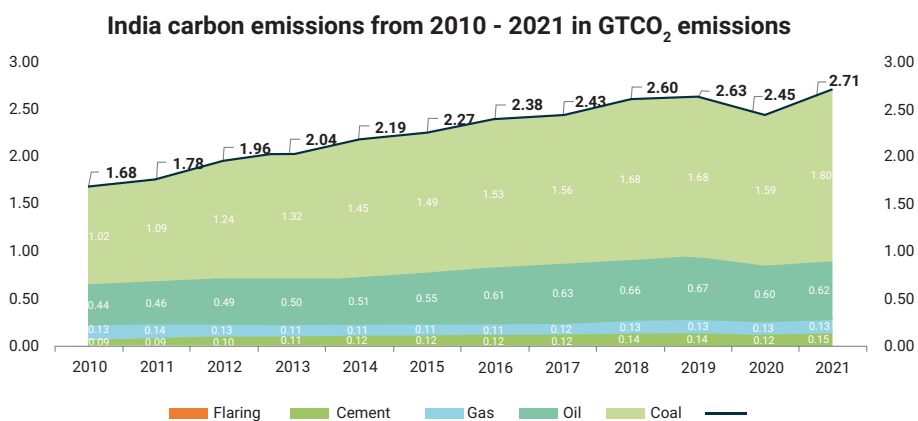


Figure 2: India carbon emissions from 2010-2021 sector wise breakup (Our World in data , 2019)



India accounts for ~7.5% of the world's carbon emissions at ~2.7 GTCO₂ in 2021 and this is estimated to increase further by 6% to ~3 GTCO₂ in 2022, (Global Carbon Project, 2022). At this rate, emissions in India are expected to cross 4.5 GTCO₂ by 2030 under business as usual scenario. The graph below highlights the major contributors of carbon emissions in India.

Increasing energy demand across various sectors and applications has been a key contributor to increasing emissions in India. India has a primary energy consumption of 846 Mtoe in 2021 (MoPNG, 2022) and the major contributors are coal, oil and natural gas (fossil-fuels) making up around 90% of India's energy demand.

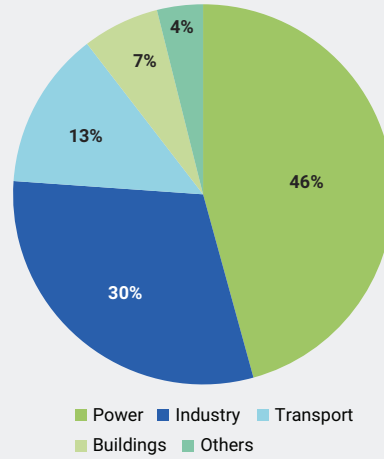


Figure 3: India carbon emissions by sector, IEA (IEA, 2022)

Further, India's primary energy consumption is on an increasing trend driven by population and combined forces of rapid urbanization and industrialization. During 2016 to 2021, as indicated in the graph below (IEA, 2021), India has witnessed a gradual rise in coal, natural gas, and oil consumption. Consequently, there has been a rise in CO₂ emissions in the country, which is evident from increasing levels of emission from ~2.4 GTCO₂ to 2.9 GTCO₂ during 2018-2022.

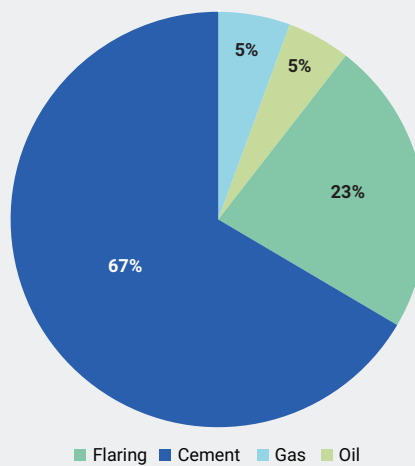


Figure 4: India carbon emissions by fuel and industry (Our World in Data, 2021)

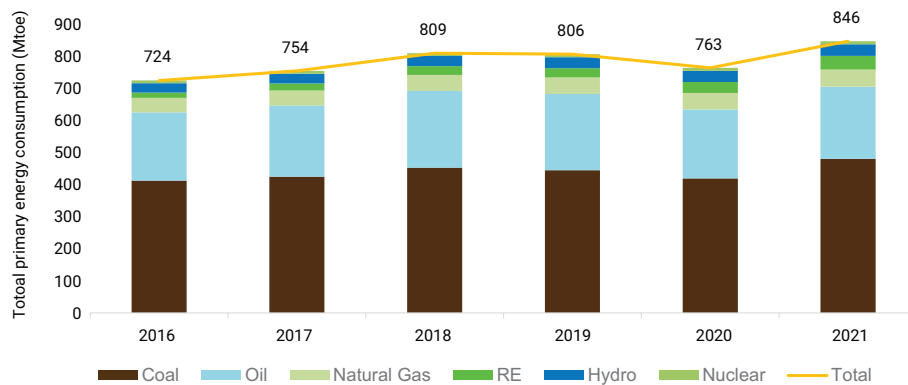


Figure 5: India primary energy consumption by fuel 2016-2021 (Mtoe)

To reduce emissions, India is undertaking a resolute march towards a sustainable energy future. Prime Minister Narendra Modi’s pledge at COP26 for a net-zero India by 2070 promises to accelerate this momentum. Government has announced targets and policies such as the 500 GW non-fossil fuel electricity capacity by 2030, scheme for Faster Adoption and

Manufacturing of Electric Vehicles- Phase II (FAME II), production-linked incentives for encouraging manufacturing of advanced cell chemistry (ACC) batteries and advanced solar technologies in the country, national green hydrogen mission, as concrete steps towards fulfilling these ambitions.

2.1 Andhra Pradesh’s decarbonisation context

The state has announced various policy measures to attract investments in solar, wind, solar and wind hybrid and pumped hydro storage systems with a view to enhance the clean energy adoption.

Andhra had a total of ~169 million ton CO₂e emissions in 2018 (6% of India’s emissions) and per capita emissions of 2 metric ton CO₂ with 79% contribution from energy sector, dominated by coal at ~81% and Oil & Gas at ~17% (GHG Platform India, 2018). Fossil fuels contributes to ~95% of the overall emissions, hence decarbonizing the key emitters such as power generation and industrial sector is critical to lowering emissions.

Andhra Pradesh carbon emissions in million ton CO₂ for 2005 and 2018

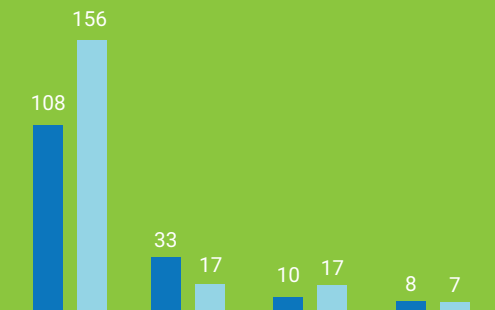


Figure 6: AP GHG emissions (Million Ton CO₂) comparison in 2005 and 2018

2.2 Andhra Pradesh energy demand

The state has consumed 51,756 GWh of electricity (CEA, 2021), and 7,547 thousand metric ton (MoPNG, 2022) of petroleum products which constituted ~70% of AP's primary energy supply.

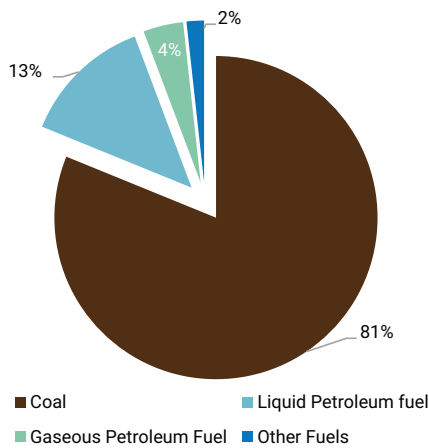


Figure 7: Andhra Pradesh GHG emissions by fuel in 2018 (GHG Platform India, 2018)

Andhra Pradesh is categorized as group two⁴ state according to BEE's State Efficiency Index

for primary energy supply. Andhra's primary energy supply stood at ~27 MTOE in 2015 (BEE, 2019) as compared to ~18 MTOE (NITI Aayog, 2022) in 2022. From 2015 to 2022, the state saw a net reduction of ~9 MTOE of primary energy supply. These reductions are driven by energy saving measures in the energy sector such as a) Domestic Efficient Lighting Program (DELP), Ujala with 100% coverage from of LED bulbs with promotion of 5 star rated electrical appliances, b) National Energy Efficient Fan Program with 100% coverage, c) Energy Efficiency Street Lighting Project with 100% street lighting with LED bulbs d) Energy Conservation Building Code (ECBC) adopted and mandated all new buildings to adhere to the norms e) National Energy Efficient Agricultural Pumps Programme which included distribution of 200,000 BEE star rated pump sets f) technology upgradation in thermal power plants and industries.



⁴ States have been categorized based on their Total Primary Energy Consumption (TPEC) in MTOE, for Group 2 it ranges between 10-28 MTOE

State witnessed a rapid scaleup of RE, (around 9 GW in 2022 from ~3 GW in 2015). In fact, Andhra Pradesh achieved a power capacity mix of ~40 percent RE, higher than the national average of ~30 percent (excluding hydro). The state is planning to facilitate installations of **50GW RE projects for export and 34 GW of pumped hydro storage projects**. Other interventions in the state include waste to energy initiatives and industrial parks with plug and play models to bring load centers together. Andhra Pradesh also desires to be a leading destination for global investments in electric vehicles (EV) by 2030.

The state is now looking to enable a wider adoption of clean energy by supporting technologies such as green hydrogen which can play a critical role in decarbonization of various industries. It has applications in industries such as oil refineries, ammonia production for fertilizers, methanol production etc., as fuel or feedstock. Green hydrogen can also be utilized for blending with city gas distribution network or with CNG fuel for vehicles and steel. Emerging applications also include use of hydrogen in long haul transport such as trucking or in other transport segments such shipping through derivatives.

Hydrogen – sources of production and carbon emissions

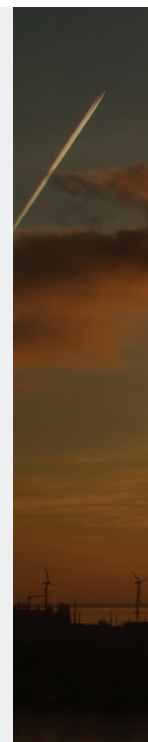
Hydrogen is the most abundant chemical element and contributes 75% of the mass of universe. When fossil fuels such as coal and natural gas are burnt, they produce energy at the expense of carbon emissions. However, combustion of hydrogen produces water as a by-product with zero emissions. Currently it is mostly utilized in refineries and fertilizers. In refineries the primary application is desulphurization and hydrocracking to refine the oil produced and limit the sulfur contents. In fertilizers hydrogen is used to produce ammonia which in turn is utilized in production of Urea, DAP and NPK (Nitrogen based) fertilizers. These primary applications account for 99% of the hydrogen demand in the country. Most of the hydrogen demand today is sourced from fossil fuel-based sources through steam methane reformation of natural gas and naphtha.

Grey Hydrogen 11 kg of Co ₂ Produced by Steam Methane Reforming	Brown Hydrogen 20 -25 kg of Co ₂ Produced by Coal Gasification	Pink Hydrogen No carbon emission but Nuclear waste Produced by Electrolysis using Nuclear Energy	Blue Hydrogen 3-6 kg of Co ₂ emitted Produced by SMR but with Carbon Capture	Green Hydrogen No Carbon emission Produced by Water Electrolysis from RE
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Hydrogen can be produced primarily from 5 sources which vary according to the carbon emissions per kg of Hydrogen produced

India's hydrogen demand is estimated to increase with a CAGR of ~4% as represented in the figure below from ~7 MTPA in 2020 to ~21 MTPA⁵ in 2050 (Niti Aayog, 2022) with lion's share of refineries and ammonia.

⁵ The analysis includes capacity additions for oil refining and fertilizer production and possible H-CNG blend for usage in transport sector



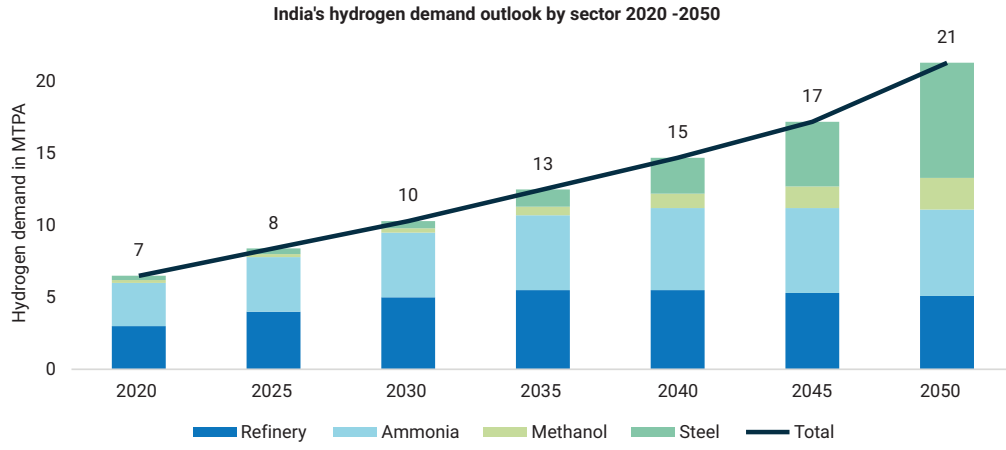


Figure 9: India hydrogen demand outlook by sector 2020 - 2050



Hydrogen produced today is derived from Steam Methane Reforming (MNRE, 2023), with estimated emission of ~67 MMTCO₂ (Niti Aayog, 2022) for production of 7 MMT of hydrogen to cater India's demand. Andhra Pradesh has an estimated demand of ~400 KTPA (2022)⁶ of hydrogen for its industrial usage, particularly in fertilizer and refineries and is expected to increase to ~500 KTPA by 2032.

These figures correspond to an estimated ~4.4 million metric ton of CO₂ emissions, which is estimated to further increase by 38% to ~5.6 million metric ton CO₂ by 2032⁸ relative to state's expected demand by the end of this decade without any transition to green hydrogen.

2.3 Green hydrogen: bringing multiple benefits to the state

Green hydrogen has multiple use cases ranging from easy substitution as feedstock, blending in fuel, or in hard-to-abate sectors and the adoption would be driven by technology development and cost parity. Its application in short-term can be in sectors where it can be directly used as feedstock by replacing conventional hydrogen produced via fossil fuels such as in oil refineries, fertilizer production, methanol production and blending with city gas distribution/CNG. In the longer term, it can be used as replacement/blend in sectors such as long haul transport, power generation, steel, cement etc. (Energy Transitions Commission, 2021). In these sectors, the cost of technology and its readiness is not at a level of deployment at scale currently.

2.3.1 Decarbonization potential

Green hydrogen and its derivatives have widespread application in today's economy. It presents an opportunity to decarbonize sectors where direct electrification is not an option. It can also be used as combustion fuel or as feedstock for industrial processes. Hydrogen can be utilized to produce electricity via fuel cells which presents an opportunity to store

hydrogen for a long-term storage application. As green hydrogen is not a hard to extract resource, it can be used to improve the energy security of the nation.

Nearly 30% of emissions today are from hard-to-abate sectors. These emissions are either costly to abate or impossible to reduce with current technologies and are categorized into two applications: **heavy industries** (cement, steel, and chemicals manufacturing) and **heavy-duty transport** (trucking, shipping, and aviation) (Abatable, 2022). Green hydrogen has the potential to contribute significantly towards decarbonization of these sectors.

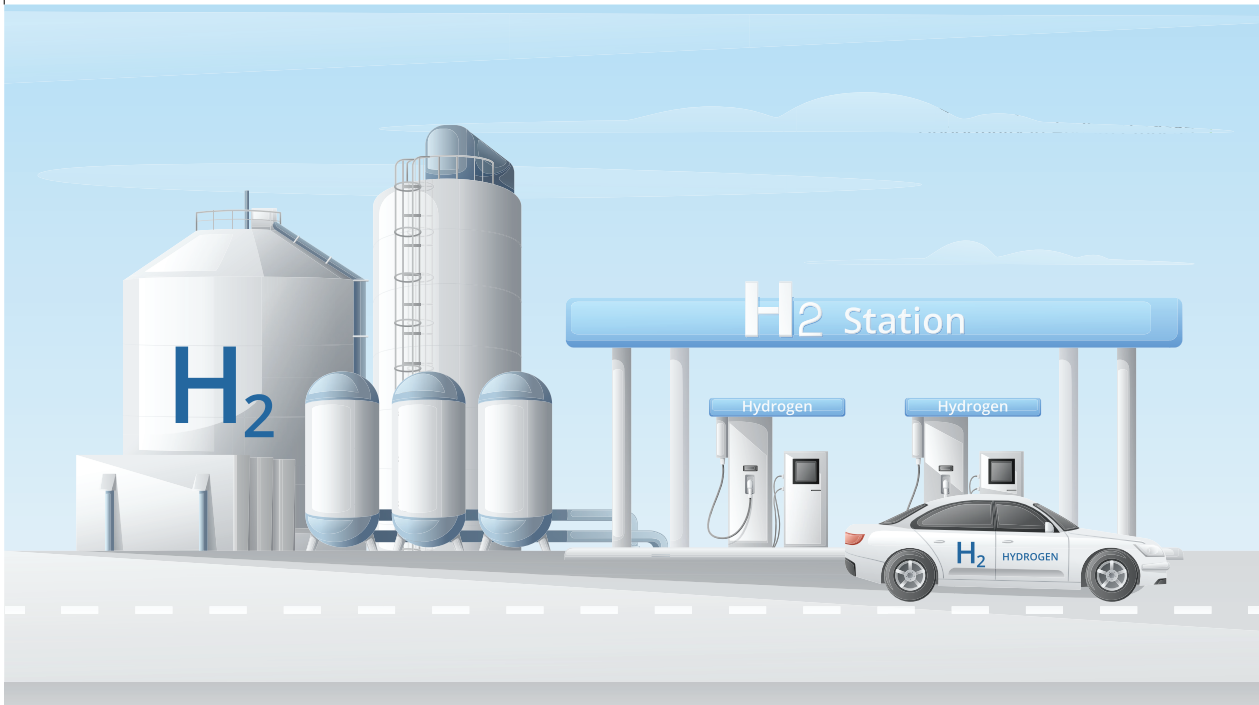
Presently, the four sectors where implementation is possible and the technology readiness exists based on industry feedback are oil refining, fertilizer production, methanol production and gas blending applications where hydrogen can be blended with natural gas and assist in decarbonization.

A 500 KTPA green hydrogen production and use by Andhra Pradesh by 2030, could result in 5-5.5 Million tons per annum reduction of carbon emissions.

⁶ Analyzed from MoPNG – India PNG statistics 2021-22 & F&I Fertilizer statistics 2020-21

⁷ Calculated for emissions from steam methane reforming at 11kgCO₂/kg of hydrogen produced

⁸ Calculated for emissions from steam methane reforming at 11kgCO₂/kg of hydrogen produced



2.3.2 Reduction in import dependency

India relies heavily on import of fossil fuels to meet its primary energy demand. According to a report by MoPNG⁹, India imported ~20% of coal, ~48% of natural gas and ~88% of crude oil (MoPNG, 2022) to meet domestic demand.

This imported fossil fuels constitutes ~40% of India's primary energy demand, valued at ~\$ 100 Bn annual imports (MNRE, 2023). This import dependency can potentially be reduced by substituting green hydrogen across various potential sectors. As per Niti Aayog, this can bring energy import savings of \$ 246 bn to \$358 bn between 2020 and 2050 (Niti Aayog, 2022).

Coal, Natural Gas and Crude Oil Domestic Production and Import dependency for India (MMT)

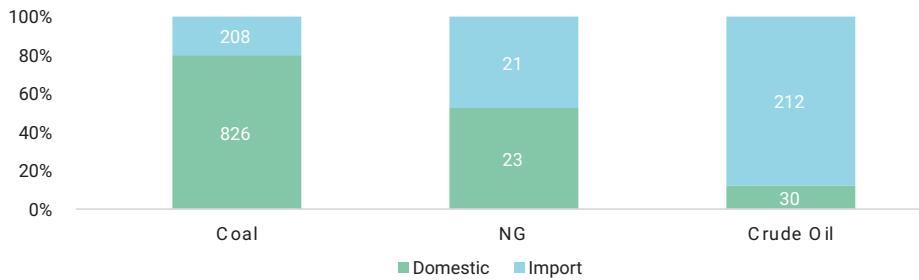


Figure 10: India imports and export in Million Metric Ton of fossil fuel (Coal, NG, Crude oil)

2.3.3 Green hydrogen and its potential for economic development

A swift shift to green hydrogen requires massive capital investments for developing renewable

energy infrastructure such as solar and wind power generation plants, green hydrogen production plants, equipment manufacturing for electrolysers, solar panels, wind turbines and other ancillaries. India presents an **opportunity**

⁹ MoPNG – Ministry of Petroleum and Natural Gas

to invest ~\$ 100 bn (MNRE ,2023) for green hydrogen production in the country. This may not only help boost country's GDP, but also place India as a top exporter of green hydrogen to major importers such as Japan, Germany, South Korea, etc. Green hydrogen project investments could further increase Foreign Direct Investment (FDI) in India.

The investments may entail associated benefits such as generating **green energy jobs** (~12000 jobs/MTPA of green hydrogen production) (MNRE, 2023), translating to ~6000 jobs for state's green hydrogen target of 500 KTPA by 2030.

For clean energy transition, **skilling and employment of women** will play an important role. According to 2018 IRENA report, women shared 32% of the renewable energy workforce globally, comprising of 45% in administrative jobs, 28% in STEM¹⁰ jobs and 35% in non-STEM technical jobs (IRENA, 2018). Women have

higher share of workforce in renewable energy space than oil & gas industry. Transition to green hydrogen may lead to employment of ~35 women per KTPA¹¹ of green hydrogen production plant, generating employment opportunity for 2000 women for a 500 KTPA target of GH plant within the state.

For states as well, green hydrogen scale up expected to have a direct impact on their GSDP¹² and help in creation of new employment opportunities in green energy sectors. Development of a robust green hydrogen ecosystem would require good technical skills and hence scaling up may promote the requirement for skilled labor and training thereby boosting skill development.

Further, states such as Andhra Pradesh may have an opportunity for export of green hydrogen as well, owing to long coastlines and ports.

2.4 Green hydrogen applications across multiple sectors for deep decarbonization

Green hydrogen has over 10 use cases some of which can be deployed in the near term while others may be more market ready in the longer term as per figure 11 below (Energy Transitions Commission, 2021).

The state is suitably placed to evaluate four sectors in the near term where conventional hydrogen can be potentially substituted with green hydrogen. It can be used as a feedstock/

fuel in oil refining, ammonia production, methanol production and for gas blending in CGD or CNG.

In medium-term applications, two sectors can be potentially explored where India and Andhra Pradesh both can create necessary infrastructure and policy ecosystem to enable usage of green hydrogen.

Replacement/blending in mobility. The technology and infrastructure exist in South Korea, Japan, China, USA, and Germany. However, the roll-out of fueling infrastructure and the price of hydrogen fueled vehicles could be key impediments for India.

Hydrogen can also be utilized as a fuel when blended with natural gas to produce power. The technology exists and Andhra has good infrastructure of gas power plants and blending can be evaluated in the near term.












¹⁰ STEM – Science Technology Engineering and Mathematics

¹¹ GH will enable RE development hence, 35% is assumed of total jobs/KTPA

¹² Gross State Domestic Product

In long-term applications, major hard-to-abate sectors are identified where green hydrogen can be used as fuel, in industries such as steel, cement, shipping, aviation, and ammonia co-firing with coal. In these sectors the technology may exist, but it is costly and requires further work to attain maturity and cost parity. Uptake in these sectors can be catalyzed if cost

parity of green hydrogen with grey hydrogen/ existing fuels is achieved along with technology advancements. For this, widespread adoption of green hydrogen projects facilitated by various policy measures and government mandates in the near-term use cases, as well as R&D and pilot efforts in future use cases are key.

	End-use sectors*	Hydrogen application in the sector	Market readiness**	Ease of Substitution
	Oil Refining	Hydro-treating and hydrocracking for desulphurization and catalytic conversion	Exists	Drop in
	Ammonia (fertilizer)	Used as feedstock to produce ammonia, used to make nitrogenous fertilizers	Exists	Drop in
	Methanol	As a feedstock and fuel for methanol production	Exists	Drop in
	Steel	Primary fuel for H2-DRI, partial replacement of coal and natural gas	Beyond 2032	As Blend
	Mobility	As fuel for FCEVs based vehicles (passenger and heavy-duty vehicles)	2025	New Fleet
	Gas blending - spiked (Industry & transport)	H2 blended with NG for use in Industry and CNG vehicles	Exists	As Blend
	Aviation	Fuel for jet engine, fuel cell producing electricity to propel an aircraft	2035	Drop in
	Shipping (Marine bunkers)	As fuel for shipping and FCEV based ships	2035	Drop in
	Cement (process boilers)	As fuel to power the reactor and cement production mainly in rotary kiln	Beyond 2030	Drop in
	Ammonia co-firing with coal	Co-firing ammonia in coal-based boilers	2030	As Blend
	Hydrogen for power gen	Used for generator cooling in thermal and gas-based power plants.	2025	As Blend

*The list of sectors is indicative

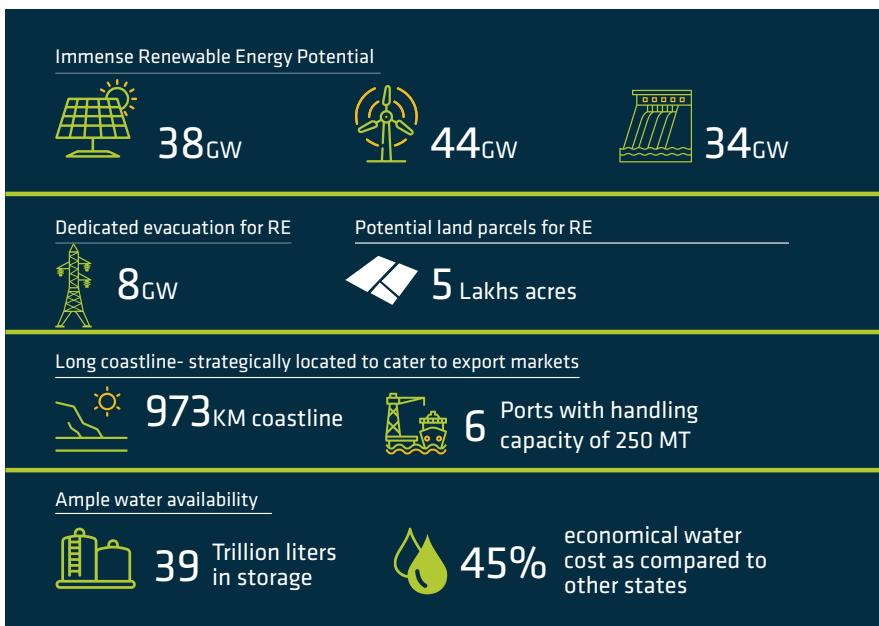
Figure 11: Green hydrogen implementation basis market readiness and ease of substitution



3 CONDUCTIVE POLICY ENVIRONMENT AND RESOURCE FOOTPRINT TO FACILITATE ANDHRA'S GREEN HYDROGEN LEADERSHIP IN INDIA

Andhra Pradesh ranks first in Ease of Doing Business ahead of other states such as Gujarat and Tamil Nadu as per BRAP 2020¹³ with a rating of ~98% (EDB AP). In 2021 Andhra ranked 9th in export preparedness, 2nd in export performance, 10th in export ecosystem pillar and 8th in

business ecosystem pillar (NITI Aayog, 2021). Andhra Pradesh has approved investment of ~\$13 bn for green energy sector (*Advantage AP, 2022*). The state's readiness for a green hydrogen economy is highlighted below.



¹³ BRAP – Business Reforms Action Plan



Figure 12: Andhra Pradesh readiness in for green hydrogen and its supporting infrastructure



3.1 Andhra Pradesh’s enabling infrastructure for green hydrogen adoption

Andhra Pradesh is well equipped with the necessary infrastructure for setting up green hydrogen production facilities. The image below highlights the critical infrastructure such as industrial nodes and land capacity, existing ports

and airports, demand centers for hydrogen, inter-state transmission capacity to cater to RE import/export in nearby regions of Odisha, Telangana, Karnataka, and Tamil Nadu.

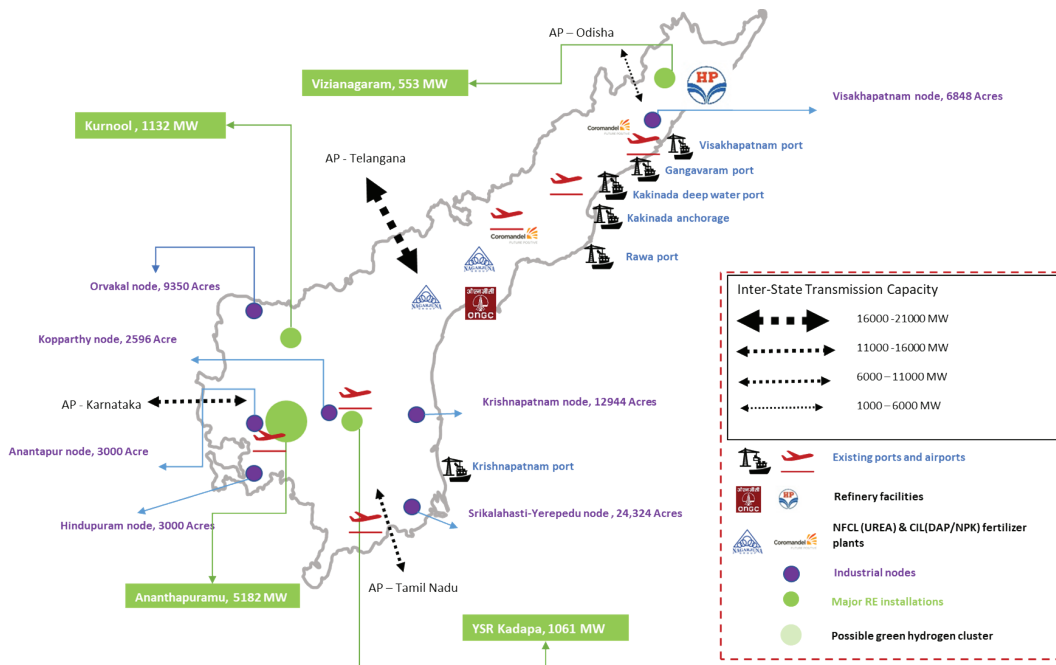


Figure 13: State’s map representing critical infrastructure and possible green hydrogen plant cluster

3.2 Andhra Pradesh’s readiness to accelerate green hydrogen adoption

The state is equipped with various demand and supply side advantages for setting up green hydrogen production and electrolyser manufacturing. Green hydrogen production requires extensive investments in renewable energy and

electrolyser technologies, skilled human resources, huge parcel of lands and availability of water. Andhra Pradesh has abundance of these critical resources to carry out successful production of green hydrogen within the state.

3.2.1 Dedicated Green Hydrogen and Green Ammonia policy

To promote green hydrogen and green ammonia

production, the state has rolled out a conducive and investor friendly policy with a target of 0.5 MPTA of green hydrogen or 2 MPTA of green ammonia production in five years' time.

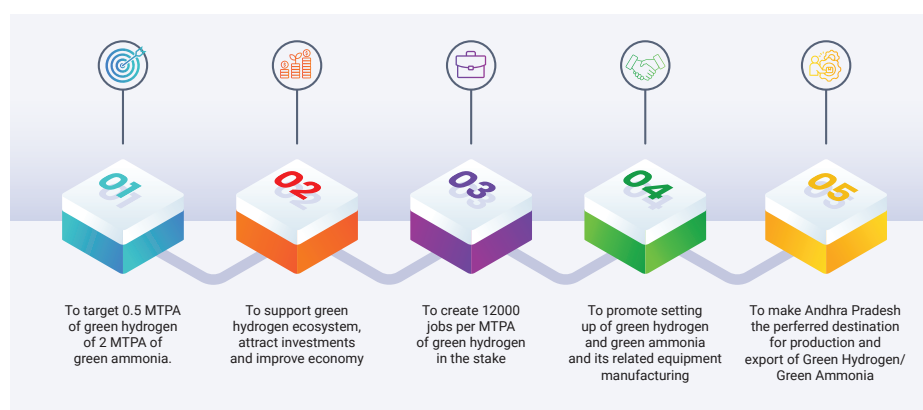


Figure 14: Objectives of Andhra Pradesh Green Hydrogen and Green Ammonia Policy 2023

The following incentives shall be provided for the Green Hydrogen/Green Ammonia projects set up during the policy operative period:

- a. Reimbursement of net SGST revenue from sale of Green Hydrogen/Green Ammonia within the State:** 100% reimbursement of net SGST revenue to the developer from sale of green hydrogen/ Green Ammonia within the State for a period of five (5) years from commercial operation date (CoD).
- b. Exemption from Electricity Duty:** 100% exemption of Electricity Duty for the power consumed for production of Green Hydrogen/Green Ammonia from RE plants (with or without storage) for a period of five (5) years from CoD
- c. Reimbursement of Intra-State Transmission charges for wheeling of power:** 25% of Intra-state transmission charges shall be reimbursed to the developer for a period of five (5) years from CoD for the power procured from RE (with or without storage) plants located within the State subject to maximum of INR 10 Lakhs/MW/year of installed electrolyser capacity.
- d. Reimbursement of Cross-subsidy surcharge:** The cross-subsidy surcharge, as applicable for Energy Intensive Industry category, shall be reimbursed on the energy drawn from RE plants located within the State for production of Green Hydrogen/Green Ammonia for a period of five (5) years from CoD.
- e. Grid Connectivity:** Grid connectivity to Intra-state transmission system at the generation end and production end for RE plants established for production of Green Hydrogen/Green Ammonia shall be granted on priority. APTRANSCO/APDISCOM(s) will dispose the proposals for the technical feasibility for evacuation within 21 days from the date of receipt of application. Any upstream system strengthening requirement shall be borne by APTRANSCO/ APDISCOM(s) on priority basis.
- f. Renewable Purchase Obligation (RPO):** As per Green Hydrogen Policy notified by Ministry of Power, Govt. of India on 17th February 2022, Renewable Energy consumed to produce Green Hydrogen/ Green Ammonia shall count towards RPO compliance of the

consuming entity. The renewable energy consumed beyond the obligation of the producer shall count towards RPO (i.e., Hydro Purchase Obligation or Energy Storage Obligation) compliance of the APDISCOM in whose area the project is located.

g. Land allotment:

- i. NREDCAP shall allocate the Government land for development of both RE plants and Green Hydrogen/Green Ammonia Plants on priority basis at lease rate of INR 31,000 per acre per year with an escalation of 5% every two years during the project period. Alternatively, Green Hydrogen/Green Ammonia plants can also be developed in any of the proposed industrial zones/parks as per prevailing policies
- ii. Green Hydrogen/Green Ammonia producers shall be allowed to set up bunkers near Ports for storage of Green Hydrogen/Green Ammonia. The land for storage purpose shall be provided by respective port authorities at applicable charges.

h. Land usage incentives: 100% exemption from payment of land use conversion charges and stamp duty

i. Production of Green Hydrogen/Green Ammonia or Fuel Cells and Manufacturing

of Green Hydrogen/ Green Ammonia

Production Equipment: Green hydrogen/ green ammonia production units, fuel cell production units using green hydrogen, green hydrogen equipment manufacturing facilities and ancillaries related to green hydrogen production equipment shall be treated as eligible industry under the schemes administered by the industries department and incentives available to industrial units, if any, under such schemes shall be made available

j. Pollution clearance: Green Hydrogen/Green Ammonia production plants will be exempted from obtaining any NOC/Consent for establishment under pollution control laws from AP Pollution Control Board.

k. Other Incentives:

- i. The incentives if not modified/changed above, as available under State's solar/wind/wind solar hybrid policy shall be available to the solar/wind/ wind solar hybrid plants to be established for Green Hydrogen/Green Ammonia production
- ii. Any other incentives as provided by the Central Government for production of Green Hydrogen/ Green Ammonia shall be extended by the Nodal Agency to the Developer without any financial commitment by the State Government



3.2.2 Renewable energy potential

The state is blessed with 82.5 GW potential of RE, majority from wind (44 GW) followed by solar (38.5 GW) (MNRE, 2019). The current renewable energy installed capacity stands at ~9 GW. With green hydrogen production target of 500 KTPA within the state, the RE capacity required is estimated to be in the range of 10-15 GW dedicated to green hydrogen production, presenting a strategic opportunity for investments in 10-15 GW of renewable power generation plants.

Andhra Pradesh government has identified 76 projects across 11 state departments with a cumulative project investment of \$ 40 bn of which more than 50 % is dedicated to 14 RE projects with ~\$20bn investments (upcoming) (EDB AP, 2022).

Andhra Pradesh has rolled out Renewable Energy Export Scheme, offering various incentives and enabling infrastructure to invest in renewable energy parks dedicated to

exporting green energy. Under this scheme a total outlay of \$ 9.5 bn is dedicated to adding seven UMPP¹⁴ projects totaling ~18,000 MW in Kurnool, Kadappa and Anantapuramu region (EDB AP, 2022). Andhra Pradesh has also identified 5 lakh acres of land parcel to accommodate its colossal target of 120 GW under RE export scheme (EDB AP, 2021).

The following enabling factors enhance the RE resource availability for green hydrogen production:

a. Pumped hydro storage

Energy storage forms a critical part of green hydrogen production to tackle the intermittent nature of renewable energy. This enables round the clock green power to operate electrolyzers efficiently and produce uninterrupted green hydrogen. The state has already identified 29 locations to set up ~34 GW of Pumped Storage Power Projects (PSP) (EDB AP, 2021) and this may help further in enabling a favorable green hydrogen ecosystem.

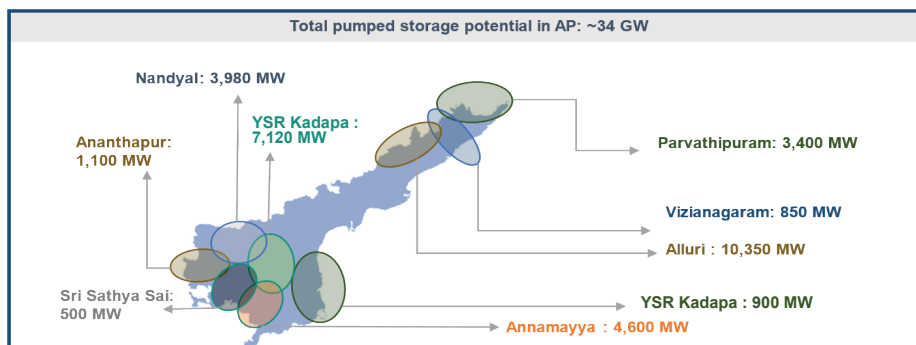


Figure 14: AP pumped hydro storage potential

¹⁴ Ultra-Mega Power Plant

Andhra Pradesh is home to world's largest upcoming Integrated Renewable Energy Storage Project (IRESPP) with ~\$3bn investment and 5,230 MW capacity with a daily storage capacity of 10,800 MWh (GreenKo, 2022).

3.2.3 Dedicated T&D corridor

India has planned ISTS transmission system

for integration of **66.5 GW** RE capacity by 2022 (CEA, 2022). **In the state, Anantapur 3.5 GW and Kurnool 4.5 GW transmission capacity schemes are being taken up for bidding/implementation.** Details of potential RE zones in the state along with likely storage to be installed and evacuation system required for the same is detailed below:

Table 1: Andhra Pradesh upcoming RE capacity additions, maximum dispatch capacity and RE evacuation system requirement

State/ District	Pooling stations	Identified Potential (GW)		Maximum Dispatch (GW)	BESS (GW) To be setup by RE Generators	Evacuation System (GW)
		Wind	Solar			
Kurnool	Kurnool -IV Kurnool -V	8	15	18	6	12
Anantapur	Anantapur, Anantapur-II	10	10	15	5	10
Kadapa	Kadapa-II	0	8	8	3	5
Sub total		18 GW	33 GW	41 GW	14 GW	27 GW

Phase wise allocated capacity of 51 GW of RE capacity additions by December 2030, presents a maximum dispatch potential of **41 GW (27 GW evacuation + 14 GW BESS¹⁵)**. This may enable power to be evacuated and be available for powering the green hydrogen production.

3.2.4 Dedicated renewable energy authority

At present NREDCAP¹⁶ is identified as the dedicated authority for RE and green hydrogen projects. This is expected to ease the process of RE generation, evacuation etc. as well as create ease in setting up GH/GA projects. For this, NREDCAP envisages to actively coordinate with critical stakeholders such as Ministry of New and Renewable Energy (MNRE), Andhra Pradesh Transmission Corporation (APTRANSCO), Andhra Pradesh Electricity Distribution Companies

(APDISCOMs), Andhra Pradesh Industrial Development Corporation Limited (APIDCL), Andhra Pradesh Green Energy Corporation Limited (APGECL) and other central/state agencies.

3.2.5 Dedicated land banks for setting up RE parks

AP government has notified the potential to facilitate over 5 lakh acres land for RE export projects. These land parcels are largely located within the regions of Kadappa, Kurnool and Anantapuramu regions. Andhra Pradesh has EC/statutory cleared land at 50-60% lower land price compared to other states (EDB AP, 2021). Most land parcels are in near vicinity to international airport and proximity to mega cities of Karnataka, Telangana, and Tamil Nadu (EDB AP, 2021). Due to above factors the state is well positioned for RE project development.

¹⁵ BESS – Battery Energy Storage System

¹⁶ NREDCAP – New & Renewable Energy Development Corporation of Andhra Pradesh

3.2.6 Abundant water resources

Andhra Pradesh is estimated to have water resource of 39 trillion liters¹⁷ (APWRIMS, 2022) in storage and total water availability of ~54 trillion liters. To produce 500KTPA of green hydrogen, water required for electrolysis is estimated to be ~23 billion¹⁸ liters of raw water, which corresponds to a meagre ~ 0.06% of the estimated water resources potential. Water cost in AP is at INR 50-55 per KL, which is 45 percent lower than other states (EDB AP, 2021).

3.2.7 Availability of skilled labor

Andhra Pradesh has a wide skill base of human resource, with several educational institutes, focused on promoting specific skill sets pertaining to sectors to ensure availability of high skilled labor. It has 67% (EDB AP, 2022) working age population. Andhra Pradesh boasts an availability of huge talent pool owing to the presence of top-class academic institutions (NIT, IIT, IIM etc.) and abundant skill availability (50000+) average within 20-35 KM of all industrial parks as well as reducing housing and transportation cost. Over 15 lakh people are expected to be added into the labor pool by 2023.

3.2.8 Attractive economic features

Andhra Pradesh has several attractive economic features which have an important bearing for investors seeking to evaluate favorability

of states from a green hydrogen investment standpoint.

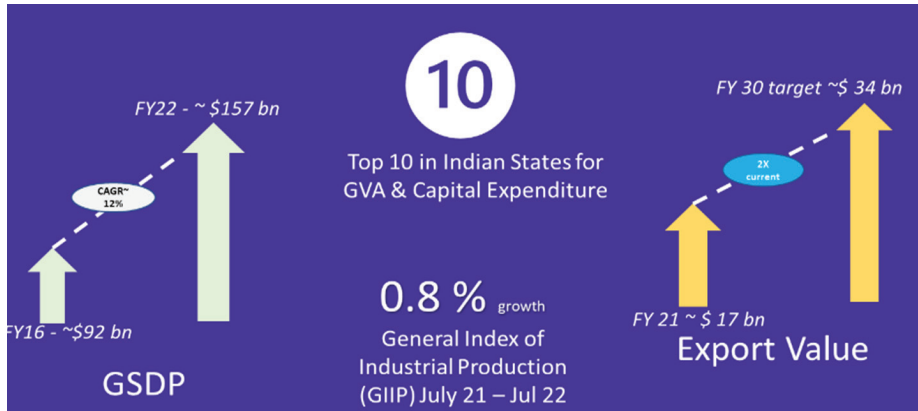
- **High GSDP growth rates:** The state's GSDP has increased from \$ 92 bn in FY16 to \$ 157 bn in FY22 with a CAGR of ~12% (IBEF, 2022) which indicates that state is on track for an accelerated growth.
- **Gross Value Added:** Andhra Pradesh is within top 10 states in India, contributing INR 51,700 Crore as of FY 2020 for Gross Value Added and ~ INR 38,000 Crore as the net value added in FY 20 (Reserve Bank of India, 2021)
- **Focus on enabling infrastructure:** Andhra Pradesh ranks 10th in India with a total capital expenditure in FY22 at INR 47,583 crore. This indicates the willingness of state and other private bodies to nurture a rapid economic growth via creation of infrastructure and other assets.
- **Export Value:** Andhra Pradesh contributes ~6% of total Indian exports, valued at ~\$17 bn in FY21 with a growth rate of ~9%, and expects to grow to ~\$ 34 bn in FY30. Top exporting destinations are ASEAN region at 25%, North American 18%, Northeast Asia 17%, European Union 12%, Gulf Nations 7% and Southeast Asia holds 6% (EDB AP, 2021). As a high performing export state, Andhra Pradesh is well poised to attract investments for creating export hub for green hydrogen in the state.

25 Skill Colleges are proposed across Andhra Pradesh, one each in 25 Parliamentary constituencies



¹⁷ Calculations done basis water in reservoirs, ground water & WC structures as per Andhra Pradesh Water Resource Information & Management System

¹⁸ Raw water requirement at 22.5 - 40 liter/kg of green hydrogen



- **Strong industry ecosystem:** Andhra Pradesh has a strong ecosystem of industries and ranks first in Ease of Doing business (EODB). It ranks 3rd in India with total factories at ~17,000, with INR 2,73,578 + crore invested (Reserve Bank of India, 2021). Additionally, Andhra Pradesh is the only state in India to have 3 industrial corridors with allocated land area of ~90,000 acres to develop industrial infrastructure in the state (EDB AP, 2021). Currently, total vacant land plots stands at ~47000 acres.

The state has further identified a land bank of 3 lakh acres and is in the process of consolidating additional industrial land bank of approximately 7 lakh acres (APIIC, 2022). Andhra Pradesh houses over 300 industrial parks, the land parcels identified as industrial parks come with plug and play infrastructure (APIIC, 2022). With ambitious green hydrogen production target, India is also looking to set up electrolyser manufacturing facilities domestically. These facilities require skilled human resource, big parcels of land, technology partnerships and

plug and play infrastructure, which are readily available in the state.

3.2.9 Conducive policies and ecosystem

- **Single window clearances:** Andhra Pradesh has set up a single window system termed as Single Desk Portal (SDP). The one stop shop helps industries to obtain more than 39 regulatory clearances belonging to 19 departments within 21 days, with a track record of over 23,100 industries cleared through SDP since 2015 (DOI AP, 2019).
- **Construction approvals:** The state has introduced Development Planning Management System (DPMS) a conducive ecosystem for approvals of plans required for construction and setting up of industries. Approvals such as construction permit, factory plan approval, fire department approvals and NOC etc. can be submitted online and the entire process of approvals will be cleared in 5 – 7 days (*Department of Industries*).


AP Solar Power Policy 2018-23

- Develop solar parks with necessary infrastructure
- To promote local manufacturing facilities which will generate employment in the state


AP Wind Power Policy 2018-23

- To encourage wind power generation in the state
- To attract private investments in the state of large wind power projects
- To promote investments in setting up manufacturing facilities in state generating local employment


AP Wind - Solar Hybrid Power Policy 2018-23

- Aims to encourage new technologies methods and way-outs and other emerging technologies
- To provide a framework for promotion of large grid connected wind-solar systems for optimal and efficient utilization of transmission infrastructure


AP RE Export Policy 2020

- To facilitate 50 GW RE projects
- To facilitate 5 lakh acres of potential land to RE export project developers
- To promote RE equipment manufacturing facilities in state


AP Pumped Storage Power Promotion Policy 2022

- To harness the potential of 34 GW PSP capacity available in the state
- To facilitate development of Pumped Storage Hydro Power Projects (PSP) within the state
- To facilitate private Investments for developing PSP projects in fast-track mode
- To support in meeting Renewable Purchase Obligation targets set by Central government for balancing/ peak requirement of power at National and State levels.

Figure 16: State's 5 RE policies namely, RE Export, Solar, Wind, AP Wind-Solar Hybrid policies and AP PSP promotion policy2022

- Dedicated renewable energy policies: Andhra Pradesh has achieved significant capacity additions in renewable energy since the launch of AP solar, wind and solar-wind hybrid policies in 2018. Against the target of 5 GW solar in 2023, the state has installed ~4 GW of solar capacity. Andhra Pradesh observed wind power capacity additions of ~4.5 GW primarily on account of its wind power policy 2015 which had supported through several fiscal incentives. This was replaced by the AP wind policy 2018-23.

Currently the state has **five** dedicated policies on RE Export, Solar, Wind, Wind-Solar Hybrid and AP Pumped Storage Power Promotion 2022 policy. The policy objectives and incentives are listed below (EDB AP, 2021)

3.2.10 Facilitative nodal agency

NREDCAP acts as the nodal agency for implementation of RE policies. Following activities are undertaken by NREDCAP:

- 01 Allocation of wind/solar resources and giving permissions on a first come first serve basis.
- 02 Coordination with MNRE/NTPC/SECI/APTRANSCO, AP DISCOMs and other Central and State Agencies in obtaining necessary clearances, approvals, grants, and subsidies
- 03 Facilitate land lease from the Land Aggregating Agency of Government.
- 04 Act as park developer if required
- 05 Facilitate in getting power evacuation and/ or Open Access as per the regulation issued by APERC and amended from time to time.
- 06 Facilitate water allocation from concerned departments.

NREDCAP also currently has the responsibility for facilitating green hydrogen projects.

3.2.11 AP Industrial Policy 2020-23

The prime objective of the policy is to achieve environmentally sustainable growth balanced across regions and communities with employment generation for youth of the state.

Government of Andhra Pradesh recognizes the importance of support towards new/ existing investors, hence, provides for pre and post setup support and ensures backward and forward linkages. For investors to succeed, the government has setup assistance platform

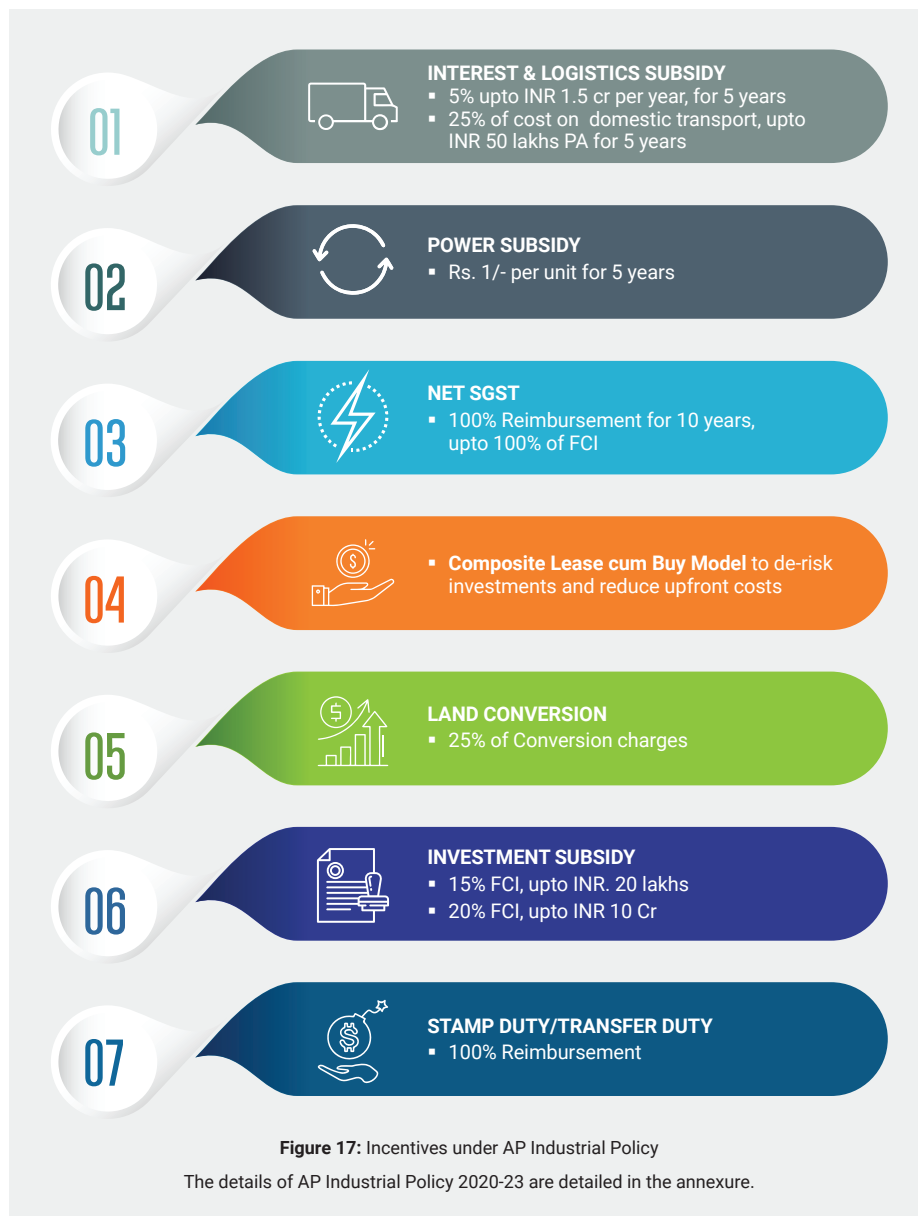
comprising of multiple state agencies coming together to form a multi-faceted capability center.

This policy clearly dictates the fiscal incentives available for MSMEs as well as large and mega enterprises by providing 100% reimbursements on stamp duties on land and 100% reimbursements of net SGST as well to eligible enterprises, investment subsidy up to 15% and interest subsidy of 3% on term loans on fixed capital investments etc. The government has planned special package for women

entrepreneurs establishing manufacturing units belonging to SC/ST/BC/minority communities.

The government may extend tailor-made benefits to mega projects on case-to-case basis based

on gestation period, pioneering nature, locational aspect, technology, project criticality to industrial growth in the state and overall economic impact or revenues to the state.



3.2.12 Enabling ecosystem

a. Domestic demand of hydrogen

Andhra's current domestic hydrogen demand of ~400 KTPA arises from its existing four fertilisers and two refinery plants. Fertilizers are major contributor towards hydrogen demand with ~330KTPA.

Refineries use vast quantities of hydrogen in the de-sulphuration and hydrocracking of crude oil to make petrol, diesel, and other chemicals. Currently Andhra Pradesh has an estimated demand of 70 KTPA from refineries. This brings the total demand of Hydrogen to ~400 KTPA which comprises nearly 8% of the total India's industrial demand of conventional hydrogen which stands at 5 MMT (MNRE ,2023). The state's demand is estimated to increase to nearly 550 KTPA by the end of

this decade (CAGR ~3%) owing to capacity additions in fertilizer and refinery plants, with an initial target to produce 500 KTPA of green hydrogen by 2030. Therefore, the state has strong domestic demand hydrogen which would enable a rapid creation of a green hydrogen ecosystem.

b. Export ecosystem

Andhra contributes ~6% of the total exports in India and ranks 2nd in terms of value exported from India. State is targeting to double its export value from current ~\$17 bn by 2030 to \$ 34 bn. The top export destinations are ASEAN region at 25%, North America – 18%, Northeast Asia -17%, European Union – 12%, Gulf Nations – 7% and finally South Asia holds 6% (EDB AP, 2021).

Green hydrogen exports from Andhra Pradesh presents an opportunity which can be leveraged by the state owing to its existing strong export ecosystem including storage and bunkering facilities. The state has strategy in place to boost its export ecosystem such as (GoAP, 2018):

- 1 PUSH strategy to promote exports (Promote Value Addition + Upgrade Institutions and Infrastructure + Streamline Process + Harness Human Capital).
- 2 Export promotion committees at district level, executed export action plan for 6 districts
- 3 Seeking out embassies and creating market access with potential importers, engagement with 34 export promotion councils to provide handholding support to enterprises.
- 4 Dedicated trade portals are being setup to ease the process of exports
- 5 Strengthening association with export promotion councils, international trade bodies, FIEO¹⁹, ITPO²⁰ and NCTI²¹
- 6 E-governance support to exporters in state
- 7 Creation of a strong analytical database on market potential for exports and develop new markets for exporters
- 8 Promoting public private partnership in developing competitive export infrastructure
- 9 Setting up export promotion institutions on state and district level
- 10 Identification of key performance indicators for a specific sector and support measures to boost the exports in this sector.

¹⁹ FIEO - Federation of Indian Exports Organization

²⁰ ITPO - India Trade Promotion Organization

²¹ NCTI – National Centre for Trade Information and Product Sectoral Associations

Common fiscal incentives to major export sectors are (GoAP, 2018):

- 1 **Export subsidy** – Any exporters who achieve double the value of exports over previous year would be reimbursed with 1% of their export value limited to INR 20 lakhs
- 2 **Reimbursement of land cost** – Limited to 25% of land cost capped at INR 15 lakhs for general category and for BC and SC/ST up to 50% capped at INR 25 lakhs.
- 3 **Reimbursement of land conversion charges** – 25% of the land conversion charges from agriculture to industrial use may be reimbursed to export oriented MSMEs capped at INR 15 lakh
- 4 **Reimbursement of space rent to MSMEs** – For participation in industrial exhibitions at international level up to INR 2 lakh subsidy will be provided on rent space, and within India a maximum of INR 50,000

c. Logistical support

Logistics plays a vital role in green hydrogen ecosystem especially when green hydrogen or its derivatives such as ammonia are not produced at the demand centers. Logistics infrastructure will provide a safe storage of GH/GA or derivatives in warehouses along with suitable transport connectivity via trucks/pipeline/shipping. For domestic transfer of green hydrogen and its derivatives, trucking and pipeline connectivity are critical, but for green hydrogen export, shipping of green ammonia is more economical, hence requiring port infrastructure to be developed.

- 1 **Warehouse** – Andhra has 109 warehouses creating a capacity of ~13 Lakh MMT along with 104 cold storages with a total capacity of 66 MMT (EDB AP, 2021)
- 2 **Cargo movement** – 55% of cargo is transferred through rail and conveyor belts, which is higher than national average of 35%, road accounts for 32% of freight movement, and the rest is shifted either through pipeline or shipping (EDB AP, 2021)
- 3 **Connectivity** – AP has six existing airports, in addition to few upcoming ones, six operational ports worth 250 MT of cargo handling capacity, 7040 km of rail network, 888 km of national waterways to support inland water transport, and 1,32,415 km of road including national highways, state highways, district, and rural roads (Department of Industries, 2019).
- 4 **Port infrastructure** – The state has second longest coastline among Indian States at 974 km, with total port handling capacity at 250 MMT. The state has six operational ports and a few minor ports. The state is investing heavily in the development of nine additional ports which might be operational soon. The state is investing ~ INR 12,000 crore to boost its cargo handling capacity to 400 MMT, along with four major ports planned, namely, Machilipatnam Port, Ramayapatnam Port, Kakinada SEZ port and Bhavanapadu port (Standards, 2020).

Table 2: Andhra Pradesh's port infrastructure

#	Operational Port (Department of Industries, 2019)	Handling Capacity (Andhra Pradesh Maritime Board)	Planned expansion (Andhra Pradesh Maritime Board)	Port Storage	Available Warehousing (Shipnext)
1	Vizag Port	70 MMT	-	Liquid Storage -2.3 MMT Dry Storage – 0.9 MMT	LPG, Chemicals, Liquid Ammonia, General Cargo etc.
2	Gangavaram Port	64 MMT	-	5 MMT Storage in Coal Stackyard (Andhra Pradesh Maritime Board)	Dry Bulk (ore, coal etc.), General Cargo
3	Kakinada Deep Water	25-30 MMT	175 -200 MMT	10 MMT LNG terminal upcoming (Andhra Pradesh Maritime Board)	Dry Bulk (ore, coal etc.), Liquid, General Cargo
4	Kakinada Anchorage	4 MMT	-	-	
5	Rawa Port	1.56 MMT	-	-	
6	Krishnapatnam Port	25 MMT	154 MMT (FY26)	~1100 acre allotted for storage area 5.3 MMT (upcoming for Liquid cargo and Fertilizers)	Dry Bulk (ore, coal etc.), Liquid, General Cargo

4 POSSIBLE COLLABORATIONS WITH MAJOR PLAYERS IN THE GREEN HYDROGEN VALUE CHAIN



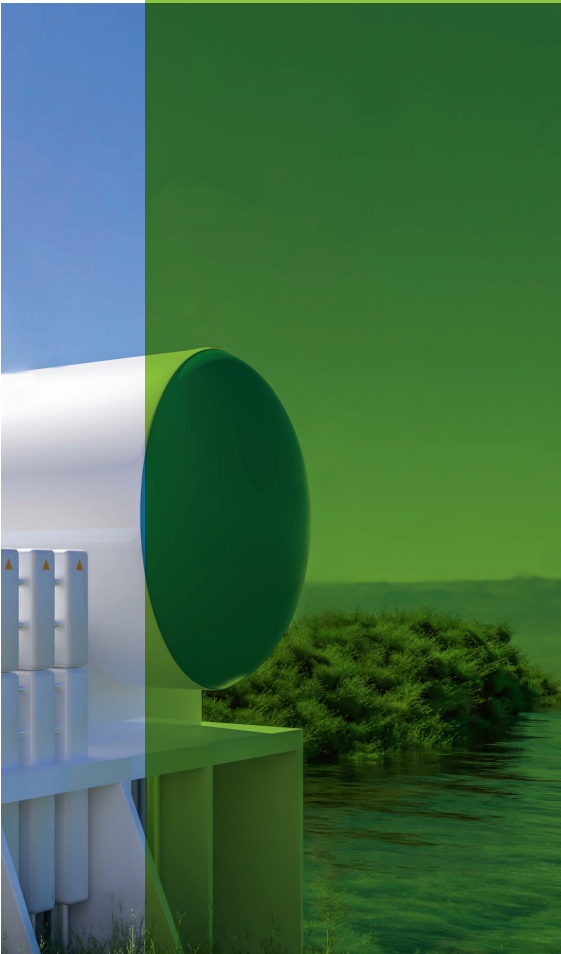
Green hydrogen ecosystem necessitates huge capital investments associated with RE, electrolyser manufacturing, solar panel, and wind turbine manufacturing. As one of the leading states in RE capacity additions, Andhra Pradesh offers significant partnerships opportunities with various players in generation and equipment manufacturing of renewable energy landscape.

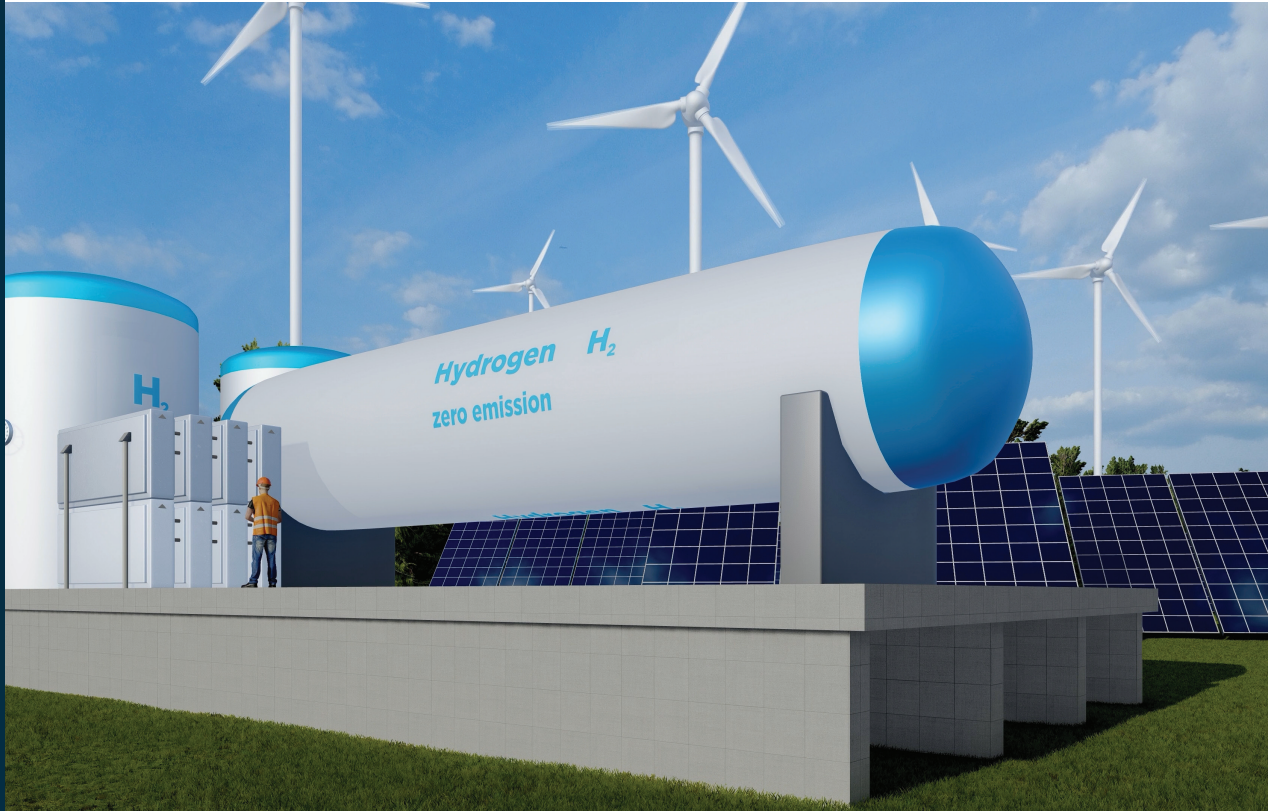
Electrolysis technology is constantly evolving. At present, AWE (Alkaline Water Electrolyser) and PEM (Proton Exchange Membrane) are mature enough for widespread deployment, but soon technologies like AEM (Anion Exchange Membrane), SOEC (Solid Oxide Electrolyser Cell) and PEM electrolyser without use of platinum group metals will also come up. Technologies will need to keep improving to attain critical technical aspects such as high electrical efficiency, no-gap configuration for anode and cathode, and high current density. This requires either a technology partnership with an existing player for manufacturing electrolysers inhouse or a strategy to import.

Another critical aspect for success in this space is agreements for offtake for GH/GA within the states or export to international energy companies in major importing regions such as Germany, Japan, and South Korea.

To tackle this dynamic landscape, collaborations are pivotal in the green hydrogen value chain. State can help create strong partnerships in the abovementioned elements. There are multiple modes where a collaboration can be formed:

- **Investments:** Financial partnerships such as equity/debt support, grants etc. for GH/GA projects.
- **Project development partnerships:** Alliance between hydrogen and ammonia developers to invest and/or co-develop GH/ GA projects to leverage respective parties' strengths
- **Technology Partnerships:** Partnerships to facilitate electrolyser and associated technology supply chains to enable access to technology or establish a local manufacturing plant for electrolysers
- **Research & Development:** Cooperation between technology developers, academia, startups, and established organizations to accelerate R&D activities to support more efficient technologies
- **Agreement of supply:** Transactional partnerships via MoU/ supply contracts to secure GH/GA supply within the state, elsewhere in India or abroad.





5 GREEN HYDROGEN TO PROPEL AP FORWARD

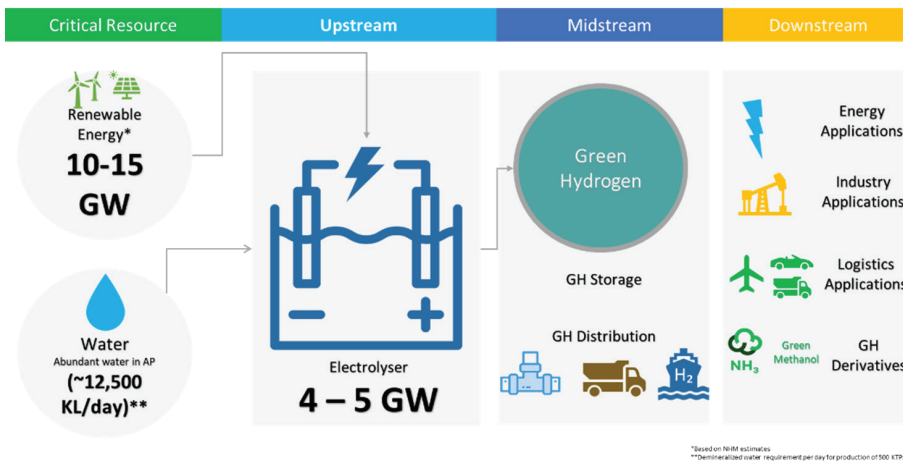
Green hydrogen will play a key role in enabling Andhra Pradesh's ambition towards a sustainable accelerated growth of the economy. It presents substantial potential to decarbonize the current as well as expected usage of fossil fuel-based fuel and feedstock in several hard to abate sectors while also promoting energy security for the state.

At present, the state has the 3rd largest demand for hydrogen in India for fertilizer after Gujarat and Uttar Pradesh, and 9th largest for refinery sector.

The state is looking to produce 500 KTPA of green hydrogen by 2030 which may be processed further to produce hydrogen derivatives such as green ammonia, green

methanol, etc. An estimated investment of ~\$ 10-15 bn might be required to enable this target. A large part of this (approximately

70%) is estimated to be required in creating RE infrastructure with balance for electrolyser capacity additions.



Andhra Pradesh is well positioned to attract the envisaged investments for creating a strong green hydrogen eco-system with significant local consumption opportunity, right policy environment, conducive incentives, and significant ease of doing business for industries. It additionally has an impressive

skilled resource base, strong export ecosystem, as well as a drive to reduce carbon emissions substantially. These factors integrate well in creating a favorable outcome for investors, who are keen to invest in projects targeting sustainable development.

ANNEXURES






A. National Green Hydrogen Mission

National Hydrogen Mission published January 2023, with total mission outlay of INR 19,744 Crore targeting 5 MMTPA production capacity by 2030, with 125 GW of RE installations

requiring INR 8 Lakh Crore of total investment, creating 6 lakh jobs and abating 50 MMTPA Co₂ emissions. The mission targets to reduce India's Import dependency targeting reduction in fossil fuel import over INR 1 lakh crore. Lastly, a robust Standards and Regulations framework may also be developed:

National Green Hydrogen Mission 2023: MNRE, GoI

National Hydrogen Mission Document was released in Jan. 2023 following cabinet approval to provide several areas of support to GH ecosystem

Envisaged Outcomes		Ambition	
	50 MTPA Overall CO ₂ emission abatement		5 MTPA Overall GH production target 10 MT including exports)
	₹ 8,00,000 Cr. (~\$100 Bn.¹) Overall investment in GH sector		125 GW RE Capacity installation (to support GH target²)
	6,00,000 Expected green jobs generated		
Financial Support		Organization Structure	
₹ 19,744 Cr. / (\$2.47 Bn) Overall NHM financial outlay		<ul style="list-style-type: none"> Chaired by Empowered Group headed by Cabinet Secretary Empowered Group to contain members from end-use ministries like MoPNG, MoP, Shipping, Railways, MoRTH; Niti Aayog; Scientific Advisors and Industry members Will be supported by Advisory Group comprising of Scientific Advisor to GoI, Academic and Research Institutes, Industry etc. Mission Secretariat to be in MNRE and NHM to be led by MNRE. Secretariat to be headed by Mission Director 	
₹ 17,490 Cr. SIGHT Programme (Electrolyser Mfg. and GH projects)	₹ 400 Cr. R&D		
₹ 1,466 Cr. Pilot Projects	₹ 388 Cr. Other components		

Benefits of the mission –

- Creation of export opportunities for green hydrogen and its derivatives
- Decarbonization of industrial, mobility and energy sectors
- Reduction on dependence of fossil fuels
- Development of indigenous manufacturing capabilities
- Employment creation

Two distinct financial incentive mechanisms

- Targeting domestic manufacturing of electrolyzers
- Domestic production of green hydrogen

Some incentives which might be applicable as per the Green Hydrogen Policy 2022 are –

- ISTS transmission cost waived off
- Grid Connectivity on priority, OA within 15 days of application
- RE banking permitted for a period of 30 days
- Single window clearance by MNRE, Land in RE park allocated for GH/GA production units, setting up of manufacturing zones, Bunkers allowed to be set up for storage near port
- RE used in GH/GA production to be counted towards RPO obligation
- MNRE may aggregate demand from different consumers and have consolidated bids for the procurement of GH/GA

B. Annexure

Scheme guidelines for implementation of Strategic Interventions for Green Hydrogen Transition (SIGHT) Programme (SIGHT)

The union cabinet has approved the National

Green Hydrogen Mission with an outlay of INR 19744 crore up to 2029-30. The SIGHT programme is a major financial measure under the mission, with an outlay of INR 17490 crore. The financial measures are focused on two key areas including green hydrogen production and electrolyser manufacturing.

Table 1: Summary of incentives to promote green hydrogen/green ammonia production under SIGHT programme

Incentive outlay	INR 13050 crore
Capacity offered	Technology agonistic pathways: 410000 MTPA Biomass based pathways: 40000 MTPA
Incentive period	3 years
Incentive mechanism	Incentives will be capped at INR 50/kg in the first year of production, INR 40/kg in second year and INR 30/kg in the third year
Bid size	Technology agonistic pathways: minimum capacity shall not be less than 10000 MT and maximum capacity that can be allotted to single bidder will be 90000 MT Biomass based pathways: minimum capacity shall not be less than 500 MT and maximum capacity that can be allotted to single bidder will be 4000 MT
Bid process	Least average incentive basis (INR/kg) (Refer to the link for detailed scheme guidelines)
Eligibility	Technology agonistic pathways: Net worth of the last date of previous financial year should be equal to or greater than INR 15 crore per thousand MT per annum of quoted production capacity of green hydrogen Biomass based pathways: Net worth of the last date of previous financial year should be equal to or greater than INR 1.5 crore per thousand MT per annum of quoted production capacity of green hydrogen
Implementing agency	Solar Energy Corporation of India (SECI)

Table 2: Summary of incentives to promote electrolyser manufacturing under SIGHT programme

Incentive outlay	INR 4440 crore
Capacity offered	Electrolyser manufacturing based on any stack technology: 1200 MW Electrolyser manufacturing based on indigenously developed stack technology: 300 MW
Incentive period	5 years
Incentive mechanism	The base incentive (INR/KW) available in each year will be as per a defined tapering trajectory: INR 4400 (year 1), INR 3700 (year 2), INR 2960 (year 3), INR 2220 (year 4), INR 1480 (year 5)
Bid size	Electrolyser manufacturing based on any stack technology: minimum capacity shall not be less than 300 MW and maximum capacity that can be allotted to single bidder will be 100 MW Electrolyser manufacturing based on indigenously developed stack technology: The maximum capacity that can be allotted to single bidder will be 300 MW
Eligibility	<ul style="list-style-type: none"> ▪ Net worth of the last date of previous financial year should be equal to or greater than INR 1 crore per MW of quoted manufacturing capacity ▪ The beneficiary will have to demonstrate minimum 50% of annual sales of electrolysers for installation of projects in India ▪ The electrolysers manufactured by the bidders must fulfill the following requirements: <ul style="list-style-type: none"> • Specific energy consumption (SEC) to be equal to or less than 56 KWh per kg of hydrogen production • Guaranteed lifecycle of electrolyser to be at least 60000 hours • Minimum 40% local value addition (LVA) during first year of production for alkaline electrolysers and minimum 30% for other technologies
Bid process	The selection parameter will be calculated as the sum of products of the quoted LVA factor and performance quotient over the 5-year period (<i>Refer to the link for detailed scheme guidelines</i>)
Implementing agency	Solar Energy Corporation of India (SECI)

C. AP Industrial Policy 2020-23

The objective of the policy is to (GoAP)

- To create employment for youth of the state
- To match the national average in industrial GVA per capita
- To plan balanced growth across regions and communities
- To achieve environmentally sustainable growth

The prime focus of the policy is to promote not only prospective investors but also existing units, key factors required to unlock the potential of the thrust sectors in the state, focus on asset creation in both infrastructure and skill pool development, reduce the upfront cost and time of setup, focus on de-risking businesses through end-to-end hand holding support, and special support for socio-economic progression of SC/ST/BC and minority communities especially women.

Government has integrated services from multiple state agencies under a central multi-faceted platform to guide the investors to success, currently the following 10 services are there:

Industrial policy defined across five themes covering entire business value chain
Key unlocks for major industries factored them into each theme






		Approval		Setup		Operate			
	01		02		03		04		05
Infrastructure Pre-cleared ready built facility with flexible payment options		Ease of doing business <ul style="list-style-type: none"> ▪ Resolve issues in SDP ▪ Setup mechanism to ensure on-ground implementation of deemed approvals 		Skilling and Labour availability <ul style="list-style-type: none"> ▪ Create pipeline of skilled labour tailored to needs of industry ▪ Develop to class talent in AP through international collaboration 		End to end hand holding One stop shop to be set up to help units with all aspects of operations, strategy, marketing and sales		Incentives Incentive and package for MSEs & SC/ST/BC and Minority communities	

Figure 7: Key themes of Industrial policy 2020-23



Figure 21 : A central multi-faceted capability center

Fiscal Incentives for Micro and Small enterprises

- Reimbursement of 100% stamp duty and transfer paid by the industry on purchase of land meant for industrial use
- Reimbursement of 100% stamp duty for lease of land/shed/buildings, mortgages and hypothecations
- GoAP is committed to supplying uninterrupted 24x7 power to all industries operating in the state

Fiscal Incentives for Medium, Large and Mega Enterprises

- GoAP is committed to supplying uninterrupted 24x7 power to all industries operating in the state
- 100% reimbursement of net SGST accrued to the state for 5 years or 100% fixed capital investment, whichever is lower, from the date of commencement of commercial production, linked to employment <1000 - 50%, 1000-2000-75%, 2000+-100%
- GoAP places significant thrust on adoption of sustainable green measures across industries in the state. Common facilities like wastewater treatment, continuous emission monitoring systems (CEMS), etc. would be setup in new APIIC industrial parks

D. Green Hydrogen Value Chain

Typical green hydrogen Value chain, from energy supply to Upstream, Midstream and Downstream.

Renewable Energy Supply: Supply of Electricity generated from Renewable sources such as Solar, Wind, Hydro etc. Either we can set up our own plants for RE supply, or we can always get energy from exchanges and other bilateral contracts such as PPAs, but to firm our electrolyzers to produce green hydrogen efficiently we can set up a new RE power plant,

Midstream (Hydrogen Distribution and Storage): Once, we have green hydrogen produced from electrolyzers, next process is its distribution and storage.

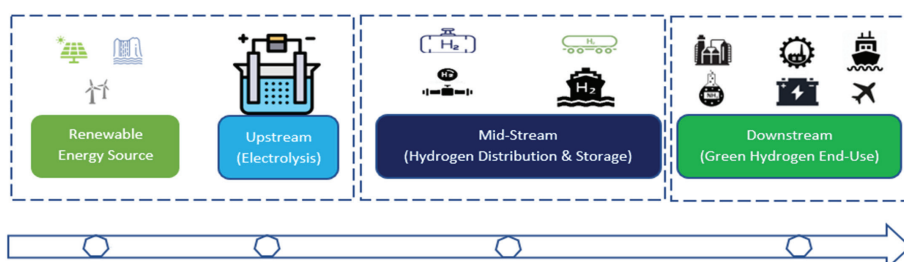
- Hydrogen Storage (Liquid, Gaseous and Solid State)
- Hydrogen Transport via Pipelines
- Hydrogen Transport via ships
- Hydrogen transport via trucks

which will have incentives and support from the government such as waivers on regulatory charges, allowance of banking provisions etc.

Upstream (Electrolysis): This is the heart of the operation, where water is split into Hydrogen and Oxygen atoms, via electricity. Currently, we have mature technologies such as Alkaline Electrolyzers commonly known as AWE, and its close but a bit pricey contender which is Proton Exchange Membrane electrolyser (PEM). Usage of electrolyzers vary depending upon, situation and requirement of location, space, RE intermittency, output pressure etc

Each of these methods, incur certain costs, For Hydrogen storage, we find various ways such as Salt and Rock Caverns and depleted gas fields and pressurized containers for gaseous state, whereas in Liquid state we can use Liquid Ammonia conversion and storage, LH2 tanks etc,

When it comes to Hydrogen Distribution, we find Pipelines being the most economical option



E. Green Hydrogen calculations and assumptions

Estimated Requirement	Unit	For 500 KTPA GH target
Electrolyser capacity	MW	4,000 – 5,000
RE installed capacity	MW	10,000 – 15,000
Transmission capacity	MVA	12,500 – 19,000
Electrolyser investment	INR crore	22,960 – 28,700
RE investment	INR crore	50,000 – 75,000
Full time job creation	Nos.	~ 6,000
DM/DI water consumption	ML/Annum	~ 4,500
Raw water consumption	ML/Annum	11,250 – 22,500

Parameter	Unit	Assumption Value
Electricity requirement for production of Hydrogen	kWh/kg of GH	53
Electrolyser availability	%	95%
Electrolyser utilization	%	65% to 75%
H2 production per 1 MW electrolyser	Ton per annum	102
CUF of RE plant	%	30%
Investment for electrolyser	USD/kW	1,000 (current); 700 (2030)
Investment for RE	INR crore/MW	6 (current); 5 (2030)
DM/DI pure water	Ltr/kg of GH	9
Raw water (multiple of x DM/DO water)	Ltr/kg of GH	2.5 to 5
Transmission capacity ²²	Per MW of RE	~1
Full time job creation ²³	Nos. per KTPA of GH	12

²² 25% additional capacity of transmission capacity requirement over RE capacity requirement considering MVA to MW and max 80% loading of transmission line

²³ Ratio is estimated from National Green Hydrogen Mission 2023 target and estimated job creation

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Contact Details:
Nishant Singh, Senior Advisor
Foreign, Commonwealth and Development Office (FCDO)
Nishant.Singh@fcdo.gov.uk

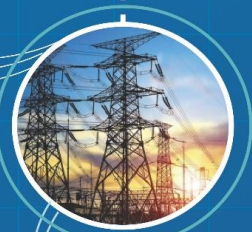
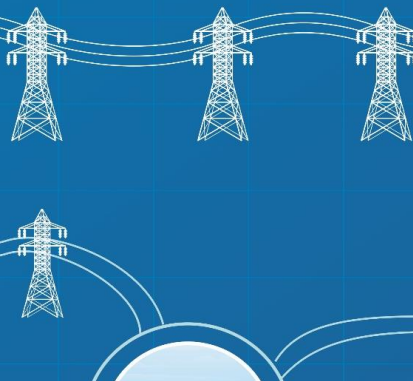


Green Electrons to Green molecules

Solar & Wind Power



Pumped Storage
Hydro Power



Power Grid



Green Hydrogen



Green Ammonia

Steel



Chemical



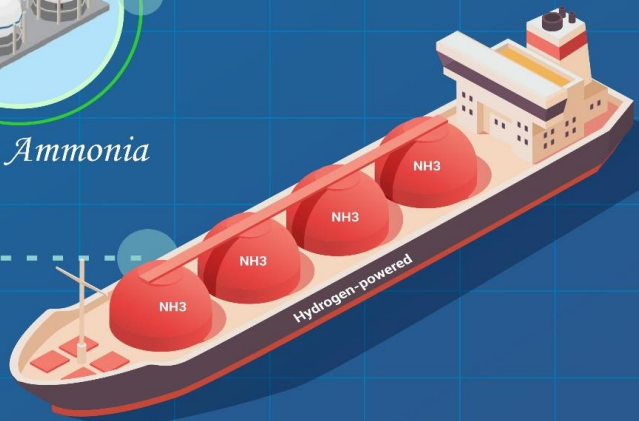
Refinerles



Transportation



Heating



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