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AFRICA'S GREEN ENERGY REVOLUTION

Hydrogen's role in unlocking Africa's untapped renewables

A joint report by

ABU DHABI SUSTAINABILITY WEEK

Masdar
A MUBADALA COMPANY

CEO FOREWORD

With some of the world's most favorable wind and solar conditions, Africa holds enormous potential to become a renewable energy leader. At the same time, hydrogen, and green hydrogen in particular, is shaping up to be a game-changer in decarbonizing industries and driving a new clean energy future. If Africa can leverage the power of green hydrogen, it will not only realize its full potential in the clean energy economy, but it will also play an instrumental role in supporting the global energy transition.

Mohamed Jameel Al Ramahi
Chief Executive Officer

As a global clean energy powerhouse and one of the largest and fastest-growing renewable energy companies in the world, Masdar is helping to unlock this potential. Leveraging our global footprint in over 40 countries and the unique skills and expertise we have garnered over a decade and a half of pioneering clean energy; we are leading the development of renewable energy projects across Africa and around the world.

These projects span several areas of clean energy, including onshore and offshore wind and solar, waste-to-energy, battery storage, and – of course – green hydrogen. From working with leading partners in the energy and aviation space to explore the use of green hydrogen in sustainable aviation fuels, to establishing a billion-dollar strategic alliance to help drive the UAE hydrogen economy, and to developing green hydrogen electrolyser capacity in the UK, Egypt and elsewhere, Masdar is committed to investing in green hydrogen and unlocking its potential in Africa and on a global scale.

Masdar and Abu Dhabi Sustainability Week (ADSW), one of the largest sustainability events in the world, has produced this report, with analytical support provided by McKinsey & Company, entitled "How green hydrogen can unlock renewables in Africa". Released on the sidelines of COP27, this report will help bring into sharper focus the significant renewable energy opportunity that Africa possesses. It will also pave the way to ADSW and its inaugural Green Hydrogen Summit in January 2023, and COP28 in the UAE next November, where the focus on clean energy and climate action will continue.

Bringing together McKinsey & Company's unmatched analysis, Masdar's global clean energy and green hydrogen expertise, and ADSW's proven track record of facilitating high-level dialogue and climate action, this report will provide a pathway to unlock the potential of green hydrogen, not just for the benefit of Africa, but for the entire world.

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EXECUTIVE SUMMARY

Hydrogen is increasingly recognized as a critical element in the global net-zero transition. Addressing climate change is increasingly urgent, and hydrogen's role as a decarbonization vector in hard-to-abate sectors is clear. Hydrogen also plays a role in addressing concerns about energy security given the war in Ukraine as hydrogen will be critical to transport significant amounts of clean energy to energy-constrained global demand centers. Furthermore, it could play a key role in accelerating socio-economic development in Africa.

Green hydrogen tackles emissions that cannot be eliminated through direct electrification with renewables. It decarbonizes existing hydrogen applications such as ammonia production and refining, and new ones like maritime and aviation propulsion, steelmaking, and heavy-duty trucking. All these applications need a "clean molecule" if they are to phase out fossil fuels, and this molecule needs to include a hydrogen atom.

Hydrogen also plays a critical role as an energy carrier in a global decarbonized energy system. It can store large volumes of energy and transport it over long distances via pipelines and ships. This allows clean energy to flow from areas with abundant availability of wind and solar power – like Africa, the Middle East, Latin America, and Australia – to resource-constrained regions with high demand such as Europe or Asia.

Because of these advantages, governments and regulators all over the world are increasingly backing hydrogen. Forty nations have announced hydrogen strategies and launched supportive measures to encourage early hydrogen uptake. These include mechanisms like the Hydrogen Bank and IPCEI support under REPowerEU in the EU and the Inflation Reduction Act's USD 3 per kilogram (kg) production tax credit in the US.

The private sector is also increasingly investing in hydrogen as hydrogen's momentum accelerates globally. Companies and alliances have so far announced more than 700 projects amounting to about 30 million metric tons per annum (mtpa) of clean hydrogen supply by 2030. Demand for hydrogen is expected to grow more than sevenfold to approximately 610 mtpa by 2050 (up from about 80 mtpa today) in a world where most countries achieve their net-zero commitments.

Africa is strongly positioned for a clean hydrogen world

The African continent is well positioned to produce low-cost, renewable hydrogen for export and domestic use, with several regions in the Northern and Southern parts of Africa having highly favorable wind and solar resources. Ample land is available, and while many of the renewable resources on the continent were previously "stranded" and inaccessible, hydrogen and its derivatives can now help make use of them. Consequently, there is no conflict between developing renewables for hydrogen export and domestic energy access and affordability – both are possible, and green hydrogen deployment at scale can enable and accelerate domestic renewables deployment.

Domestic and international stakeholders increasingly recognize this potential, and hydrogen activity on the African continent is picking up. African countries today account for about 3% of global hydrogen project announcements. While this is still a small share of announced projects globally, more should come since announced capacity has doubled in the past year alone.

Africa could see 30 to 60 mtpa of hydrogen production by 2050, requiring investments of USD 680 to 1,300 billion

The development and ultimate size of the African hydrogen industry depend on how the energy transition unfolds. Considering two market development scenarios,[1] green hydrogen production on the continent will likely be between 30 to 60 mtpa in 2050. Of this, 20 to 40 mtpa would be for the export of pure hydrogen, ammonia, and synthetic fuels. The remainder (10 to 20 mtpa) would serve domestic demand within the industry, mobility, and power sectors. To enable this production ambition, 1,500 to 3,000 terawatt-hours (TWh) of renewable energy would be needed, equivalent to more than 50 times the current African production from solar and wind. In total, USD 680 to 1,300 billion of investment would have to flow into the region by 2050. The largest share of the investments (USD 320 to 610 billion) would go to the renewables needed to produce the hydrogen, followed by electrolysis plants (USD 115 to 220 billion). For export projects, most of the needed capital is expected to come from foreign investors.

Realizing this ambition would have significant positive socio-economic effects across the continent. A hydrogen industry producing 30 to 60 mtpa of hydrogen would likely create 1.9 to 3.7 million jobs in the African economy and have a positive gross domestic product (GDP) impact of USD 60 to 120 billion in 2050. Other socio-economic benefits include broader economic development and the electrification of African societies, the creation of a cleaner energy system, and reduced reliance on imported fossil fuels.

The focus of this report is the symbiotic relationship between hydrogen and renewables deployment on the African continent

Green hydrogen can accelerate and expand renewables deployment in Africa in three ways:

1. **Green hydrogen serves as an anchor offtake for adding renewables to the energy system.** Green hydrogen projects require the installation of renewables and thus directly increase the volumes of renewable energy deployed in a country. These projects can often connect to the grid, feeding in additional volumes of low-cost clean energy that can benefit local communities. Renewable energy capacity for hydrogen projects can in these instances consciously and cost-effectively be oversized to supply affordable clean energy to local communities, building on green hydrogen export projects as anchor offtake and making use of project economies of scale. Thus, green hydrogen exports with credible foreign offtakes lower the risk profile of renewable energy build-out on the African continent.

2. **Green hydrogen production facilities function as a grid buffer that facilitates better integration of renewables into the system.** Grid-connected green hydrogen projects help balance intermittent electricity systems because electrolyzers can act as a flexible load. For instance, when there is high demand for energy in the grid, the electrolyzer can reduce its load to lower the demand peak. Correspondingly, the electrolyzer can ramp up its production when energy supply outpaces demand. This enables the grid to integrate more volatile renewable energy.

3. **Green hydrogen projects create a renewable energy ecosystem and infrastructure that enable faster renewables deployment.** The development of renewables capacity for hydrogen production supports the creation of a qualified local workforce and streamlines access to technologies such as solar panels or wind turbines. It co-subsidizes infrastructure and opens the door to new foreign investors. All these actions will enable and encourage the further and faster construction of renewable generation capacity beyond the hydrogen sector.

1 «Current Trajectory» and «Achieved Commitments» by McKinsey Global Energy Perspective; Key assumptions detailed in Chapter 1.

Green hydrogen and its positive impact on renewables deployment and society more broadly will not happen by default

Both governments and the private sector must act to realize the full potential of green hydrogen. There are six critical unlocks that could facilitate the required investments:

1. Integrated renewables-plus-hydrogen energy vision and masterplan: To guide stakeholders, having an integrated plan for hydrogen industry development and renewables scale-up will provide an important foundation. Such a plan should consider identified synergies between hydrogen and renewables and reflect considerations such as grid capacity planning, land allocation, and the broader electrification of the economy.
2. Governance, (international) coordination, and mobilization: Large-scale renewables-plus-hydrogen projects will likely have a complex set of domestic and international stakeholders and interfaces to manage, making strong coordination mechanisms important.
3. A regulatory framework adapted to hydrogen exports at scale: To enable exports, alignment with international standards and a stable domestic regulatory framework for international investors will be crucial.
4. Infrastructure: Large-scale infrastructure investments in grid capacity, roads, port capacity, and water desalination will likely be required. Governments should consider what the private sector should fund and build themselves and where governments have a role in enabling infrastructure through co-investing or facilitating investments via public-private partnerships. (PPPs)
5. Innovation and skills: Gaining access to a highly skilled workforce in areas that may not have seen significant prior development and are likely remote will be critical. A clear talent roadmap will identify what labor is needed and how to source it. Initially, talent may need to be sourced internationally, but there should be a clear plan to build local capabilities and close potential skill gaps.
6. Project de-risking mechanisms: De-risking investments is decisive for these types of large projects that deploy relatively new technology under challenging circumstances and where the weighted average cost of capital (WACC) is a key driver of competitiveness. The attraction of credit-worthy international offtakers that can pay for hydrogen derivatives in foreign currencies will help de-risk local renewable projects. Hence, the focus of governments, donor parties, and the private sector should be on deploying a variety of instruments to help facilitate international offtake agreements and lowering investment risk.

Report objectives

This report seeks to illuminate green hydrogen's untapped potential in Africa and the positive effects it can have on local economies. It focuses on the complex interplay between renewables and hydrogen and explores how green hydrogen can positively influence renewables deployment on the African continent and ultimately improve domestic energy access and affordability. In this context, the report explores the key challenges and unlocks needed to realize green hydrogen's full potential in Africa.

The report comprises three main chapters:

Chapter 1: *The potential for green hydrogen in Africa* describes Africa's cost competitiveness and potential for domestic use of hydrogen and energy exports.

Chapter 2: *Green hydrogen's potential catalytic impact on renewables deployment* investigates how hydrogen could enable accelerated deployment of renewable energy on the continent.

Chapter 3: *Critical unlocks to realize green hydrogen's potential* explores ways to unlock the full potential of green hydrogen and renewables.

1. THE POTENTIAL FOR GREEN HYDROGEN IN AFRICA

Green hydrogen offers an opportunity for Africa to capitalize on its massive renewable energy endowment. Africa has a theoretical potential capacity of approximately 850 terawatts (TW) of solar and wind.[2] If only 2% of this, or 17 TW of renewables, were used for green hydrogen production it would produce about 900 mtpa of hydrogen, equal to about 1.5 times the total global demand of 610 mtpa in 2050.

Africa's green hydrogen could be among the world's most competitive

Africa enjoys high renewable energy capacity factors[3] ranging from 28% to 36% for solar and 26 to 51% for onshore wind, respectively. This yields a world-class levelized cost of electricity (LCOE)[4] and highly competitive hydrogen production costs that range from USD 1.8 to 2.6 per kg in 2030 (*Exhibit 1*). The cost of green hydrogen will continue to decline, reaching about 1.2 to 1.6 USD per kg in 2050 as hydrogen production technology such as electrolyzer manufacturing scales up and performance improves and renewable energy LCOEs continues to decline, driven by lower equipment costs and improved capacity factors.

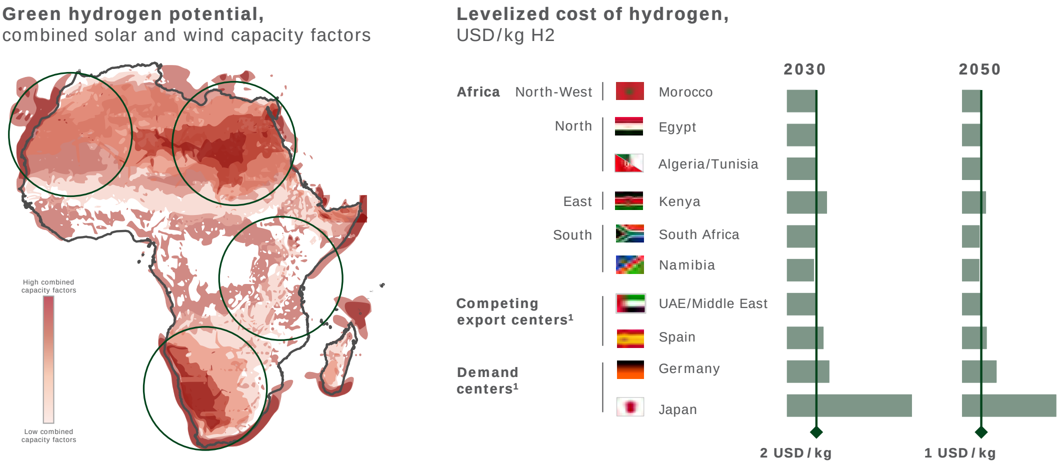
The competitiveness of green hydrogen production varies across regions, countries, and specific project sites depending on local resources, proximity to demand, and infrastructure availability. In this report, African green hydrogen competitiveness is considered through a regional lens with four regions defined. Egypt and Algeria represent Northern Africa, Kenya represents Eastern Africa, South Africa, and Namibia represent Southern Africa, and Morocco represents North-Western Africa. Green hydrogen is here defined as hydrogen produced from renewable energy through water electrolysis.

Hydrogen can enable domestic growth and energy exports

Green hydrogen has two specific pathways in Africa: one, exports to energy-constrained regions, and two, the deployment of green hydrogen for domestic consumption. To size Africa's hydrogen market, this report considered two energy transition scenarios, the *Current Trajectory* and *Achieved Commitments*, reflecting different levels of decarbonization ambition and paces of the energy transition. The Current Trajectory[5] scenario reflects a world that is about 2.4 degrees Celsius

Exhibit 1

Green hydrogen production cost competitiveness



1. Not exhaustive
Note: Cost differences based on location within the respective country, system configuration, and level of annual firmness (here 95% assumed); levelized cost of hydrogen are sensitive to assumed weighted average cost of capital
Source: McKinsey H2 Cost Optimization Model

2 IRENA - Renewable Energy Market Analysis: Africa and its Regions 2022.
3 Actual electrical energy output over a period of time (a year) divided by theoretical maximum energy.
4 Levelized cost of electricity / energy accounting for capital costs, fixed and variable operations and maintenance, and financing costs over the lifetime of the asset.
5 EUR 55 to 130 per ton carbon dioxide equivalent globally from 2030 to 2050.

warmer than pre-industrial levels by 2100 as current active policies are insufficient to significantly reduce emissions. The Achieved Commitments[6] scenario reflects global warming of about 1.7 degrees Celsius by 2100 as decarbonization frontrunners achieve their net-zero targets while followers transition at a slower pace.

In these two energy transition scenarios, the potential for green hydrogen production in Africa amounts to 30 to 60 mtpa of clean hydrogen in 2050 (*Exhibit 2*), or about 5% to 10% of the global demand for hydrogen. In 2030, clean hydrogen production could range between 2 to 4.5 mtpa across domestic and export uses, of which more than three-quarters would go to exports.

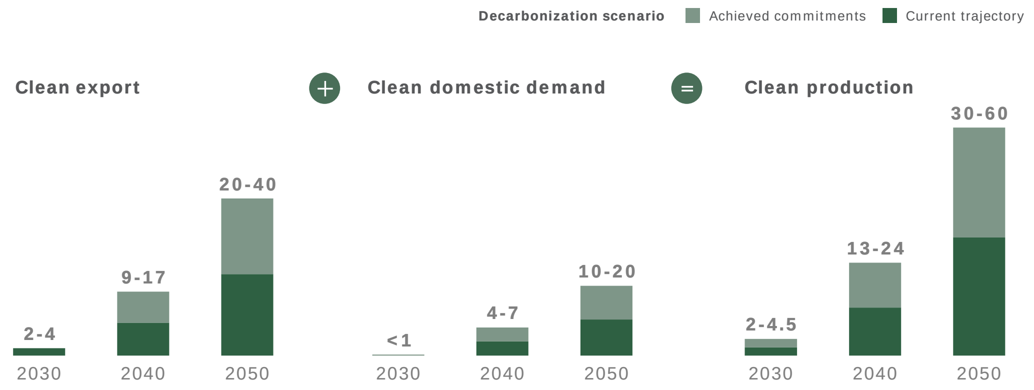
Energy exports via green hydrogen and derivatives could be 20 to 40 mtpa in 2050

Energy exports can take the form of pure green hydrogen or hydrogen derivatives. Suppliers can build an export-oriented hydrogen sector based on Africa's attractive energy profile and proximity to demand centers in Europe and Asia. Green hydrogen export volumes, including the shipment of hydrogen derivatives such as ammonia, e-methanol, and e-kerosene, along with pure hydrogen, could reach 2 to 4 mtpa in hydrogen equivalent volume[7] by 2030, targeting exports to end-users in East Asia and Continental Europe. In 2050, volumes could reach 20 to 40 mtpa in hydrogen equivalent volume. Much of this will likely take the form of pure hydrogen, reflecting expected significant pipeline exports from Northern Africa to Europe (about 50% of the export volumes in 2050). The remainder is expected to consist of shipments of hydrogen derivatives, which are exports of synthetic fuels such as e-methanol and e-kerosene (30%), and ammonia (20%).

Exhibit 2

Green hydrogen production ambition in Africa

mtpa of clean[1] hydrogen equivalent

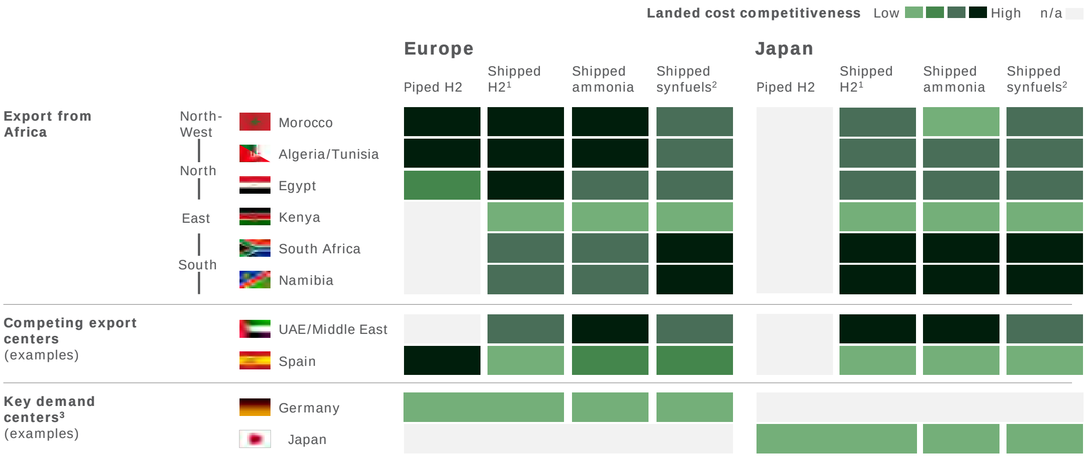


6 EUR 100 to 180 per ton carbon dioxide equivalent globally from 2030 to 2050.

7 In this report, demand and supply volumes are expressed in hydrogen volume equivalent. For instance, export volumes of ammonia are expressed by their hydrogen content tonnage rather than the tonnage of ammonia. This allows for more easily identifying total hydrogen potential and the comparative importance of each derivative in the hydrogen economy.

Exhibit 3

Landed costs competitiveness of hydrogen and derivatives export



1. Shipped H2: H2 can be shipped bound to H2 carriers (e.g., ammonia, liquid organic hydrogen carriers (LOHC), liquid H2), process includes conversion and re-conversion that can be energy intensive
2. Synfuels: Including e-methanol, e-kerosene
3. For demand centers local production costs considered

Source: Hydrogen Council, McKinsey & Company

Africa is highly competitive in hydrogen exports

The export potential will vary for different types of products and across different parts of the continent (*Exhibit 3*). Overall, Northern and Southern Africa are likely to be the most attractive locations for exports of hydrogen or its derivatives, as well as parts of North-Western Africa such as Morocco.

Northern Africa. Uniquely positioned to serve European demand centers, Northern Africa can directly supply hydrogen due to the limited distances involved (e.g., about 3,300 km from Algeria to Germany). Companies can retrofit existing natural gas export infrastructure to hydrogen pipelines (e.g., Algeria, Tunisia, and Libya). The cost of exporting hydrogen via pipelines could be as low as USD 2.2 total cost per kg landed in Northern Europe by 2030, while the cost of local European production would be higher at about USD 2.5 per kg when using attractive renewables resources, or even costlier when using less attractive resources. Although the cost differential appears limited, Europe's case for importing clean hydrogen is clear. Europe is a net energy importer today, importing about 60% of its energy,[8] and is widely expected to remain an importer. The region is unlikely to build out sufficient volumes of renewable energy to decarbonize the grid, electrify end-uses like passenger vehicles, and produce hydrogen for the industrial and mobility sectors that need it. As such, Europe will probably import more than 60% of its needed hydrogen and derivatives.

Considering hydrogen derivatives, Northern Africa is likely the best positioned to focus on ammonia exports due to the limited availability of biogenic[9] carbon dioxide (CO_2) needed to produce synthetic fuels such as e-methanol or e-kerosene, whereas ammonia only requires hydrogen and nitrogen from the air. In 2030, the landed costs of ammonia in Rotterdam would be about USD 530 per ton of ammonia versus USD 630 for a ton of locally produced equivalent.

North-Western Africa. Western Africa will probably focus on hydrogen production for local demand given that renewable resources are likely not optimal in a global context, perhaps except for Nigeria, which might be attractive for blue hydrogen production given its natural gas resources.[10] However, parts of North-Western Africa (such as Morocco or Mauritania) are competitive on a global level due to attractive solar and wind resources and proximity

8 Eurostat, 2020.
9 Biogenic CO_2 refers to sources of CO_2 that are considered carbon neutral.
10 Hydrogen produced from natural gas with carbon emissions captured and stored.

to Europe. This yields a favorable cost position to export ammonia to Europe and potentially pure hydrogen through pipelines, or even HBI[11] for green steelmaking (particularly in Mauritania, which has iron ore resources). For Morocco specifically, ammonia export may be attractive with a landed cost of about USD 530 a ton in Europe, notably lower than domestic production.

Southern Africa. While Southern Africa cannot export hydrogen through pipelines, it is nonetheless well positioned to export ammonia or synthetic fuels such as e-methanol and e-kerosene due to attractive natural resources and existing port infrastructure that can be leveraged (e.g., the port of Lüderitz in Namibia or the port of Durban in South Africa, the busiest port in Africa).

The attractive cost position of synthetic fuels for exporting results from the complementary profiles of solar and wind resources as well as the presence of industries such as pulp and paper, bioethanol production, and biomass power production that can serve as sources for biogenic CO_2. About 15 mtpa of biogenic CO_2 is available in Sub-Saharan Africa, of which about 7 mtpa is found in South Africa. In 2030, the landed cost of e-methanol for use in maritime applications in Japan could be as low as USD 680 a ton versus the USD 2,300 a ton costs for local production.

For ammonia, exports to Europe and Asia from Southern Africa share similar landed costs to those from Northern Africa. Consequently, Southern Africa could become a major exporter depending on whether the at-scale market demand for synthetic fuels or ammonia materializes first.

Eastern Africa. Eastern Africa's renewable and hydrogen cost position is less attractive than in other parts of the African continent. Although ammonia exported to Europe from Eastern Africa would cost less than domestic production in Germany, for example, other parts of Africa are likely more competitive. There could potentially be some upside from using geothermal energy resources (that Kenya, for instance, has in abundance) for clean hydrogen production. However, it remains unclear whether this energy source is sufficiently scalable beyond its current capacity. Hence, the main green hydrogen potential for East Africa likely involves displacing imported fertilizer or ammonia with domestic supply.

James Humfrey
Executive Vice President,
Growth & Industry, ADNOC

"ADNOC is committed to deepening private and public sector collaboration in clean hydrogen projects to reduce carbon emissions and the carbon intensity of the energy that we use every day."

Domestic hydrogen demand in Africa can reach 10 to 20 mtpa in 2050

Green hydrogen can also meet Africa's domestic demand for affordable clean energy and reduce the fossil fuel imports used, for example, in the production of nitrogen-based fertilizer or refined petrochemicals including fuel. It can unlock demand in end-uses like trucking, rail, and mining, and enable a competitive low-carbon export supply chain by decarbonizing mining vehicles. Furthermore, hydrogen could support the development of resilient off-grid energy systems in areas that lack stable grid connections. Although other storage technologies

11 Hot briquetted iron, a compact form of direct reduced iron (DRI) that is less reactive and easier to handle and transport, e.g., via ship.

(e.g., batteries) are often more cost-efficient, hydrogen can complement these and store energy for later use in transport, buildings, and local industries when the sun is not shining and the wind is not blowing, thus enabling a cost-efficient, self-supplied energy system.

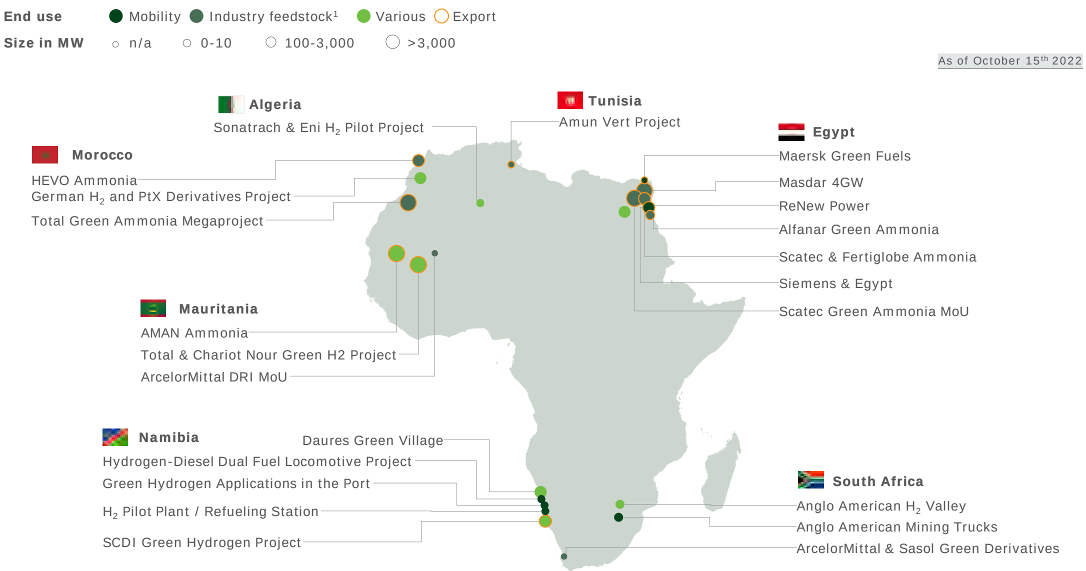
Few expect Africa to be a first mover in the domestic consumption of clean hydrogen. Yet, domestic demand on the African continent could reach about 3 mtpa of hydrogen in 2030 (including grey), growing from roughly 2 mtpa today based on the two energy scenarios employed in this report. Of the approximately 3 mtpa of domestic hydrogen demand in 2030, about 0.2 to 0.5 mtpa is expected to be green hydrogen, while the remainder will predominantly consist of grey hydrogen.[12] In these demand scenarios, growth in the coming decade would primarily result from the adoption of hydrogen-fueled heavy vehicles in ground transport (about 10% of the additional demand of up to 1 mtpa), the production of ammonia for fertilizer to substitute for imports, and other industrial uses (75%), refining (10%), and potentially, remote or backup power generation (5%). By 2050, as the green hydrogen economy reaches a higher scale and stronger cost competitiveness, demand could reach 10 to 20 mtpa (about 3% of the global market) from industry (about 50% of total demand), mobility (25%), synthetic fuels (15%), and use in power and heat (10%).

Hydrogen project momentum continues to increase in Africa

African governments and companies, international investors, and global energy companies all increasingly recognize the opportunity hydrogen represents. Project momentum has grown over the past three years with more than 20 projects across Africa[13] (*Exhibit 4*) amounting to approximately 48 gigawatts (GW) of electrolyzer capacity. More than 90% of these volumes focus on exports (mainly ammonia), with the remainder targeting domestic demand within the transport, chemical and fertilizer sectors.

Exhibit 4

Green hydrogen project announcements in Africa



23 green hydrogen projects

3% of globally announced projects

48 GW electrolysis capacity

USD 30 bn announced investment in hydrogen value chain

1. E.g., ammonia, refining, H2-DRI
Note: Only electrolysis-based hydrogen projects (excluding e.g., waste-to-hydrogen)
Source: Hydrogen project & investment tracker

12 Hydrogen produced from natural gas without carbon emission capture and storage.
13 As of October 2022.

Announcements amount to about USD 30 billion in total investments in hydrogen value chains and approximately USD 70 billion for the renewables needed to produce the hydrogen. Most hydrogen investment volumes (more than 60%) target hydrogen supply with the remainder slated to build out hydrogen infrastructure and end-use applications. Many of the investments are already in advanced development. About 15% of the volumes are undergoing feasibility or front-end engineering design (FEED) studies, while roughly 85% are in the early announcement stages.

Despite the notable volumes announced, less than 1% have reached the final investment decision (FID), are under construction, or become operational. Although low by global standards, where about 10% of announced investments have reached the FID stage or beyond,[14] projects are expected to further mature toward final investment decisions in the coming one to two years.

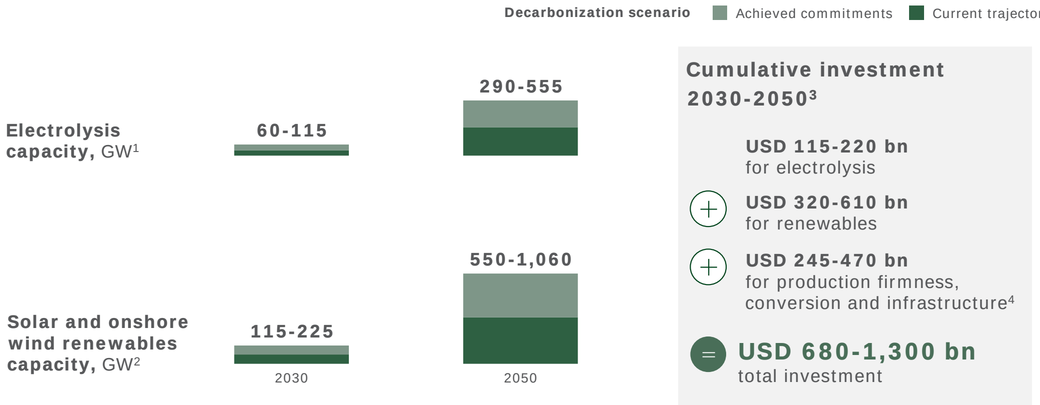
Progress continues, but more must be done

Africa's green hydrogen ecosystem is developing gradually, and momentum is growing. However, it does not yet reflect Africa's full potential. More projects targeting the supply, infrastructure, and end-use of hydrogen are needed to cement Africa as a major hydrogen economy and realize the massive potential offered by green hydrogen. Investments needed by 2050 to realize 30 to 60 mtpa production are about USD 680 to 1,300 billion in production, distribution, and export infrastructure (*Exhibit 5*). Today's project announcements only cover about 10% of the needed investment, resulting in an investment gap of about USD 580 to 1,200 billion.

The next chapter more fully explores the potential power of hydrogen to strengthen African economies and energy systems and accelerate the deployment of renewables.

Exhibit 5

Investments needed into electrolyzers and renewables capacity



1. Assuming electrolyzer load factor of 60%
2. Assuming energy supply split of 80% solar and 20% wind at average capacity factors of 30% and 40% respectively
3. Including mark ups of 20%, 15%, 15% for electrolysis, solar, and wind respectively
4. Assuming infrastructure costs to be split equally between exporting and importing parties

Source: McKinsey Global Energy Perspective, McKinsey Hydrogen Cost models, Hydrogen Council, IRENA

14 Hydrogen Council – Hydrogen Insights 2022.

2. GREEN HYDROGEN'S POTENTIAL CATALYTIC IMPACT ON RENEWABLES DEPLOYMENT

Green hydrogen links closely with the renewable energy (electricity) used in its production, as it is nothing but the product of the conversion of green electrons into molecule form. It can be stored or transported or used as a feedstock for other products such as ammonia, or directly employed as a fuel in, for instance, generators or vehicles. Hence, green hydrogen at scale requires significant investments in renewable energy.

Scaling up green hydrogen is an opportunity to accelerate the deployment of renewable energy overall on the African continent. One mtpa of green hydrogen requires about 50 TWh of clean electricity, equivalent to about 18 GW of solar and wind capacity, depending on the exact technology mix, load profile, and project design.[15] Between 1,500 to 3,000 TWh of renewable energy solely for green hydrogen production, equivalent to 0.5 to 1 TW of renewable power, is needed to produce the 30 to 60 mtpa needed by 2050. This is more than 50 times the amount of renewable energy produced from solar and wind resources on the African continent today.[16]

Green hydrogen projects show how hydrogen affects renewables deployment

Green hydrogen can accelerate and expand renewables deployment in Africa in three primary ways. First, green hydrogen serves as an **anchor offtake** for adding renewables to the energy system. Second, green hydrogen production plants function as a **grid buffer** that facilitates the better integration of renewables into the system. Third, green hydrogen projects create a **renewable energy ecosystem** that enables faster renewables deployment.

Three project archetypes can illustrate and concretize how green hydrogen could enable and accelerate renewable energy deployment (*Exhibit 6*) based on the benefits described. Each of these three project archetypes (grid-connected exports, export islands, and green hydrogen for onsite demand) brings a distinct set of benefits, and all contribute to accelerating the deployment of renewable energy in Africa. The following describes how each archetype influences renewables.

Grid-connected exports

The first archetype of the projects considered involves large-scale hydrogen projects with multiple GWs of renewables and electrolysis connected to the grid. The grid-connected export archetype seeks mainly to produce either pure hydrogen (for pipeline injection) or derivatives such as ammonia or synthetic fuels for export. The project connects to the grid for the full or partial energy volume and can draw power from the grid – or feed energy to the grid to meet local demand. Such projects may exist in export locations where there is also significant potential local energy demand, such as near Cairo in Egypt. Upgrades to the existing transmission network (e.g., higher line capacities) may be required to integrate the new energy. Foreign investors or energy companies will likely be involved as owners and developers, working closely with local stakeholders such as transmission system operators (TSOs), port authorities, and government entities to ensure the project is well integrated with the local economy and energy system.

These projects have the broadest set of benefits due to their significant direct impact on the electricity grid, and lay the foundation for a broader renewable energy ecosystem:

Anchor offtake. Large volumes of renewable energy are directly enabled as part of projects involving hydrogen for export. These projects are underpinned by certain offtake agreements with a credible counterparty that reduces risk, lowers financing costs, and results in more affordable energy. Without solid offtake arrangements, these projects would not be realized,

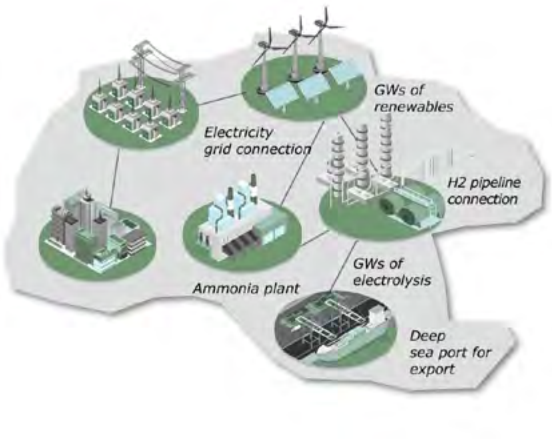
15 Project design refers to, for instance, the sizing of an electrolyzer versus renewables (which will depend on the end-use requirements such as plant uptime), solar irradiance and wind resources, infrastructure choice such as pipeline or electricity transmission line, and the usage of storage in the forms of hydrogen, batteries, or other options.

16 IRENA Data and Statistcis; 11.4 GW solar (17 TWh generated in 2020) and 7.3 GW wind (11 TWh generated in 2020) installed in Africa as of 2021.

Exhibit 6

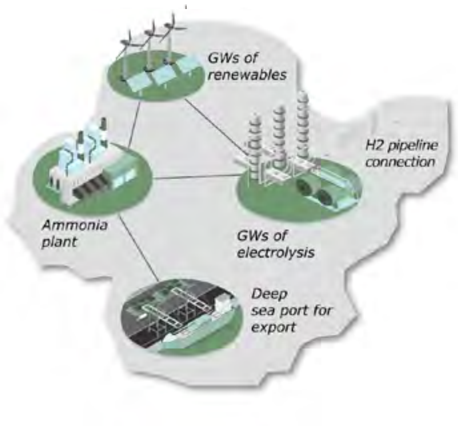
Green hydrogen project archetypes

Grid-connected export project



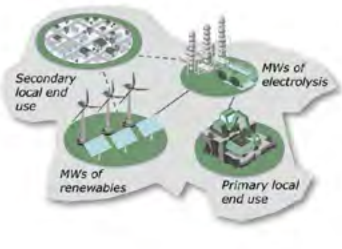
Infrastructure connection	Full/partial grid connection, hydrogen pipeline connection possible
Project size	RES and electrolysis capacity in GWs
Production focus	Pure hydrogen, derivatives (e.g., ammonia, synfuels)
Target use	Export (primary), local use (secondary)
Involved stakeholders	Investors (foreign), transmission system operators (local), government entities (local/foreign)

Export island project



Infrastructure connection	No grid connection, hydrogen pipeline connection possible
Project size	RES and electrolysis capacity in GWs
Production focus	Pure hydrogen, derivatives (e.g., ammonia, synfuels)
Target use	Export
Involved stakeholders	Investors (foreign) government entities (local/foreign)

Green H2 for onsite demand



Infrastructure connection	Isolated
Project size	RES and electrolysis capacity in MWs
Production focus	Pure hydrogen
Target use	Local ecosystem demand (e.g., energy storage, fuel, industrial feedstock)
Involved stakeholders	Private sector (local or foreign), government entities (local)

Martin Nagell
Advisor, Office of the CEO, Masdar

"I think the most exciting element relating to Hydrogen in Africa is that it decouples local production from consumption of renewable energy. That creates new opportunities for projects in emerging markets, independent of local offtake risk, sovereign risk and regulatory condition. A real game changer for renewables."

and with no demand for green hydrogen, the renewable power plants would not ramp up, either. The grid-connected renewables used for green hydrogen production can also feed energy into the grid to provide affordable clean energy to areas that may be underdeveloped (notably, Sub-Saharan Africa has an average electrification rate of only 48%[17]). For instance, a solar-powered green hydrogen project of 2 GW of solar power and 1 GW of electrolysis could have up to 1.8 TWh of curtailed low-cost power a year that it could feed directly into the grid. The amount of power available for the grid can be increased by intentionally overbuilding the renewables further, which should come at a 10% to 30% lower cost per unit of energy than distributed generation due to economies of scale.

Grid buffering. The integration of flexible green hydrogen loads facilitates a more resilient grid that can absorb higher renewable energy volumes. Because electrolyzers can operate at full or partial load depending on the available energy and its cost, they can lower demand peaks by reducing the load or they can consume additional energy and lift demand troughs. A grid with a flatter and more stable load is more flexible and can absorb more renewable energy.

Export islands

The second archetype, export island, is like the grid-connected export archetype in terms of size and end use. However, these projects are fully isolated energy islands that make use of stranded renewable resources for energy export without developing any physical connection to the overall domestic energy system or grid. Project developers and owners are typically predominantly foreign, and the involvement of local stakeholders may be less than for grid-connected export projects given the lower system integration complexity. Such projects may occur in remote desert locations, for instance in Southern Namibia away from large local cities.

These projects have similar positive effects to the grid-connected exports archetype, introducing large renewables volumes anchored on green hydrogen offtake. Although they provide no direct benefits to the electricity grid such as buffering or feeding in additional energy, they contribute to adding renewable energy production plants on the African continent:

Anchor offtake. Export projects in areas with no electricity grid could develop attractive energy resources that would otherwise not have been developed due either to unfeasibility or the high costs associated with capturing the electrons via a transmission line. Green hydrogen can be a cost-efficient carrier and monetize these stranded renewable resources by ensuring demand is met in energy-constrained regions. The standalone energy system developed by such a project could connect to the grid (or even to other projects) at a later stage, gradually moving toward an integrated energy system. Furthermore, connections could be built to supply nearby communities with low-cost electricity, and thus have a direct positive impact on local communities.

17 World Bank, World Development Indicator

Green hydrogen for onsite demand

The final archetype of projects targets small- or mid-scale local demand in areas with no grid or a weak grid, supplying a local ecosystem (e.g., a small city, industrial cluster, or a metals mine). A concrete example could be a South African platinum mine, for instance. The renewables and hydrogen produced can have several uses. Examples include hydrogen for energy storage or fuel for generators or vehicles, while renewables could provide heating or lighting, or power home appliances. These projects will likely vary from a few megawatts (MW) to tens of MW.

These distributed projects are different from export-oriented efforts when considering scale, type of demand, investor type, and the enabling impact on renewables deployment. They are likely easier to realize on the back of the renewable energy ecosystem created by large-scale export projects. This is in line with green hydrogen demand projections for Africa; export leads the way and domestic demand follows. If realized, these projects can have significant local benefits:

Anchor offtake. Demand for green hydrogen strengthens the case for distributed electrification. In areas with latent demand for electricity for lighting, cooling, heating, cooking, and other uses, demand may not be sufficient to enable a solid business case for investors. By introducing hydrogen as a new demand outlet for renewable electricity (e.g., as fuel for mining trucks), the overall scale of demand for electricity increases while the risk declines due to demand diversification. This increases the likelihood of the development of an off-grid system. For example, without hydrogen, mines may continue using diesel for their trucks. With hydrogen, miners can produce clean fuel that powers the trucks, eliminates diesel, and reduces scope 2 emissions.[18]

Grid buffering. Hydrogen can act as a buffer in a distributed local system like a mini-grid. Green hydrogen can align energy supply and demand, making it possible for users to store the hydrogen for later use (e.g., overnight when the sun is not shining). Although users could consider other technologies such as batteries for this purpose, hydrogen can play a role in a system built solely on volatile renewable energy by making the energy available when needed.

Cross-cutting ecosystem benefits

Hydrogen projects will also have four types of ecosystem benefits that will indirectly encourage further domestic deployment of renewables:

Technology access. New value chains will take root on the continent. Deploying GWs of renewables and electrolyzers relies on access to required technologies like solar panels, wind turbines, and electrolyzers, as well as a multitude of other components including electronics, compressors, and storage tanks. This is only possible by producing some components locally or importing them from global technology hubs and handling potential hurdles such as import duties, different technological standards, or a simple lack of relevant regulation. Initial projects need to overcome these challenges, ultimately laying the foundation for further renewables deployment.

Workforce. A renewables-savvy workforce will require training. Green hydrogen projects intended for exports can serve as the catalyst. Constructing a green ammonia export project with 2 GW electrolysis and 4 GW renewables, of which about 60% focus on the renewables, will create about 43,000 jobs. In total, an estimated 1.9 to 3.7 million jobs are needed to build and operate the 30 to 60 mtpa of green hydrogen production in Africa in 2050. Companies can readily build on these resources and capabilities to further develop more renewables for direct electrification. For instance, large-scale hydrogen projects will allow for the incubation of new engineering, procurement, and construction (EPC) companies with renewable energy capabilities, which can then tackle other local renewable projects.

18 Indirect greenhouse gas emissions associated with the purchase of electricity, steam, heat, or cooling

Infrastructure. Most situations will require new infrastructure to enable hydrogen projects. Many of these plants are likely to be in underdeveloped areas and will need newly built infrastructure to get projects off the ground. Furthermore, large-scale export projects can co-subsidize required infrastructure. For instance, workers will need roads to access the project site, which might require new transmission grid capacity, along with ports and terminals to ship products such as ammonia or synthetic fuels and to import wind turbines. All this infrastructure can be a stepping stone for the further deployment of renewables, not only for export but also for potential local electrification and industrialization.

Investor access. Most current announced projects rely on foreign investors. These range from renewables developers, technology providers, and private investment funds, to institutional investors. Some have a history of conducting business on the African continent, but many have limited experience operating in Africa. For these investors, a green hydrogen project can serve as a first entry point, which lays the foundation for future development on the continent and in sectors beyond green hydrogen, including renewables investment.

As shown, green hydrogen closely intertwines with renewables and can help unlock and accelerate them on the African continent in different ways for each archetype *(Exhibit 7)*. However, there are misconceptions about building out hydrogen in Africa and its impact on renewables deployment. Particularly, the perception that focusing resources and renewables development on energy exports via hydrogen is detrimental to domestic development is prevalent. In such a view, energy exports to affluent countries in Europe and Asia could divert focus from the development and electrification of African societies. This is only true if the underlying belief is that it is impossible to do both; that is, companies can only deploy renewable energy either for green hydrogen exports or for domestic use. This is likely incorrect: hydrogen can serve as a springboard for accelerated renewables deployment, and energy, land, and water resources are abundant, as well as sufficient capital globally, to allow for these projects at scale. Green hydrogen at scale means a renewable energy ecosystem must be in place, and this ecosystem will naturally enable further deployment of renewables for direct domestic use.

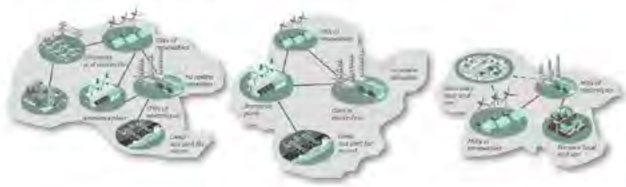
Consequently, green hydrogen can act as a catalyst for renewables deployment and will likely have a broader set of socio-economic benefits such as job creation, GDP growth, and affordable electrification. However, this potential will not come about by default, as explored in the next chapter.

Exhibit 7

Green hydrogen benefits on renewables deployment

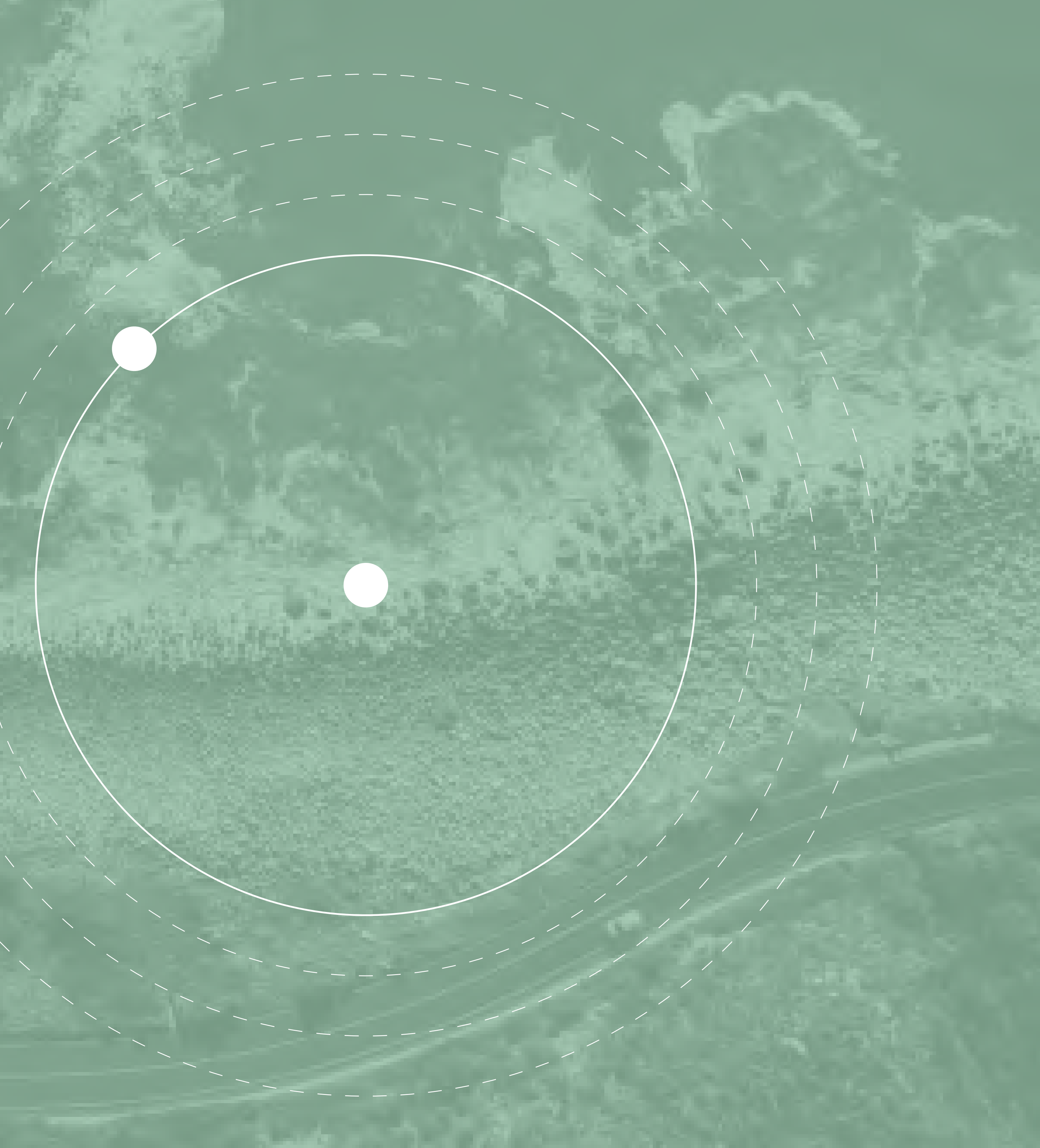
Impact assessment ● Project type with high impact ◌ Project type with partial impact

Large scale export



Impact type	Role of H_2	Impact on renewables deployment	Grid-connected export	Export island	Green H2 for onsite demand
1 **Drive buildout of RES**	Anchor off-take for RES	Increases RES scale, de-risks projects and helps decreasing average system energy costs	●	●	◌ *Given no grid connection available*
2 **Facilitate integration of more RES in the system**	Buffer for grid balancing	Promotes installation of additional RES capacity	●		◌ *Mini grid*
3 **Enable RES ecosystem**	Enabler for RES ecosystem	Facilitates deployment by enabling (a) technology access (b) workforce development (c) infrastructure buildout (d) investor access	●	●	◌

3. CRITICAL UNLOCKS TO REALIZE GREEN HYDROGEN'S POTENTIAL



While green hydrogen can positively influence the deployment of renewable energy on the African continent, stakeholders must overcome challenges, some of which specific local conditions may exacerbate. Realizing the renewables-plus-green hydrogen production ambition of 2 to 4.5 mtpa in 2030 and 30 to 60 mtpa in 2050 will require significant investments in hydrogen production plants, infrastructure development, and workforce training. Yet, stakeholders must overcome several potential challenges.

Common challenges include (1) a **lack of clarity** regarding national hydrogen visions and planning, which can make it difficult to make informed country-level investment decisions. (2) **Insufficient alignment** and coordination among the high number of stakeholders involved locally as well as internationally for export-oriented projects can cause friction and confusion. (3) **A lack of regulatory certainty** can reduce the "invest-ability" of projects by making returns more uncertain. (4) **Insufficient infrastructure** such as service roads, transmission lines, and port facilities may be a concern, as it is needed to enable giga-scale infrastructure projects in remote areas. (5) Certain **capability prerequisites** for installation and operation may also be lacking, such as an on-the-ground supply chain presence or a workforce with the required training and experience. Finally, (6) large-scale hydrogen projects like these may involve **high investment risks** that require mitigation, such as notably higher financing costs and WACC than in other geographies.

Six enablers can help

While resources are finite and many governments on the continent face budget constraints, a clear set of efficient enablers can accelerate the uptake of renewables-plus-hydrogen on the African continent in a resource-efficient way:

7. Integrated renewables-plus-hydrogen energy vision and master plan

To instill confidence among investors, countries need a clear renewables-plus-hydrogen roadmap that sets out clear ambitions and milestones. Hydrogen roadmaps often focus purely on hydrogen, but nations need a more comprehensive integrated energy plan to integrate hydrogen effectively and reap its benefits for the energy ecosystem. Such a plan should consider total energy demand, access, and affordability for residents and energy exporters, and use those elements to build a vision for the required renewable energy and hydrogen. The plan should take into consideration the current grid capacity and identify the critical (future) bottlenecks as priority areas to expand. It should provide a geographic plan for where these large-scale renewables-plus-hydrogen projects should be located. Ideally, the master plan would also stipulate where it makes sense to overbuild renewables capacity to serve local demand in addition to hydrogen production demand.

8. Governance, (international) coordination, and mobilization

The success of a typical large-scale renewables-plus-hydrogen project requires the involvement of a complex set of stakeholders, ranging from state-owned enterprises (SOEs) and TSOs to different industry bodies, port authorities, as well as international offtakers and developers. Governments should consider an internal coordination mechanism, like a specialized delivery unit, to ensure coordination and track delivery across these numerous stakeholders. In addition, there is a larger need for international orchestration and mobilization than in typical renewable projects. Stakeholders can consider several mechanisms to coordinate and attract international investors, for instance:

- **Investor roadshows:** Countries like Chile have shown that international roadshows to attract local hydrogen investments can be an effective tool to unlock investor interest. To be effective, a public/private delegation can meet a variety of foreign public and private sector stakeholders in priority trade partner countries to pique investor interest.

- **Tenders:** Tenders are important tools to formalize expressions of interest in local renewables-plus-hydrogen investments. Given the potential benefits of hydrogen projects on renewables deployment as discussed in the previous chapter, there are three evaluation criteria that stakeholders should consider for such tenders. First, the benefits of adding renewable capacity to local systems, including the intention to overbuild renewable capacity to supply additional affordable power to local communities and industries. Second, the contribution to the overall energy balance of the country, including plans to address intermittency from renewables expansion. And third, local content, employment, and partnership requirements will ensure that the country develops the capabilities required to further expand the renewable ecosystem locally. Simultaneously, ensuring that such localization requirements do not excessively increase complexity for investors is important; countries will need to balance between the two objectives of improving local value and not setting too stringent requirements for investors.

Siddhartha Sativada
Director Corporate Strategy, Generation, TAQA

"With the right kind of institutional framework, and support from international stakeholders, Green Hydrogen could be a game changer for Africa in the global energy space. It has the potential to create jobs and enable local industry clusters, thereby aiding the overall socio-economic upliftment."

9. Regulatory framework adapted to hydrogen exports at scale

Regulation should be predictable and enable the creation of effective business case planning. This includes having predictable tax regimes and contractual certainty presided over by effective courts and institutions, but there are also specific regulatory considerations for large-scale renewables-plus-hydrogen projects:

- Ensuring conformity with international green hydrogen standards so that importers from places like the EU can claim full decarbonization impact. This could include setting standards such as lifecycle carbon content thresholds in line with the EU.
- Effective treatment of transmission and distribution fees for hydrogen producers. For instance, if hydrogen serves as an ancillary balancing service for the grid, regulators may waive these fees.
- Clear and transparent access to land and permitting processes for renewables-plus-hydrogen that ensure both investors and local populations receive fair treatment and compensation.
- Compensation mechanisms for overbuilding renewable energy in a specific area, for instance, through offtake contracts for power.

10. Infrastructure

The production and shipping of hydrogen and derivatives will require significant amounts of new infrastructure. This includes ports for exports, pipelines for hydrogen transmission, water desalination plants, grid expansion, and roads in large swathes of newly developed land for renewable resources. While it is unlikely that government finances will allow countries to make all these infrastructure investments from public funds, nations should engage in a strategic discussion on how such investments can be enabled and which assets governments should (co-) invest in to attract investments. For example, if the grid is public, then either a regulatory exception could exist for private investments in additional transmission capacity, or funds could be publicly invested through an adjusted transmission grid fee for the hydrogen project developer using the connection. Similarly, for access and service roads, one could imagine a PPP structure where private investors contribute capital, but the roads remain open to the public for usage.

11. Innovation and skills

The envisioned GW-scale renewables-plus-hydrogen projects will require a skilled workforce to develop and build in remote locations that are traditionally devoid of infrastructure. These projects are by nature more complex than single renewable projects as they require the integrated development of wind, solar, and hydrogen production, the conversion of hydrogen derivatives, grid expansions, and other project infrastructure, along with export facilities such as terminals and ports. This requires integrated EPC capabilities that go beyond what is typically on the local market today. Insourcing this and building local capabilities will be critical to the success of renewables and hydrogen in Africa. Some geography-specific innovations relevant to these kinds of projects could be beneficial. For instance, to deploy the technology efficiently, the standardization and modularization of components may be necessary to make installation more efficient in remote areas with limited access to infrastructure.

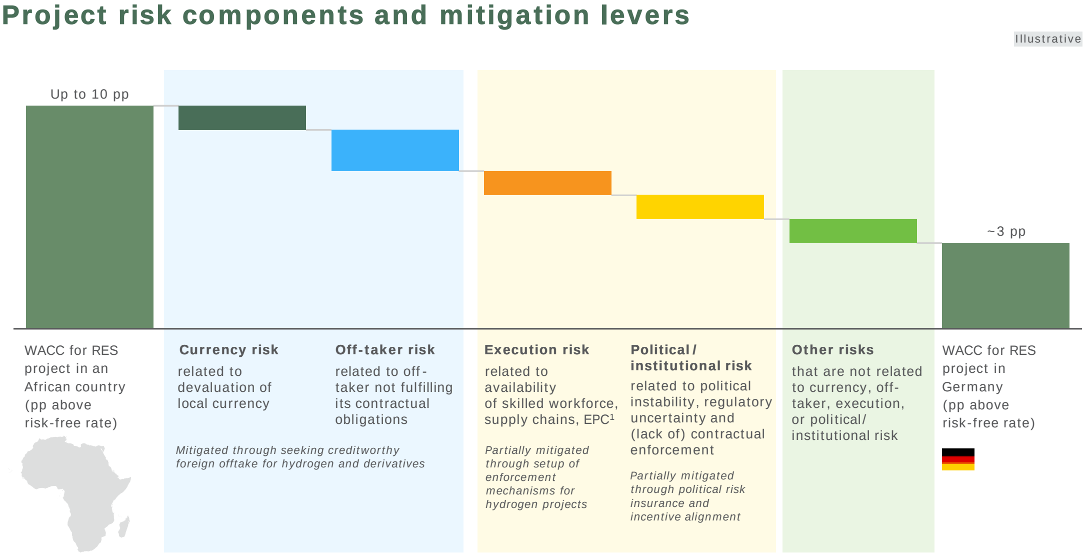
12. Project de-risking mechanisms

Large-scale hydrogen projects in African countries may be high-risk for investors (*Exhibit 8*), and de-risking mechanisms should be used to reduce risk exposure. Green hydrogen export projects with a solid foreign offtake counterparty can act as anchor offtakes for large renewables volumes, thereby reducing the risk for investors. For example, a German solar PV project may have a WACC that is 3 percentage points (pp) above the risk-free rate, whereas a solar PV plant in an African country may have a WACC that is up to 10 pp above the risk-free rate in some cases. This differential is typical for renewable projects in developed versus developing countries and can be significantly reduced for projects that combine renewables with green hydrogen. Two key levers contribute to this risk reduction. One, reducing currency risk by onboarding a foreign offtaker that pays in foreign currency such as USD or EUR, and two, reducing offtake risk by trading with a credible, credit-worthy foreign offtaker rather than a local counterparty in a power purchase agreement (PPA).

One of the most critical parts of de-risking projects involves finding trustworthy international counterparties. Governments can play a role in this through the aforementioned "hydrogen diplomacy."

Exhibit 8

Project risk components and mitigation levers



1. Engineering, Procurement, and Construction
Source: Steffen, B., 2020. Estimating the cost of capital for renewable energy projects

In addition to investor roadshows and tenders, governments can indicate readiness for international investments by providing special status to large-scale renewables-plus-hydrogen projects by streamlining import and export duties and processes, for instance, as well as establishing an investment office or "one-stop-shop" to facilitate permitting and construction on the ground.

Other risks like project execution risk and political or institutional risks can also be mitigated to an extent. This involves a combination of the enablers described above on infrastructure build-out and workforce training, through involving local entities such as state-owned companies and aligning incentives through onboarding them as project equity partners, involving strategic partners with relevant experience and high credibility, as well as measures such as insurance policies.

* * *

As this report shows, significant potential exists regarding the production of green hydrogen and its derivatives on the African continent, potentially reaching 30 to 60 mtpa by 2050, representing 5% to 10% of global hydrogen production. This will enable the uptake of renewable energy in Africa by directly increasing demand for renewable energy, acting as a buffer in the energy system, and building out the ecosystem required for further investments into renewables. The conditions are ripe for a hydrogen-fueled renewable revolution on the African continent – it is now up to the local public and private sector, development partners, and international investors to unlock this opportunity, and the above provides concrete suggestions on potential

HOW GREEN HYDROGEN CAN UNLOCK RENEWABLES IN AFRICA

By Dr. Faye Al Hersh, Technology Specialist, Strategy, Masdar

Africa is emerging as a potential major hub for cost-competitive green hydrogen production. With the continent's abundant space, easy access to key trading routes, plentiful renewable energy resources, and growing government support, Africa is well positioned to become a global source of low-cost renewable electricity derived hydrogen.

While African countries today account for only around 3 percent of global hydrogen project announcements, the continent's announced capacity has doubled in the past year alone. We have estimated that Africa could produce 30 to 60 million tonnes per annum (mtpa) of green hydrogen by 2050, of which 20 to 40 million tonnes would be exported as pure hydrogen, ammonia, and synthetic fuels, and the rest would be used domestically.

Such a significant amount of green hydrogen production will require robust investments, ranging from US$680 billion to 1,300 billion. But the benefits from such investments would be massive, as 1.9 million to 3.7 million jobs are estimated to be created in the African economy thanks to the emerging hydrogen production, leading to valuable GDP impact of the order of US$60 billion to 120 billion in 2050. Other socio-economic advantages to Africa's green hydrogen investment include broader economic development and the electrification of rural African communities, the establishment of a cleaner energy system, and reduced dependency on imported fossil fuels.

To capitalize on these multifaceted green hydrogen sector benefits, extensive investments and groundwork will need to be secured. Masdar, as one of the world's leading renewable energy companies, is at the forefront of being a part of Africa's green hydrogen sector development, as we are aiming to be a global leader in green hydrogen. Masdar has already announced a 4-gigawatt (GW) green hydrogen project in Egypt, while other project developers, technology providers and investors have also expressed interest in locating production facilities across the continent. Such interest includes further developing existing transport infrastructure to connect to export markets and setting up new transport infrastructure to move large volumes of green hydrogen and derivatives.

These new value chains will require solar panels, wind turbines, and electrolyzers, to be able to produce the green molecules. New ports and storage facilities as well as pipelines for hydrogen transmission will be essential for exports, water desalination plants will need to provide water for electrolysis, grids will need to be expanded, and road infrastructure in large swathes of newly-developed land will be necessary to tap into renewable energy resources. Finally, a skilled workforce will be required to develop, build and operate these infrastructure assets.

Although several green hydrogen projects have already been announced in Africa, most, like Masdar's project in Egypt, are located in North Africa, as that region is well positioned to serve European demand centers.

In April 2022 Masdar announced the planned development of green hydrogen production plants in the Suez Canal Economic Zone and on the Mediterranean coast of Egypt. Targeting the bunkering market and export to Europe, it looks to reach 4 GW electrolyzer capacity by 2030, with 480,000 tonnes of green hydrogen produced per year. Other African regions and countries also hold the potential to play a role in the continent's green hydrogen sector, namely Kenya in the east, South Africa and Namibia in the south, and Morocco in the northwest.

Among the green hydrogen derivatives, ammonia holds much potential to be exported from Eastern Africa to Europe, as it would cost less than domestically produced green hydrogen from Germany. Kenya also boasts abundant geothermal energy resources for clean hydrogen production, while Southern Africa is well positioned to export ammonia or hydrogen-derived synthetic fuels, such as e-methanol and e-kerosene, thanks to attractive natural resources and existing port infrastructure that can be leveraged in Namibia and South Africa. In addition, we have found that ammonia exports to Europe and Asia from Southern Africa share similar landed costs as those from Northern Africa, revealing the possibility of Southern Africa to become a major ammonia exporter.

Moreover, as unveiled in this report, synthetic fuels are also well positioned to be attractive exports from Africa, due to the complementary profiles of solar and wind resources and the presence of industries like pulp and paper, bioethanol, and biomass power, which can produce the biogenic CO2 (or carbon neutral carbon dioxide) needed for synthetic fuels production. Around 15 mtpa of biogenic CO2 is available in Sub-Saharan Africa, of which about 7 mtpa is found in South Africa. As such, the landed costs of e-methanol for maritime use in Japan, for instance, could be as low as US$680 per tonne versus the US$2,300 per tonne cost for local production in 2030.

Green hydrogen export volumes from Africa, including the shipment of hydrogen derivatives such as ammonia, e-methanol, and e-kerosene, along with pure hydrogen, could reach 2 to 4 mtpa in hydrogen equivalent volume by 2030, targeting export to end-users in East Asia and Continental Europe. As we detailed in this report, by 2050, volumes could reach 20 to 40 mtpa in hydrogen equivalent volume, which reflects expected significant pipeline exports from Northern Africa to Europe.

Ultimately, the deployment of green hydrogen projects is set to accelerate and expand the distribution of renewable energy, further stabilizing Africa's grid and developing its infrastructure. Serving as an anchor offtake for adding renewables to the energy system, green hydrogen also holds the potential of creating a robust renewable energy ecosystem, while functioning as a grid buffer that improves the integration of renewables into the system. Within that realm, Masdar has extensive experience in developing renewable energy projects globally, as well as exploring green hydrogen, sustainable aviation fuel, and green ammonia, as part of efforts to drive to the net-zero carbon by 2050 commitments. Masdar's keen interest in Africa has led to plans to significantly grow its pipeline in the continent, with green hydrogen acting as a potential enabler.

Reaching Africa's full potential as a key hub for cost-competitive production of green hydrogen and derivatives, as well as accessing all of the resulting economic and developmental benefits, will require attracting more capital and developers like Masdar. Beyond that, the development of an integrated renewable energy and hydrogen masterplan and national energy strategy is essential to guide these stakeholders. This can help ensure that the necessary infrastructure and regulatory frameworks are put in place to ensure that the green hydrogen and derivatives produced in Africa meet the requirements and standards in key import markets. With global attention on Africa as part of COP27 and the nearing deadline for the 1.5C by 2025 target, now is the time for action to unlock Africa's green hydrogen potential.

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MASDAR GREEN HYDROGEN OVERVIEW

Since its inception in 2006, Masdar has played a significant role in establishing the UAE's leadership position in the clean energy sector. More recently, it has been collaborating with other energy giants and governments to drive the development of green hydrogen as a future energy source that can help deliver economic and environmental goals.

Masdar has actually been exploring hydrogen production and power generation as far back as 2008, although those early efforts were arguably premature. With experts estimating green hydrogen to have a total market potential of US$11 trillion by 2050, Masdar believes the time is right to accelerate investment in this technology, to advance the sector in support of the UAE's economic diversification and the global clean energy transition.

A new strategic partnership, announced in late 2021, will also better position Masdar to become a global green hydrogen leader. The Abu Dhabi National Energy Company PJSC (TAQA), Mubadala Investment Company, and ADNOC will partner under the Masdar brand to create a truly global clean-energy powerhouse that will spearhead the country's 'Net Zero by 2050' energy transition while cementing the UAE's role as a global leader of the green hydrogen economy.

Among Masdar's multibillion-dollar clean energy investments is a major collaboration to produce green hydrogen and related sustainable synthetic fuels in Abu Dhabi, called Project Green Falcon.

During Abu Dhabi Sustainability Week (ADSW) 2021, Masdar and some key players in the energy field announced plans to explore the production of green hydrogen and its conversion to sustainable aviation fuel (SAF) via a demonstration project in Abu Dhabi.

Led by Masdar and in partnership with Siemens Energy, TotalEnergies, Marubeni Corporation, Department of Energy in Abu Dhabi, Etihad Airways, Lufthansa Group and Khalifa University, Project Green Falcon aims to serve as a base for a large-scale commercial facility. It will be the first of its kind worldwide to demonstrate the production of jet fuel using solar energy, water, and carbon dioxide. The project will allow for concept development and scale up, help establish the regulatory framework for the production and use of green hydrogen and sustainable aviation fuels (SAF) in the UAE and provide the basis for creating a domestic demand for these decarbonized fuels.

The demonstration plant will be powered by solar photovoltaics sourced via a power purchase agreement and clean energy certificates. The electricity will be used to power an electrolyzer to generate the green hydrogen. Most of the green hydrogen produced will be converted to SAF and a small portion may be used to demonstrate ground mobility applications with several buses.

With the help of Project Green Falcon, Masdar aims to become a global green hydrogen leader and has so far signed several collaboration agreements in the UAE and internationally with key stakeholders to develop large-scale projects for green hydrogen and its derivatives.

In yet another landmark partnership agreement, last year Masdar signed a strategic partnership agreement with France's ENGIE to explore the co-development of a UAE-based green hydrogen hub. The two companies are looking to develop projects with a capacity of at least 2 GW by 2030, with a total investment in the region of US$5 billion.

Following that agreement, a collaboration agreement was announced at ADSW 2022, between Masdar, ENGIE, and global nitrogen and fertilizer leader Fertiglobe. The three companies will study the development, design, financing, procurement, construction, operation, and maintenance of an industrial-scale and globally cost-competitive green hydrogen facility in Al Ruwais, Abu Dhabi, to be installed near Fertiglobe's ammonia production plants, with a potential capacity up to 200 MW.

Tapping into their respective global expertise, Masdar, ADNOC and bp have agreed to form a UK-UAE new energy partnership, which has resulted in two projects. The three companies will seek to collaborate on UK and UAE clean hydrogen hub development at an initial scale of 1 GW in the UAE and 1 GW in the UK, building on the UAE's position as an anchor investor in some of the UK's largest offshore wind projects. Further, Masdar and bp will together explore opportunities to develop, build and operate sustainable energy and mobility solutions in urban population centers.

In April 2022, Masdar and Egypt's Hassan Allam Utilities agreed to cooperate on the development of green hydrogen production plants in the Suez Canal Economic Zone and on the Mediterranean coast. The agreement will see Masdar and Hassan Allam Utilities set up a strategic platform to develop green hydrogen production plants on the Mediterranean coast in Egypt. The project seeks to have electrolyzer capacity of 4 gigawatts (GW) by 2030, and output of up to 480,000 tons of green hydrogen per year.

The project is backed by the General Authority for Suez Canal Economic Zone, the New and Renewable Energy Authority, the Egyptian Electricity Transmission Company and The Sovereign Fund of Egypt. Egypt enjoys abundant solar and wind resources that allow generation of renewable power at a highly competitive cost –a key enabler for green hydrogen production.

Egypt is also close to markets where demand for green hydrogen is expected to grow the most, providing robust opportunity for export. Driven by green hydrogen's export potential, its ability to attract large-scale foreign direct investment and opportunities to contribute to the Egyptian government's efforts to increase the share of renewables in the country's energy mix to 42 percent by 2030, the Egyptian Ministry of Electricity is currently revising its 2030 renewable energy strategy to include green hydrogen.

A joint report by

ABU DHABI SUSTAINABILITY WEEK

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