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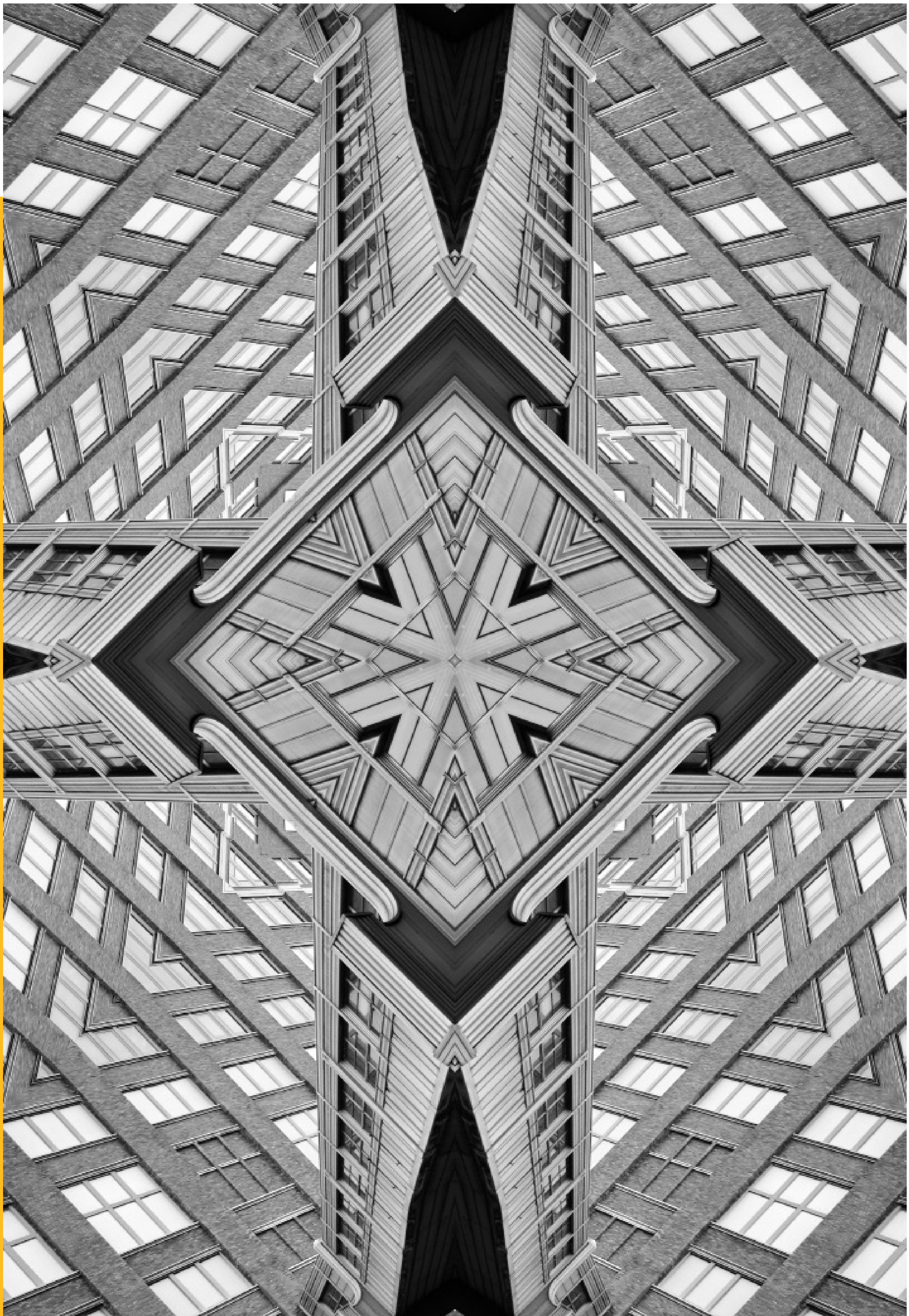
Book

Green hydrogen : an opportunity for India-Africa cooperation

OBSERVER RESEARCH FOUNDATION

Occasional Paper



ISSUE NO. 388 JANUARY 2023

Green Hydrogen: An Opportunity for India-Africa Cooperation

Apoorva Lalwani

Abstract

Although India and Africa have long shared close ties, engagement between the two regions is yet to reach its full potential. However, amid the global green transition and attempts to enhance energy security, green hydrogen—increasingly seen as the 'fuel of the future'—could provide a new avenue for cooperation between the regions. Such a partnership, focused on building a global value chain for the large-scale adoption of green hydrogen, will accrue long-term socioeconomic benefits for India and African countries.

Attribution: Apoorva Lalwani, "Green Hydrogen: An Opportunity for India-Africa Cooperation," *ORF Occasional Paper No. 388*, January 2023, Observer Research Foundation.

Introduction

Trade relations between India and Africa go back centuries, when merchants crossed the seas in search of precious metals and gemstones. A shared colonial history also saw the migration of Indian labourers to several African countries, such as Mauritius and Madagascar. Over time, trade ties have expanded substantially, with India now Africa's fourth-largest trading partner (India's total trade with Africa Africa was valued at US$68.33 billion in 2019-2020).[1] The relationship between India and the African countries was cemented in 2008 with the establishment of the India-Africa Forum Summit. While the platform initially focused on rising oil and food prices, it expanded its scope to other mutual concerns—such as health, technical assistance, and climate change—in subsequent meetings.[a]

Engaging with Africa is a key priority for the Indian government. To advance its diplomatic reach in the region, New Delhi established 18 new missions in Africa in 2019 and announced a revamp of the Indian Development and Economic Assistance Scheme (IDEAS), under which it extends lines of credit at concessional rates to other countries.[2] The previous year, in a speech to the Ugandan parliament, Indian Prime Minister Narendra Modi had outlined the 10 principles that would guide India's engagement with Africa in areas such as trade, investment, climate change, aid for development, digitalisation, agriculture, and security/terrorism.[3]

However, China's presence in Africa has derailed some of India's plans. While Beijing's approach towards Africa focuses on resource extraction and foreign direct investment (FDI) for infrastructure development, New Delhi's way is more collaborative.[4] Still, China's US$126 billion in loans and US$41 billion FDI[5] appears to hold more sway than India's US$11 billion line of credit.[6] To counterbalance China's reach in Africa and its Belt and Road Initiative, India and Japan inked the Asia-Africa Growth Corridor[b] pact with several African countries in 2017.[7]

Still, India needs to explore more avenues to advance its engagement with the African region. Amid the global turn towards sustainable and green solutions to combat and mitigate climate change impacts, India and Africa can consider

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a The last India-Africa Forum Summit was held in New Delhi in October 2015.

b The Asia-Africa Growth Corridor (AAGC) was conceived by India and Japan to counterbalance China's Belt and Road Initiative. The AAGC is based on four pillars: development and cooperation projects; quality infrastructure and institutional connectivity; enhancing capacities and skills; and people-to-people partnership.

partnering on emerging related issues, particularly energy security. Indeed, the Indian government is interested in supporting Africa's transition to green energy.[8] Given Africa's abundant natural resources and India's dominance in cost-efficient photovoltaic technology, collaborating on the adoption and expansion of green hydrogen—the "fuel of the future"[9]—is one avenue for greater cooperation between the two regions. This brief assesses the opportunities and benefits presented by green hydrogen for India and Africa.

> "Although India and Africa have long shared strong ties, there is scope for greater cooperation by partnering on the adoption and expansion of green hydrogen."

Introduction

Exploring the Potential of Green Hydrogen

Green hydrogen is the hydrogen produced from renewables-based electricity through water electrolysis (the process of splitting water into hydrogen and oxygen using electricity).[10] Currently, around 96 percent of the hydrogen used in industrial processes is produced in a carbon-intensive manner, either using natural gas (grey hydrogen) or coal (brown hydrogen).[11] As such, water electrolysis is a sustainable way of producing hydrogen and can serve as a new-age energy carrier since it is multipurpose, energy dense, can be stored in synthetic fuels, and can be transported to longer distances.[12] Green hydrogen can replace the hydrogen currently used in the chemical industry for the desulphurisation of fuels, hydrocracking, methanol production, steelmaking, and ammonia production for fertilisers and chemical feedstock.[13] It can also decarbonise hard-to-abate sectors like residential heating, cement, chemicals, and iron[14] by reducing or eliminating carbon dioxide emissions in the process of production. Over time, with technological advancements and cost efficiency, green hydrogen fuel cells can also be deployed in cars, heavy-duty vehicles, ships, and aircraft.[15]

By 2050, hydrogen is estimated to have a 10 percent share in the total global final energy consumption levels,[16] significantly rising from its current contribution of about 4 percent of final energy and non-energy use.[17] This transition will entail increasing the volume of electricity generation from renewable sources (solar, wind, and water) to produce hydrogen fuel via electrolysis, the process known as Power-to-X (P2X).[c] As renewable energy production costs decline and electrolyser efficiency—a key component in the production of green hydrogen—increases, P2X has the potential to expand, which will also enable the storage of excess power generated in the form of fuels or chemical feedstock. As such, investments in green hydrogen can help countries achieve their Sustainable Development Goals, particularly the targets related to goal 7 (access to affordable, reliable, sustainable, and modern energy for all), and generate meaningful jobs (an estimated 300 to 700 jobs for every 1 GW of P2X).[18]

However, there are two major problems with generating green hydrogen. First is the high costs. Currently, the cost of producing grey hydrogen is between US$1.5 and US$2.5 per kilogram, while the cost of producing green hydrogen is nearly triple that, between US$2.5 and US$7 per kilogram.[19] However, due to the continued reduction in the cost of renewables, higher efficiency of electrolysers, and increment in the scale of production, the cost of producing green hydrogen is expected to reduce in the future. A 2019 report estimated that the cost of producing green hydrogen using renewable energy would range from US$1 to US$2 per kilogram within the next three-and-a-half years.[20]

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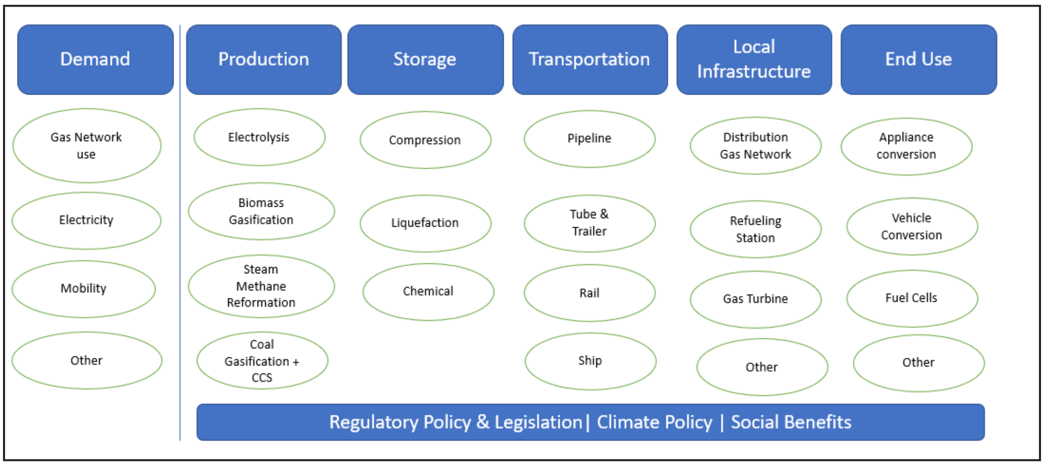
c Power-to-X, or P2X, refers to technologies that convert electricity into carbon-neutral energy carriers such as hydrogen, synthetic natural gas, and liquid fuels.

The second major roadblock in the expansion of P2X is water. Water is a key resource in the process of electrolysis. One litre of water produces one cubic metre of hydrogen. Given that fresh water is in short supply, hydrogen plants must consider adopting processes to desalinate seawater.[21]

Notably, hydrogen is a well-established industrial gas with a complex value chain involving production, storage, transportation, distribution network, and end use (see Figure 1). As such, many challenges could hinder the smooth functioning of its various stages.

Figure 1
Hydrogen Value Chain



Source: KPMG[22]

Hydrogen Value Chain and Challenges

The hydrogen value chain is complex and delicate due to the characteristics of the gas—high flammability, low density, ease of dispersion, and embrittlement—resulting in it being inundated by various challenges. The value chain is even more complex in the case of green hydrogen due to the high production costs. Leveraging the full potential of hydrogen, primarily green hydrogen, will require eliminating issues encountered during the various stages of the value chain. First, at the production level, the synthesis of green hydrogen involves the process of electrolysis. The low lifetime efficiency and high cost of electrolysers pose challenges for the large-scale commercialisation and deployment of green hydrogen plants. Second, storing hydrogen is one of the primary constraints for large-scale applications because of the element's low energy density at atmospheric pressure. Hydrogen is typically stored in three ways: compressed, liquefied, and chemical. Compressed storage of hydrogen in tanks is the simplest and most economical way to store and transport the element. But given that it is a low-density method, it requires large containers, increasing material costs. The liquefaction of hydrogen, on the other hand, increases energy density but also has higher energy costs. Finally, the chemical storage of hydrogen in the form of liquefied organic hydrogen carriers (LOHCs, like methanol and toluene) and hydrides (such as ammonia) is an emerging method due to its high energy density. However, it entails high costs of liquefaction and reconversion and must also contend with material inefficiencies for compression.[23]

Further, hydrogen can be used on-site or transported and distributed to end-user locations through pipelines, trucks, and liquified hydrogen tankers. Of these, pipelines are the least expensive method of transportation. Existing natural gas pipelines can be repurposed to transport hydrogen, enabling hydrogen blending within the existing natural gas pipeline networks. However, any concentration of over 5 percent hydrogen will affect the life of the pipeline. As such, governments and companies must consider investing in creating hydrogen-friendly pipelines. Tanker ships are used to move large volumes of liquid hydrogen, LHOCs, and ammonia over longer distances. However, this method involves added conversion costs (liquefaction or chemical conversion).[24] According to a 2016 assessment, hydrogen compression, logistics, and distribution could add between US$6 and US$10 per kilogram to the overall expenses of a hydrogen refuelling station.[25] But these costs can be lowered as the network of hydrogen refuelling stations is widened.

Hydrogen can service multiple end uses, such as the supply of electricity or heating through combined heat and power units, and power for remote or off-grid applications (such as telecom towers). Still, several challenges will need to be addressed before the large-scale expansion and commercialisation of hydrogen for end use, primarily the high overall costs (capital, operation, maintenance, and running costs), and limited user awareness and acceptance.

Why Green Hydrogen and Why Now

Hydrogen has long been recognised as an important alternative energy fuel. Countries that lacked access to coal and natural gas often turned to alkaline electrolysers to meet their energy needs. However, the limited market demand, low-cost competitiveness, lack of fuel cell technology, and non-existent enabling technologies resulted in little commercial traction for green hydrogen. Still, many countries, such as the UK, Germany, and Japan, have invested in research and developing and deploying green hydrogen.[26]

Exploring the Potential of Green Hydrogen

As the cost of renewable energy continues to decline, the production of green hydrogen is becoming more commercially viable. The deployment of fuel cells as storage for excess energy and advancements in electrolyser technology are additional factors enabling the proliferation of green hydrogen production. Also, the emergence of enabling technologies (such as drivetrains and electric vehicles) has induced the necessary demand required to further the green hydrogen landscape. Consequently, the cost is the only remaining barrier to the widespread commercialisation of green hydrogen.[27]

Integrating large amounts of variable renewable energy into local grids is a technically complex procedure. Moreover, with the increasing electricity needs, the local grids in many developing countries do not have the capacity to meet the peaks in demand. Green hydrogen provides a good storage mechanism for excess electricity produced and helps maintain sudden fluctuations and variability in power, providing more stability to the grid systems.[28]

Significantly, the current state of greenhouse gas (GHG) emissions and the urgent need for climate action have compelled countries to transition towards greener and cleaner technologies. Countries such as China, Japan and India, and the European Union are keen to transition to green hydrogen to decarbonise hard-to-abate sectors[29] (such as electricity generation, chemicals, cement, steel, and transportation) and achieve their net-zero targets. In addition to being a cleaner fuel, green hydrogen is also suitable as a storage of energy and can close the gap caused by any supply shock from solar and wind energy.[30] Also, its high energy density—it has a 3X higher energy density than diesel and 3.5X higher than that of heavy fuel oil[31]—makes it an appropriate alternative to fossil fuels. Additionally, geopolitical instabilities and volatile fuel prices have forced countries to turn to alternative avenues, including green hydrogen, to enhance their energy security.[32]

> "Green hydrogen can decarbonise hard-to-abate sectors like residential heating, cement, chemicals, and iron by reducing or eliminating carbon dioxide emissions in the process of production."

Green Hydrogen for India and Africa

With a consistent seven-percent GDP growth in recent years, political stability, and a large market, India has proven to be a dependable partner for many countries. India remains on track to become a US$5 trillion economy by 2026.[33] At the same time, Africa—with a growing middle class, rapid urbanisation, and abundant natural resources—is set to become the next big growth story in the global economy. As such, India and Africa have immense potential to collaborate, grow together, and emerge as growth frontiers of the world.

Industrialisation, growing manufacturing bases, and exports have adverse environmental and climate impacts. India is the world's third largest GHG emitter,[34] and the per capita carbon dioxide emissions of many African countries (such as Seychelles and South Africa)[35] is above the world average of 4.69 tons per person.[36] This makes both regions highly vulnerable to climate change and necessitates a sustainable energy transition.

Given these shared priorities, India and Africa have showcased a desire to partner on sustainable and green objectives. For instance, India and eight African countries[d] were among the original signatories to the International Solar Alliance (ISA),[e] reaffirming their commitment to the Paris Agreement.

Importantly, as natural gas prices rise, natural gas-based ammonia, which is used as a fertiliser, will also become expensive. This is detrimental to food security, especially for developing countries like India and those in Africa. However, green ammonia (100 percent renewable and carbon-free) can be explored as a cheaper alternative.

As such, green hydrogen is increasingly being seen as a "fuel of the future" to meet humankind's burgeoning energy needs.[37] In addition to its role in climate change mitigation and enhancing food security, green hydrogen can also assist in the post-COVID-19 global economic recovery through investment in building the required infrastructure and value chains, which will generate jobs and accrue other socioeconomic gains, such as gender inclusivity (through increased female labour force participation) and cleaner urban mobility.

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d The Democratic Republic of Congo, the Republic of Guinea, Mali, Niger, Tanzania, Ethiopia, Burkina Faso, and Madagascar.

e Forty-four of Africa's 54 countries are currently members of the International Solar Alliance.

India's Green Transition Efforts

India has made major headwinds in renewable energy in recent years, with its installed capacity growing at a compound annual growth rate of 17.33 percent.[38] India currently has a non-fossil-based installed capacity of 157.33 GW, or about 40 percent of its total electricity capacity.[39] Solar power accounts for 48.55 GW, wind for 50 GW, and hydropower for 51 GW, respectively. India also generates 6.78 GW of energy from nuclear-based installed projects.[40] At the 2021 UN Climate Change Conference, India pledged to increase its renewable energy capacity to 50 percent by 2030, with non-fossil fuel energy capacity reaching 500 GW by that year. It also committed to reducing its carbon intensity to less than 45 percent, cutting its carbon dioxide emissions by one billion tonnes by 2030, and achieving net-zero carbon emissions by 2070.[41]

In 2018, India's investments in solar energy exceeded those in coal, but the latter remains key to the country's energy supply.[42] Despite India's efforts in renewables, there is a long way to go to meet its committed targets. India requires US$500 billion in investments to achieve its renewable energy capacity targets by 2030, even as the economy remains dependent on coal and oil.[43] India's oil consumption will increase from 4.8 million barrels/day (mb/d) in 2019 to 7.2 mb/d in 2030.[44] Its demand for natural gas is also estimated to expand from 64 billion cubic meters (bcm) in 2019 to 133 bcm in 2030.[45] India is going to add 300 million vehicles of all kinds by 2040.[46] It is also highly dependent on coal and gas for electrification; it has 60 percent of installed capacity, generating 80 percent of electricity through coal and gas.[47] Given its ambitious climate targets, India must adopt an alternate fuel or technology.

Sustainable development through electrification efficiency and fuel switching can limit the growth of demand for oil to less than 1 mb/d.[48] To this end, India announced the 'Green Hydrogen Mission' in August 2021 and unveiled a policy in early 2022.[49] The mission aims to produce five million tonnes of green hydrogen by 2030 and enable renewable energy development. Under the policy, India has proposed incentives to ramp up green hydrogen production—producers will be exempted from interstate transmission charges for 25 years and will get open access to source renewable energy within 15 days of their application. Green hydrogen producers can purchase renewable energy from a power exchange platform or set up renewable energy capacity themselves or through another developer. In addition, green hydrogen/ammonia producers will be allowed to set up bunkers near ports to store green ammonia for export or use by shipping.[50]

There are multiple ongoing initiatives in India to manufacture cost-efficient electrolysers—a key component in the production of green hydrogen—to produce competitive green hydrogen.[51,52] Still, India will need to ramp up its electrolyser-production capacity to have the edge over other countries in producing viable green hydrogen and in the export of electrolysers.[53] Still, these policy and industry efforts are expected to reduce the cost of production of green hydrogen, making it scalable and competitive. In addition, increased private sector investments in this sector are critical to make India a global hub for green hydrogen.

Africa's Efforts towards Green Transition

Africa has abundant crude deposits and other natural resources, and its countries depend on natural resources for revenues.[54] In 2019, Africa's daily oil output amounted to 8.4 million barrels[55] and it generated 257.5 cubic metres of natural gas,[56] a 57-percent increase from the 1998 level. In 2020, Nigeria was the continent's largest oil producer and exporter, followed by Angola and Algeria.[57] As of 2021, Algeria is Africa's biggest gas producer and exporter, followed by Egypt and Nigeria.[58]

Africa has a young and growing population, with a median age of 19.7 years.[59] About 43 percent of the people on the continent live in urban areas, which is expected to reach 60 percent by 2050.[60] Expanding urbanisation, the growing middle class, and the region's developing economy will result in greater energy demand for food production, transportation, and other needs. Consequently, the demand for energy in Africa is increasing twice as fast as the global average.[61]

In 2015, Africa adopted 'Agenda 2063', a framework that focuses on the inclusive and sustainable development of the continent through adopting alternative technologies to fulfil its growing energy demands.[62] In 2018, the African Hydrogen Partnership—a continent-wide umbrella association dedicated to developing green hydrogen, hydrogen-based chemicals, and fuel cell technology—was established.[63]

Africa's abundant solar and wind energy supply can help bolster the continent's green hydrogen production. Europe is exploring synergies with Africa to develop a robust green hydrogen market to harness the latter's renewable energy potential and leverage gas pipelines and electricity line infrastructure between the two continents.[f] This collaboration can boost Europe's energy security while generating jobs in Africa alongside other socioeconomic benefits. The endeavour to create a common green hydrogen market will also enable both continents to accomplish their energy transition in the long run.[64] In May 2022, Hydrogen Europe, the leading hydrogen and fuel cell association for European-based companies, became the first association member of the African Hydrogen Partnership.[65]

Several African countries have already undertaken green hydrogen projects[66]:

- South Africa conducted a feasibility study in 2021 in partnership with Anglo American Platinum (a South African mining company), Bambili Energy (a South African firm that produces clean energy from hydrogen), and Engie SA (a French company that provides solutions and utilities for green transition) to establish a hydrogen valley. The study has proposed deploying hydrogen fuel technology solutions in different sectors (such as industry, construction, and transport). It has also identified three hubs and nine potential hydrogen projects across the country. With access to renewable sources such as wind and solar, and platinum metal used in the electrolyser, South Africa can achieve cost efficiency in producing and exporting green hydrogen.[67]

- Mauritania, which has one of the highest solar insolation levels[g] globally, has the potential to become one of the most cost-efficient producers and suppliers of green hydrogen, and has attracted substantial foreign investment. CWP Global, a renewable energy development company, has proposed to construct a 30 GW wind, solar, and green hydrogen plant in Mauritania's northern desert. Chariot Limited, a transitional energy group, is also developing a 10 MW green hydrogen project (Project Nour).

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f EAimed at reducing the dependence on Russian gas, Europe is accelerating and relying on intercontinental projects with Africa with the help of the existing gas pipelines between the two regions (such as the Maghreb-Europe Gas pipeline that links the Hassi R'mel field in Algeria through Morocco with Spain, and the Medgaz pipeline that links Algeria to Spain). Additionally, the upcoming Morocco-Nigeria Trans-African Gas Pipeline project, will stretch over 6,000 km and export natural gas from Nigeria to multiple landlocked West African nations and via Morocco to Europe. These existing natural gas pipelines can be made compatible to transport green hydrogen from North Africa to Europe at little cost.

g Solar insolation is the amount of solar radiation received by a planet.

- In 2021, Morocco announced the Rabat-based HEVO Ammonia Morocco project, which will have the capacity to produce 18,30,000 tons of ammonia and will reduce carbon emissions by up to 2,80,000 tons. In addition, the domestic production of hydrogen will reduce the imports of grey ammonia for phosphate production. The project is also crucial due to Morocco's geographic location with Europe.

- In 2021, Namibia conceived its first vertically integrated large-scale green hydrogen project under the Southern Corridor Development Initiative. At full-scale production, the project will produce 300,000 tons of green hydrogen from 5-6 GW of renewable generation capacity and 3 GW of electrolyser, eventually cutting about 6 million tonnes CO_2 emissions per annum. Hyphen Hydrogen Energy, a green hydrogen development company, will commence construction in 2025, with the first phase commissioned by the end of 2026.68

- Egypt plans to utilise its substantial solar and wind energy at an upcoming plant where green hydrogen will be used as raw material to produce green ammonia. The project will have a 100 MW electrolyser, producing 90,000 tons of green ammonia per year.

Despite these advances, specific bottlenecks—inadequate human, institutional, and public capital—need to be resolved to create a more attractive investment climate in Africa.[69] Africa currently faces an FDI paradox, where the region receives the lowest investment but experiences the highest return.[70] Africa accounts for only 5.2 percent of the total global FDI[71] and has received only two percent of total investments in the renewable energy sector over the past two decades.[72]

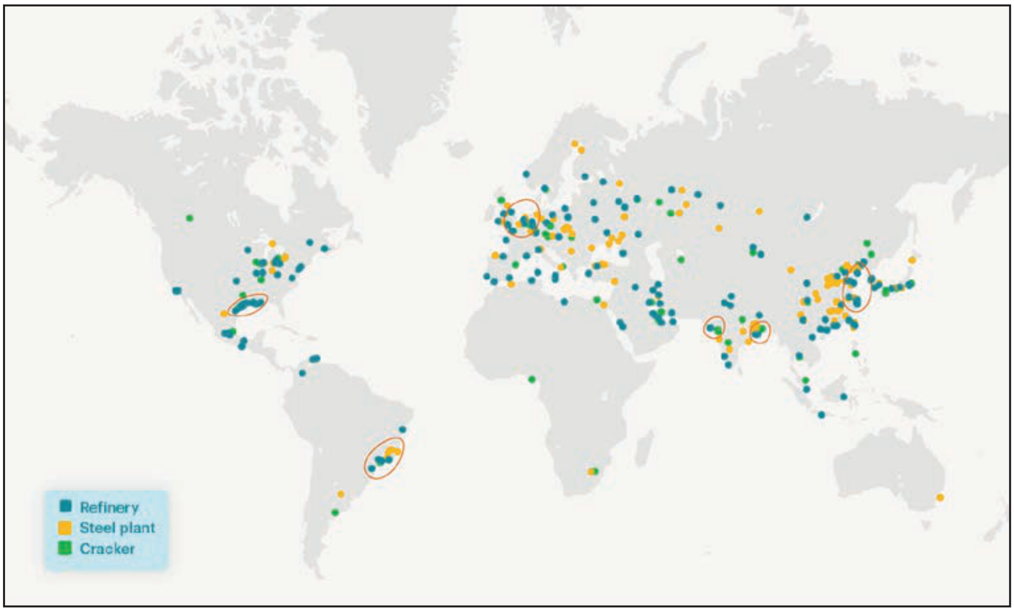
Still, the region has taken many measures to fund its green growth. For example, in 2022, the African Development Bank issued green bonds to finance eligible green projects in Africa.[73] Moreover, countries like Togo, Rwanda, Nigeria, and South Africa are enacting reforms to ease the process of doing business in their jurisdictions.[74]

The Scope for Partnership

Both India and Africa have immense potential in green hydrogen production. India can realise its vision of becoming a leader in green hydrogen by building a value chain domestically and in Africa. India can engage with Africa in multiple ways on this front, such as by developing solar power plants. Power supply is a key feedstock in producing green hydrogen, making up almost 50 percent of the system cost.[75] In this regard, India can leverage its partnership with Africa through the ISA. Forty-four African countries are members of the ISA, and India has pledged US$2 billion in concessional credit for implementing solar energy projects in Africa.[76] NTPC Limited (formerly the National Thermal Power Corporation) will oversee the development of a 500 MW solar power in Mali under the ISA.[77] India can also leverage its low-cost photovoltaic technology to help African countries unlock their capacities to generate electricity through renewables. More private sector investment can be mobilised to harness Africa's renewables potential through public-private partnerships, tender contracting, or similar instruments.

At present, the greatest demand for hydrogen is from coastal industrial clusters. As Map 1 illustrates, most existing refineries and steelmaking and chemical cracking plants (the primary takers or demand generators of hydrogen) are concentrated at the coasts.

Map 1
Global distribution of existing refining, steelmaking, and chemical cracking plants



Source: Future of Hydrogen, International Energy Association[78]

Note: Circles indicate key coastal clusters for industrial hydrogen demand

The deployment of green hydrogen P2X plants in these regions will make economic sense for two reasons: it reduces the investment cost for transmission and distribution, and the demand for hydrogen already exists in these clusters. Industrial coastal hubs armoured with green hydrogen plants can act as take-off stations for green hydrogen adoption in the transportation sector. The commercialisation of green hydrogen plants in such strategic locations will enable faster adoption and transition to fuel cell technology in vehicles like trucks, buses, ships, and aircraft. The adequate and cost-effective availability of green hydrogen will attract more players in enabling technologies, which will lower the costs of running fuel cell electric vehicles, ensure transitions at grids and distribution networks, and advance the development of refuelling infrastructure.

The long-term green hydrogen production cost in Europe is projected to be between US$3.2 and over US$4 per kilogram of hydrogen, while it is between less than US$1.6 and US$2.8 per kilogram in Africa.[79] This is why many European countries seek to partner with Africa to produce green hydrogen, utilising the existing gas pipeline network between North Africa and Europe for transportation. India can partner with African countries to develop the needed infrastructure to cater to Europe's demand for green hydrogen. For instance, India has signed a memorandum of understanding with Egypt to set up a green hydrogen plant (with an investment worth US$8 billion) in the Suez Canal Economic Zone, with an annual capacity of 20,000 tons.[80]

Further, Indian companies such as Indian Oil Corporation and ONGC, a pioneer of green hydrogen production in India, can leverage their existing positions in Africa to establish P2X plants in the region,[81,82] especially in South Africa, Morocco, Ethiopia, Djibouti, Nigeria, Ghana, Tanzania, Rwanda, Kenya, and Egypt.[83]

Furthermore, the Indian government and those of the African countries must endeavour to partner in research and development for electrolysers, fuel cells, and electric vehicles to develop more efficient and cost-effective technologies at various stages of the green hydrogen supply chain. Internationally, Germany and the UK are leading the development of the green hydrogen market. Under its green hydrogen strategy, Germany has proposed spending €7 billion (US$7.52 billion) for green hydrogen production domestically and €2 billion (US$2.15 billion) to ramp up electrolysis facilities in partner countries such as Morocco.[84] Furthermore, Indian companies have the opportunity to develop the green hydrogen value chain in North African countries under the goals of the

Indo-German Hydrogen Taskforce—strengthen cooperation to build a green hydrogen value chain, and develop joint research and development projects with necessary capital from Germany.[85] Additionally, developing and ratifying a memorandum of understanding for procuring rare metals, such as platinum (the element used in electrolyser), with platinum-rich African countries can also help reduce the overall costs. In the longer term, both regions can explore the possibilities of establishing shipping routes for the trade of green hydrogen, which will require sizeable investments. This can be met through a structured public-private partnership with some direct government funding and multistage competitions to award contracts.[86]

> In addition to its role in climate change mitigation and enhancing food security, green hydrogen can also assist in the post-COVID-19 global economic recovery through investment in building the required infrastructure and value chains, which will generate jobs and accrue other socioeconomic gains.

Conclusion

The endeavour to enhance the partnership between India and Africa in green hydrogen can enable both regions to unleash the hidden potential of their engagement. Collaborating in green hydrogen and related technologies will help them develop a global value chain in the sector. This will also enable countries in Europe and the Persian Gulf to adopt green hydrogen for the energy transition. Hydrogen is a versatile gas, and many industries can be decarbonised through the green method of its production. Moreover, as a good store of energy, hydrogen can be transported from renewable-rich countries to energy-hungry ones to enhance their energy security.

With Africa's abundant natural resources and India's cost-efficient green technology, the two regions can become global producers and exporters of green hydrogen. Such engagement between India and Africa will reap socioeconomic benefits, such as newer and more meaningful employment opportunities, cleaner air quality, reduced carbon intensity, and lesser reliance on coal and gas.

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