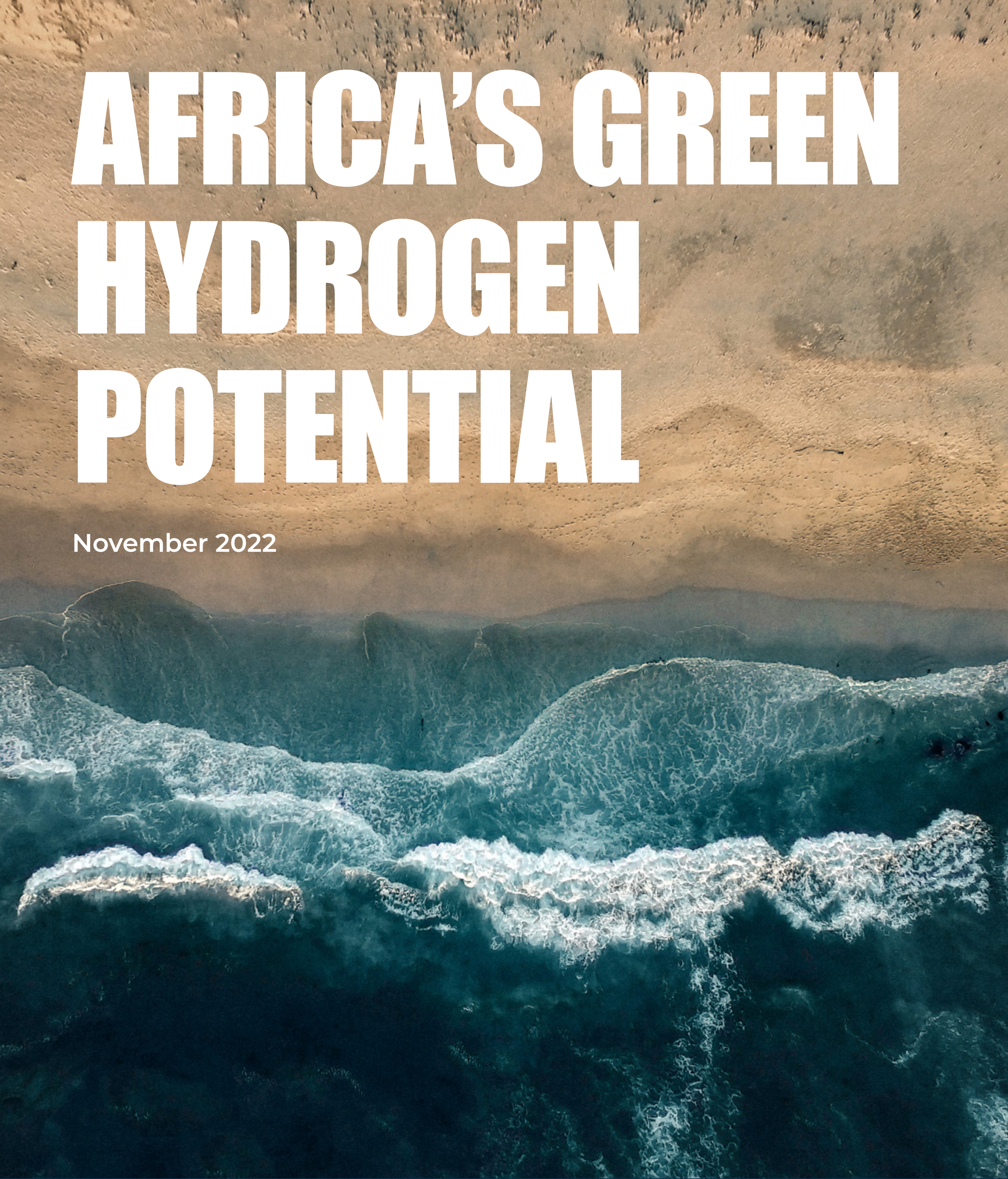
AFRICA'S GREEN HYDROGEN POTENTIAL

November 2022



RACE TO RESILIENCE

RACE TO ZERO

GH2 Green Hydrogen Organisation

PREFACE

In light of the increasing urgency to limit global warming to no more than 1.5°C, compared to pre-industrial levels—in line with the Paris Agreement—the interest in green hydrogen is growing. This research considers green hydrogen as a clean energy solution and attempts to articulate a combined green hydrogen ambition for several countries in Africa represented by the Africa Green Hydrogen Alliance (AGHA). It also outlines how the green hydrogen economy stands to benefit African countries that unlock potential opportunities.

The research considers only green hydrogen made by the electrolysis of water using solar and wind energy. It takes two potential scenarios from research done by McKinsey & Company on the five decarbonization pathways centered around the pace of technological progress and the level of policy enforcement. The first, the Current Trajectory scenario, assumes that the current cost trajectory for renewables continues; however, active policies remain insufficient to close the gap to the 1.5°C ambition, with global temperatures likely to rise by 2.4°C by 2100. The second scenario, Achieved Commitments, assumes that net-zero commitments are adopted by leading countries and implemented through purposeful policies, thereby accelerating the transition—though financial and technological constraints remain. This scenario is consistent with the expected global temperature rise of approximately 1.7°C by 2100.

The methodology adopted in this study is outlined in the Appendix. The analysis is based on the availability of natural renewable energy endowments and other competitive advantages, such as preexisting industrial bases, logistical facilities, trade partnerships, and current progress on green hydrogen in key countries across Africa. It aims to characterize the potential for the production of hydrogen for the continent as a whole, as well as to size the potential domestic and export markets for different African regions. The analysis does not aim to define a target for hydrogen production in Africa.

We hope that this research contributes to helping key African stakeholders, including business and policy leaders, better understand the potential for hydrogen on the continent as well as the implications for what needs to be done to realize this ambition. We believe that if successful, this is a path that could bring significant value to the continent—and indeed the world—in the form of better energy security, economic value added, and lower emissions, to build a sustainable and more prosperous future for all.

TABLE OF CONTENTS

Cape Town Coastline.
Photo by Finding Dan | Dan Grinwis on Unsplash

EXECUTIVE SUMMARY

Green hydrogen (hydrogen produced using renewable energy) is expected to play a vital role in the global push to reach net zero, particularly in decarbonizing hard-to-abate sectors. The global demand for hydrogen is expected to grow significantly by 2050—almost sevenfold to 607 Mt of hydrogen equivalent in a scenario in which decarbonization commitments are achieved, driven by increasing momentum to decarbonize and policy interventions by governments.[1]

Falling production cost of green hydrogen is expected to be a key factor influencing demand. Global hydrogen production costs are expected to drop by as much as 60 percent by 2030, driven by the decrease in the cost of renewable energy overall and an increase in electrolyzer capacity. This cost decrease, together with additional policy support for the adoption of hydrogen technology, could mean that by the end of the decade already, green hydrogen might displace gray hydrogen in several regions to become a leading, cost-effective, low-carbon, and clean energy solution.

However, global hydrogen supply and demand centers are mismatched. Many demand centers, notably Europe, Japan, and South Korea, have limited renewable energy potential and will likely have to import hydrogen to meet their needs.

Countries around the world are positioning themselves to take advantage of these export opportunities as well as the domestic benefits that green hydrogen could bring. Several African countries, particularly those in the north and south of the continent, are well positioned to be significant players in the green hydrogen space, mainly due to their high potential for renewable energy generation, particularly from solar and wind.

To enable these ambitions, the Africa Green Hydrogen Alliance (AGHA) was founded to serve as a catalyst for pan-African momentum toward green hydrogen and to connect and augment initiatives among its members, which currently[2] include Egypt, Kenya, Mauritania, Morocco, Namibia, and South Africa.

The green hydrogen economy could bring substantial benefits to African countries

African countries are confronted with a number of interlinked challenges, including climate change, low economic growth rates, and poverty, which a green hydrogen industry could help address.

Green hydrogen could enable African countries to become more energy independent and promote zero-carbon industrialization, creating both economic growth and new jobs, as well as helping to enable and

[1] McKinsey Global Energy Perspective; this analysis considers two decarbonization scenarios: Achieved Commitments and Current Trajectory. Throughout this report, unless specifically mentioned, the lower numbers correspond to the Current Trajectory scenario and the higher numbers correspond to the Achieved Commitments scenario.

[2] As of October 2022.

accelerate the deployment of renewable energy across the continent, which are necessary to increase energy access and affordability.

Africa also offers an opportunity for several importing nations to tap globally competitive supply and diversify their supplier base. International cross-border trade for hydrogen and its derivatives is expected to reach 100 to 180 Mt by 2050, with the majority of growth occurring between 2030 and 2050. Europe, Japan, South Korea, and Southeast Asia will potentially account for roughly 65 percent of this cross-border trade by 2050.

A large addressable market by 2050

Taking all of these opportunities—both domestic and global—into consideration, AGHA's addressable market for green hydrogen could reach 30 to 60 Mt of hydrogen equivalent by 2050. Approximately one-third of this potential could be local (i.e., within the member countries) and two-third is export, roughly equivalent to 22% of the expected international cross-border hydrogen and derivatives trade by 2050. Healthy competition is expected among African producers as the players optimize their product-market mix. Capturing this whole market would require 510 to 975 GW of renewable energy capacity and 290 to 560 GW of electrolyzer capacity by 2050. This transition would also require a significant investment of roughly $450 billion to $900 billion between now and 2050. Approximately 70 percent of the investment would be spent on renewable energy and electrolysis capacity building.

Socioeconomic and environmental benefits

AGHA's green hydrogen ambition could play a role in revitalizing domestic economic growth, helping AGHA member governments industrialize and grow their economies to create jobs and wealth. Delivering on the 30 to 60 Mt ambition could add $66 billion to $126 billion to the GDP of AGHA member countries in 2050. This is equivalent to 6 percent to 12 percent of the current GDP of these countries. This could also create 2 million to 4 million jobs by 2050 in AGHA member countries. The benefits would be based on direct and indirect impact through supply chain stimulation from both one-off investments into new infrastructure and recurring benefits that the operation of these new hydrogen assets could bring.

In addition, by delivering on AGHA's green hydrogen potential, member countries could help abate around 6.5 Gt of cumulative CO_2 emissions globally by 2050, roughly equivalent to the combined CO_2 emission in the United States and Europe in 2021.[3]

Realizing AGHA's green hydrogen potential through collaboration and coordinated action

AGHA members could focus on five key enablers to work toward realizing the ambition outlined in this report: (1) set a national vision and build strategic partnerships, (2) strengthen regulations, such as clear and transparent codification of laws and regulations relevant to the production and adoption of hydrogen, (3) improve access to low-cost financing, (4) improve critical infrastructure, such as pipeline and port infrastructure, and (5) foster innovation and skills.

To support its members on this journey, AGHA could undertake a number of actions in the next six months to foster an understanding of its role and catapult its members into a position of global leadership.

In achieving these goals, collaboration will be key to connecting all stakeholders working toward a common goal, such as private-sector players that have mobilized large-scale capital, governments that have the unique ability to create an enabling environment, African civil societies who can help understand community perspective, and industry players along the entire value chain that will be engaged in the day-to-day operation of this emerging industry.

Collaboration among AGHA members can also reduce friction and enhance synergies in critical areas such as skills development and R&D, and can also increase innovation. Working together, AGHA members can navigate the challenges, secure strong partnerships, and mobilize the necessary financing, potentially bringing jobs and enhanced competitiveness to African economies and helping ensure that the continent carves out a substantial role in the new global energy landscape.

[3] IEA global energy review 2021.

GLOBAL HYDROGEN OPPORTUNITY

7x

Global hydrogen demand could grow by 2050 in Achieved Commitments scenario

Hydrogen playes several roles in the energy transition

Enables the renewable energy system

- Enables large-scale renewable integration and power generation
- Distributes energy across sectors and regions
- Acts as a buffer to increase system resilience

Decarbonizes end uses, especially in hard-to-abate sectors

- Transportation
- Industry
- Chemicals and fertilizers

Momentum towards net-zero and hydrogen is growing

~175 GW
announced projects by 2030, as of June 2022

64+ countries
with net-zero targets

60% cost reduction
expected in green hydrogen production by 2030

180 Mt
of hydrogen equivalent
expected in international cross-border trade in 2050 in Achieved Commitments

~65% of this cross-border trade demand will come from Europe, Japan, South Korea, and Southeast Asia

Green hydrogen producers will be characterized by

- High renewables endowment
- Cost competitiveness
- Diversification of supply base for importers

Please see exhibit 22 for the definition of Achieved Committments scenario

AGHA POTENTIAL

Achieved Commitments scenario

Green hydrogen potential

6 Mt
of hydrogen equivalent
by 2030

60 Mt
of hydrogen equivalent
by 2050

~10%
of the expected global hydrogen demand

~1/3
could be local demand

~22%
of the expected international cross-border trade

$900bn
by 2050 and $55 billion by 2030

70%
capital spend in renewable energy and electrolyzer capacity building

$122bn
expected addition to Africa's GDP by 2050, equivalent to 12% of AGHA members' current GDP

4mn
new jobs created or sustained by 2050

5 critical actions for AGHA members to unlock the green hydrogen potential

Set a national vision and build strategic partnerships	Lead by example in order to signal national commitment to mobilizing resources in support of hydrogen, seeking out support from like-minded national and multilateral partners and seeking buy-in from the wider public
Strengthen regulations	Create certainty in projects to make them bankable and ensuring that the rules of the game are set in advance and understood by stakeholders
Improve access to low-cost financing	Ensure that no project fails for lack of financing, especially in countries where risk premiums tend to be higher or countries which may not be fully integrated into global financial markets
Improve critical infrastructure	Enable integration of value chains to remove physical barriers to generation, transmission, production, and transportation to end users
Support innovation and skills	Address skills and knowledge gaps, especially in countries which have not previously integrated downstream value chains

Please see exhibit 22 for the definition of Achieved Committments scenario

INTRODUCTION

There is growing international consensus that green hydrogen will likely play a vital role in the world's transition to a sustainable energy future. Produced by using renewably generated electricity to split water molecules into hydrogen and oxygen, green hydrogen holds significant promise for meeting global energy demand, notably in the hard-to-abate sectors. It could also help increase energy security by diversifying supply, while reducing greenhouse gas emissions to help the world reach net zero.

Green hydrogen could play multiple roles within a decarbonized energy system, notably in the hard-to-abate sectors and long range mobility applications, potentially abating up to 75 Gt of emissions by 2050.[4] As governments and businesses commit to ambitious decarbonization targets, and the costs of renewable energy continue to fall, green hydrogen could overtake gray hydrogen (produced using power from gas and coal) to become one of the most cost-effective forms of hydrogen energy before the end of the decade. At the same time, demand for hydrogen could increase sevenfold by 2050 in a scenario that sees leading countries achieve their current net-zero commitments through purposeful policies. (See the Appendix for the methodology used in this report.)

Global hydrogen demand and supply are mismatched, creating a significant import market. Around the world, governments are positioning their economies to take advantage of the opportunities that the hydrogen economy could bring, including increased energy security, new jobs, low-carbon industries, and export opportunities. African economies could be well positioned to benefit from these opportunities. The continent's abundant wind and solar potential and its proximity to key demand centers put it in a strong position to export green hydrogen and its derivatives to international markets, including Europe and Asia. And importantly, if African countries are able to develop and scale this new industry effectively, they may also find abundant applications for green hydrogen in domestic markets, helping boost energy independence, foster new green industries, and create new and sustainable jobs. Green hydrogen could also help enable and accelerate the deployment of renewable energy across the continent, thus helping Africa meet its electrification needs.

To help realize the significant value at stake, the Africa Green Hydrogen Alliance (AGHA) was launched in Barcelona on May 18, 2022, with support from the Climate Champions Team, Green Hydrogen Organisation And African Development Bank, with the UN Energy Commission for Africa and AUDA-NEPAD also part of the secretariat and acting as observers. AGHA primarily aims to serve as a catalyst for pan-African momentum in the hydrogen space and augment hydrogen initiatives among the member countries. To date, six African countries have joined the initiative: Egypt, Kenya, Mauritania, Morocco, Namibia, and South Africa. These countries have announced their intention to intensify collaboration toward the development of green hydrogen projects on the African continent. The moment is right for African countries to explore how they can work together to tap into the continent's green hydrogen potential and deliver domestic economic growth and climate benefits, while supporting the world in its transition toward net zero.

This report unpacks AGHA's green hydrogen opportunity, assessing the high-level infrastructure and financing needs required to facilitate a shift toward green hydrogen and outlining the benefits and challenges of implementing a green hydrogen development plan.

To realize AGHA's green hydrogen potential, targeted action would likely be needed to overcome barriers and reduce financing costs. But with greater coordination, strategic partnerships, and the deliberate creation of a sustainable enabling environment to scale Africa's green hydrogen industry, several AGHA members could emerge as credible global actors in the important and exciting emerging hydrogen economy.

[4] McKinsey Global Energy Perspective 2022, Achieved Commitments scenario.

1. GREEN HYDROGEN, A TANGIBLE OPPORTUNITY FOR THE ECONOMIC DEVELOPMENT OF THE CONTINENT

The global transition to a low-carbon future continues to gain momentum. By November 2021, 64 countries had pledged or legislated targets for achieving net zero over the coming decades, in line with the Paris Agreement, covering 89 percent of global emissions.[5] Countries including Canada, Japan, New Zealand, and those in the European Union—responsible for about 17 percent of global emissions combined—have already signed net-zero targets into law, while others, including China, the United States, and Australia—responsible for 72 percent of emissions combined—have pledged to reach net zero by 2050 or beyond.

While this falls short of the response needed to keep the world below a 1.5°C rise in mean global temperature compared to preindustrial levels, it is nevertheless spurring change. Global energy systems in particular are being reshaped as the world accelerates its transition away from fossil fuels—a critical enabler to reaching net zero by 2050.

In this shifting landscape, green hydrogen is emerging as a front-runner for achieving a clean, secure, just and affordable energy future for the world. This is opening up exciting economic opportunities for African economies. With abundant wind and solar potential, many parts of Africa are ideally positioned for green hydrogen production to build their own energy independence and industrialization, while also meeting rising global demand.

The global outlook for green hydrogen is buoyant

Green hydrogen—hydrogen that is produced using renewable energy—has been called a “transformative fuel” by virtue of its potential to power a cleaner future for the planet.[6] But while hydrogen is already used in many industries, it has not yet realized its full potential to support the clean energy transition by replacing fossil fuels in industrial process, mobility and applications in many hard-to-abate sectors.

One of the reasons for this is cost. But as momentum toward green hydrogen builds—including an exponential rise in project announcements for electrolyzer capacity—the cost of producing it is expected to fall by approximately 60 percent globally by 2030. Green hydrogen project announcements have accelerated since 2019, and, as of June 2022, are at 175 GW of electrolyzer capacity by 2030. This is ten times the announcements made in December 2019 and three times

5 The Paris Agreement is an international treaty on climate change that was adopted by 196 parties at COP 21 in Paris on December 12, 2015, and entered into force on November 4, 2016.

6 “‘Green hydrogen’ from renewables could become cheapest ‘transformative fuel’ within a decade,” *The Guardian*, October 2, 2020.

the announcements made in December 2020.[7]

This increase in capacity, together with significantly strengthened and targeted policy and financing support for the adoption of green hydrogen technology, could mean that green hydrogen displaces gray hydrogen to become a leading, cost-effective, low-carbon, and clean energy solution by the end of the decade.

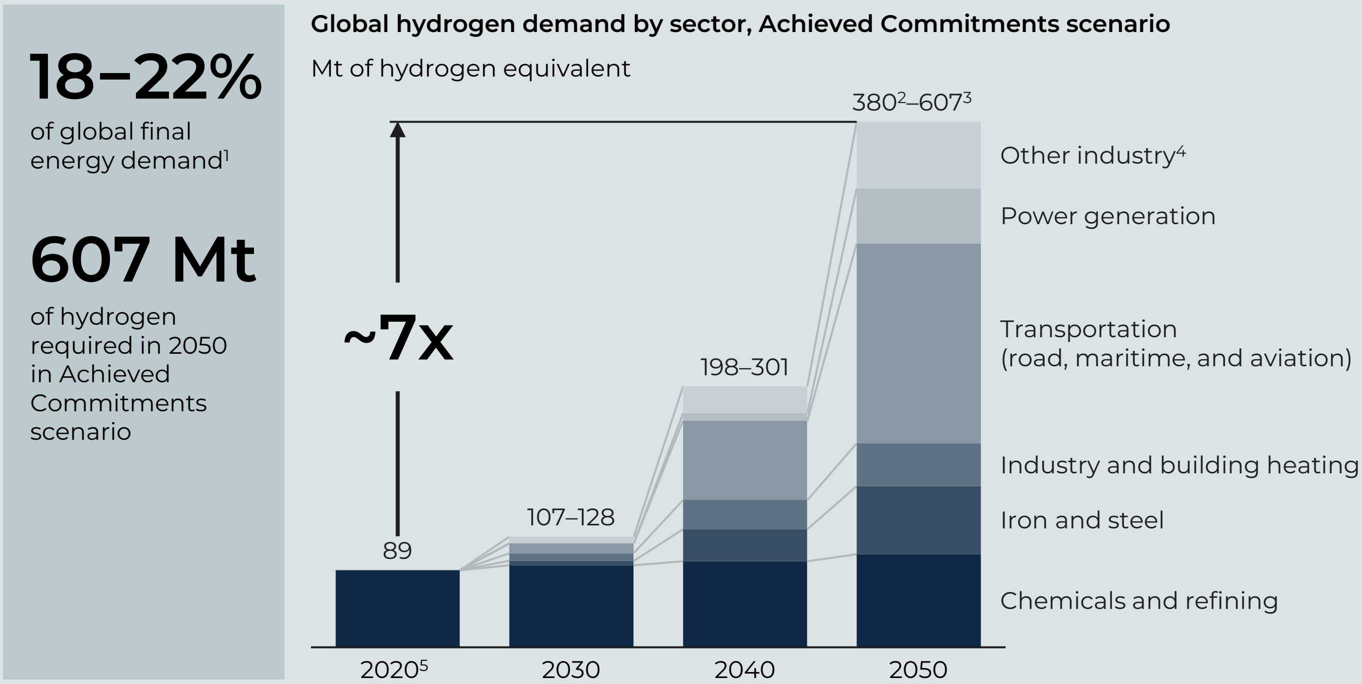
As a result, global demand for hydrogen could increase sevenfold by 2050 to meet roughly 18 to 22 percent of global final energy demand, in a scenario that sees leading countries achieve their current net-zero commitments to keep global temperatures well below 2°C above preindustrial levels. This translates to the production of around 128 Mt of hydrogen equivalent by 2030, growing to around 607 Mt of hydrogen equivalent by 2050 (**Exhibit 1**).

While the chemical and refining sectors will have the highest demand for green hydrogen early on, the transportation sector is expected to drive the highest growth in green hydrogen demand in the long run, followed by iron and steel, other industries (including cement, nonferrous metals, materials, mining, manufacturing, construction, food and tobacco, and agriculture and forestry) and power generation mainly as a long duration storage and energy system resiliency, and industrial heating, in particular for high-grade heat.

[7] Projects without known deployment timeline capacity additions were interpolated between known milestones.

Exhibit 1

Global hydrogen demand could grow sevenfold by 2050 in Achieved Commitments scenario



[1] International Energy Agency net-zero scenario with 340 exajoules of final energy demand in 2050; high heating value assumed; excluding power.
[2] Current Trajectory.
[3] Achieved Commitments.
[4] Cement, non-ferrous metals, materials, mining, manufacturing, construction, food and tobacco, agriculture and forestry, and other unspecified industry.
[5] International Energy Agency Global Hydrogen Review 2022.
Note: Sector shares shown represent Achieved Commitments.

Source: McKinsey Global Energy Perspective 2022

A versatile fuel for the future

The high potential of hydrogen is in part due to its versatility. Hydrogen can be used to produce, store, and move energy in a variety of ways, and also has a number of uses, especially in hard-to-abate sectors such as long-range modes of transportation and heavy industry. There are several roles that hydrogen could fill in the energy transition (**Exhibit 2**).

First, hydrogen has a key role to play across mobility (including maritime and aviation), existing feedstocks (in chemicals and refining) and steel. Mobility, accounting for about 19% of global emission today, is expected to be the largest single hydrogen end-use segment by 2050.[8] Heavy-duty trucks are expected to be the largest consumer of hydrogen long-term due to their high mileage and power characteristics. Aviation is expected to become a major consumer of synthetic fuels, based on hydrogen combined with CO_2 from biogenic sources or directly captured from the air. Steelmaking is one of the most challenging sectors to abate due to few alternative decarbonization pathways and relies on hydrogen for full decarbonization.

Hydrogen has a key role to play in power generation, mainly as a long duration form of storage and potentially as a grid balancing resource. The key decarbonization solution within the power generation is expanding renewable energy generation capacity. However, solar and wind power is inherently volatile, and the energy system will require both short- and long-duration balancing. Hydrogen could play a crucial role in decarbonizing the final 1% to 3% of the demand in a fully decarbonized grid, because it can provide long-duration and seasonal storage, as well as peak shaving, and will be critical for stabilizing the grid.[9]

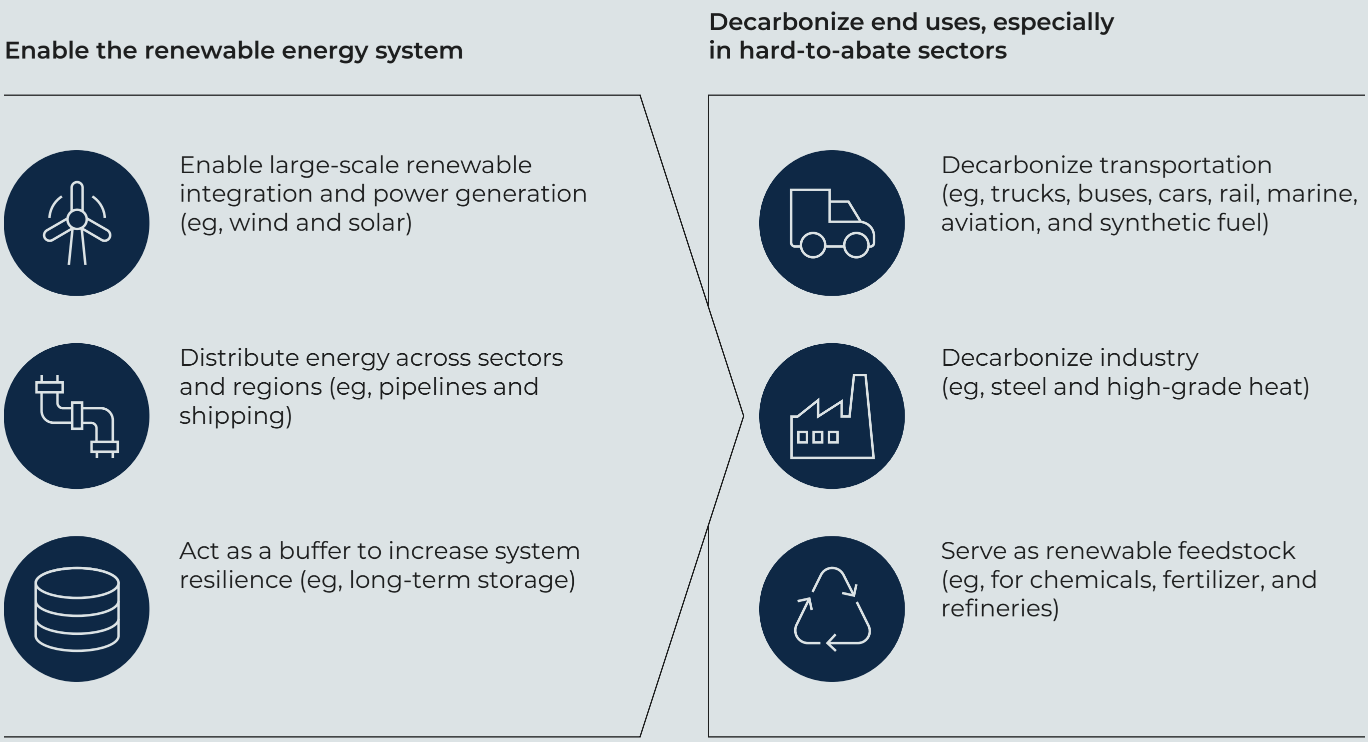
---

8 McKinsey and Hydrogen Council: Hydrogen-for-Net-Zero.
9 Ibid.

Exhibit 2

Hydrogen fulfills several roles in the energy transition

Non exhaustive



Source: McKinsey and Hydrogen Council: Hydrogen Insights

Green hydrogen could also play a role in energy transmission. Hydrogen can move clean energy from areas with attractive energy resources to areas with less attractive domestic resources, enabling both regional and global transmission. Green hydrogen could also enable extremely competitive yet otherwise untapped "stranded" renewable energy potential in remote, thinly populated locations. These renewable resources often exist in high volumes and quality, but have been inaccessible because of the infeasibility of building electricity transmission lines to demand centers.

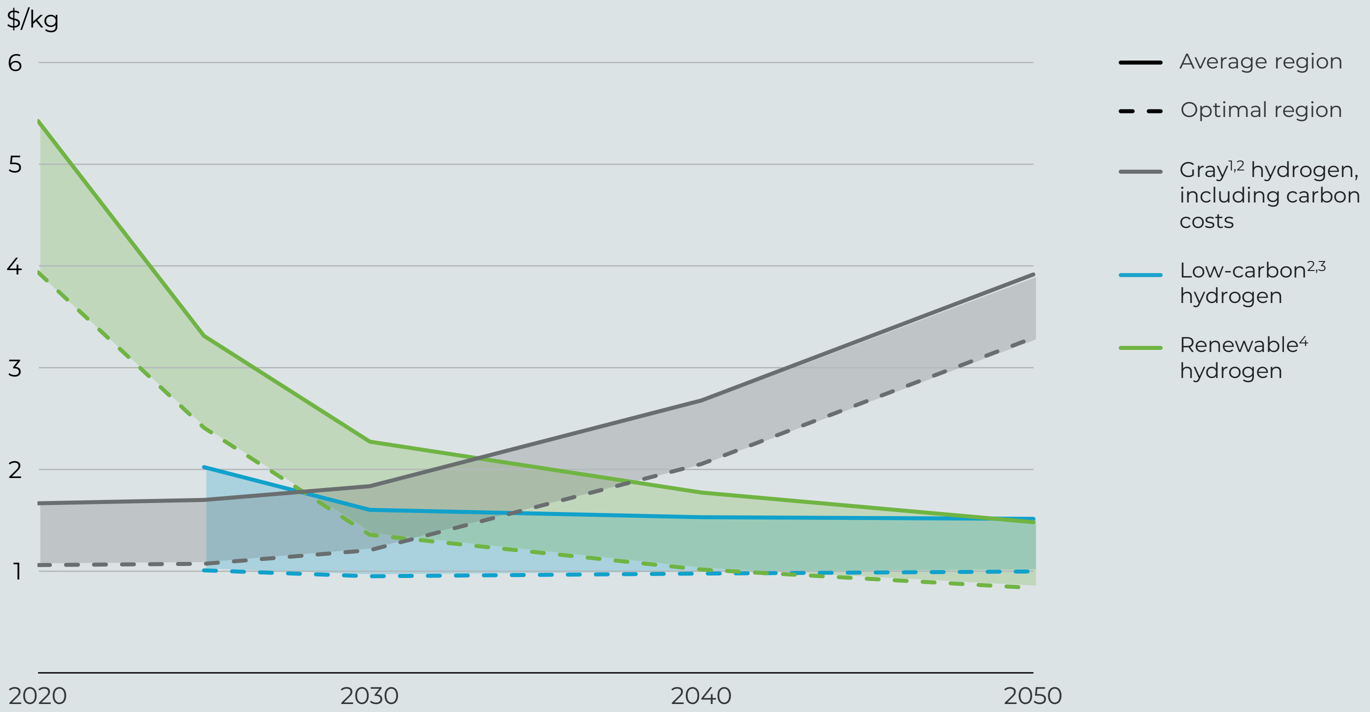
Green hydrogen could be cost competitive in several applications by 2030

Policymakers are increasingly moving to support the adoption of green hydrogen technology, electrolyzer capacity is ramping up, and the cost of renewable energy continues to fall. In light of this, the cost of producing renewable hydrogen is expected to decrease by around 60 percent by 2030, potentially shifting the energy landscape permanently. Currently, achieving breakeven between gray hydrogen and green hydrogen in optimum locations is estimated to require deployment of about 65 GW of electrolyzer capacity (corresponding to about $50 billion in funding), to enable the learning and scale effects to drive costs down sufficiently. This, together with the introduction of CO_2 tariffs as a response to decarbonization pressure, could mean that green hydrogen is at cost parity with gray hydrogen as early as 2028 (**Exhibit 3**).

There are around 20 clean hydrogen applications that could become more competitive than other low-carbon alternatives by 2030. In 10 or so applications, clean hydrogen

Exhibit 3

Renewable hydrogen production costs are expected to fall by ~60% by 2030



[1] Steam methane reforming without carbon capture and storage.
[2] Flat gas price $2.6–6.8/MMBtu; based on $30/ton CO_2 (2020), $50/ton CO_2 (2030), $150/ton CO_2 (2040), $300/ton CO_2 (2050).
[3] Assumes autothermal reforming with carbon capture and storage and 98% CO_2 capture rate. Based on carbon transportation and storage cost of $65/ton CO_2 (2025), $17/ton CO_2 (2030), and $14/ton CO_2 (2050).
[4] Based on alkaline with size classes of 2 MW (2020), 20 MW (2025), and 80 MW (from 2030); based on levelized cost of energy of $25–73/MWh (2020), $13–37/MWh (2030), and $7–25/MWh (2050).

Source: McKinsey and Hydrogen Council: Hydrogen Insights

could become more competitive than conventional fuels. For example, green hydrogen is a competitive alternative to decarbonize industry feedstock, as these processes require hydrogen. By 2025, hydrogen could become competitive in some transport applications such as large vehicles with long ranges (trucks, trains, coaches and taxi fleets) and forklifts. By 2030, most road transport applications except short-range use cases (e.g., short-distance buses) could become competitive against low-carbon alternatives.

Green hydrogen uptake would depend greatly on the regions and local conditions would influence competitiveness of clean hydrogen applications. Given the expected increase in global hydrogen demand by 2050 as production becomes more cost competitive and pressure to decarbonize increases, green hydrogen production could reach around two-thirds of the global hydrogen supply by then. Gray hydrogen could be totally supplanted, while blue hydrogen, making up 30 percent of total hydrogen production, would likely be limited to regions such as North America and the Middle East, where costs of natural gas are lower and carbon capture and storage is more likely to be economical[10] (**Exhibit 4**).

Global hydrogen demand and supply are mismatched, creating a significant import market

Global hydrogen demand and supply are mismatched, creating a significant import market.

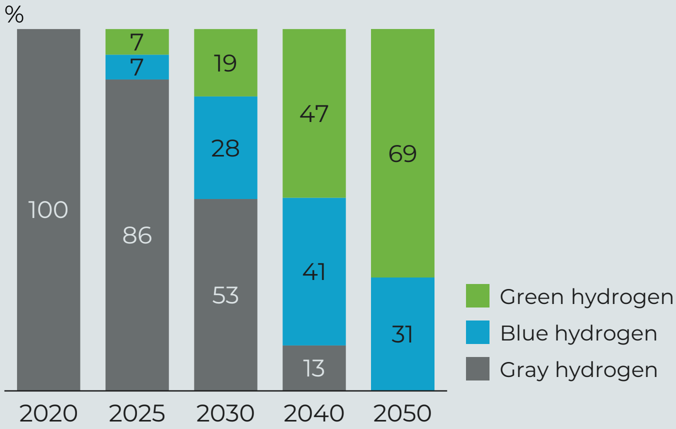
Only a few regions around the world, notably China and the United States, are expected to emerge as large centers of both hydrogen demand and supply with sufficient renewable conditions to provide their own supply of green hydrogen. As such, they are likely to be largely independent of hydrogen imports. In most other high-demand regions, low-cost supply is limited, presenting a large potential opportunity for exports from countries where renewables are more abundant. For example, the European Union, despite high existing and new green hydrogen demand applications, is constrained in terms of renewables due to varying load curves and limited space availability. This part of the world will likely need to import hydrogen to meet the expected demand in a cost-efficient manner.

[10] Provided blue hydrogen projects can operate under stringent regulations considering climate and public health risk linked to fossil fuels, with high carbon capture rates applied to all stream containing CO_2 (more than 90% carbon capture rates), captured carbon permanently stored underground with rigorous monitoring, and methane leakage minimized to near zero, if not completely avoided.

Exhibit 4

Green hydrogen production could reach ~70% of global hydrogen supply by 2050 in the Achieved Commitments scenario

Global hydrogen demand share by source, Achieved Commitments scenario[1]



- Production is expected to become more cost competitive as renewables and electrolyzers are likely to go significant cost improvements with the expected increase in deployment
- Pressure to decarbonize pushes gray hydrogen out of the mix
- Blue hydrogen adoption is mostly limited to regions such as North America and the Middle East, where costs of natural gas are lower and carbon capture and storage is more likely to be economical

[1] Might not add to 100% due to rounding.

Source: McKinsey and Hydrogen Council: Hydrogen Insights

Similarly, Japan and South Korea also have significant plans to scale up hydrogen across their economies. However, they are constrained by a lack of space and limited offshore wind conditions due to the deep-sea areas surrounding them, which prevent them from tapping into their own wind resources.

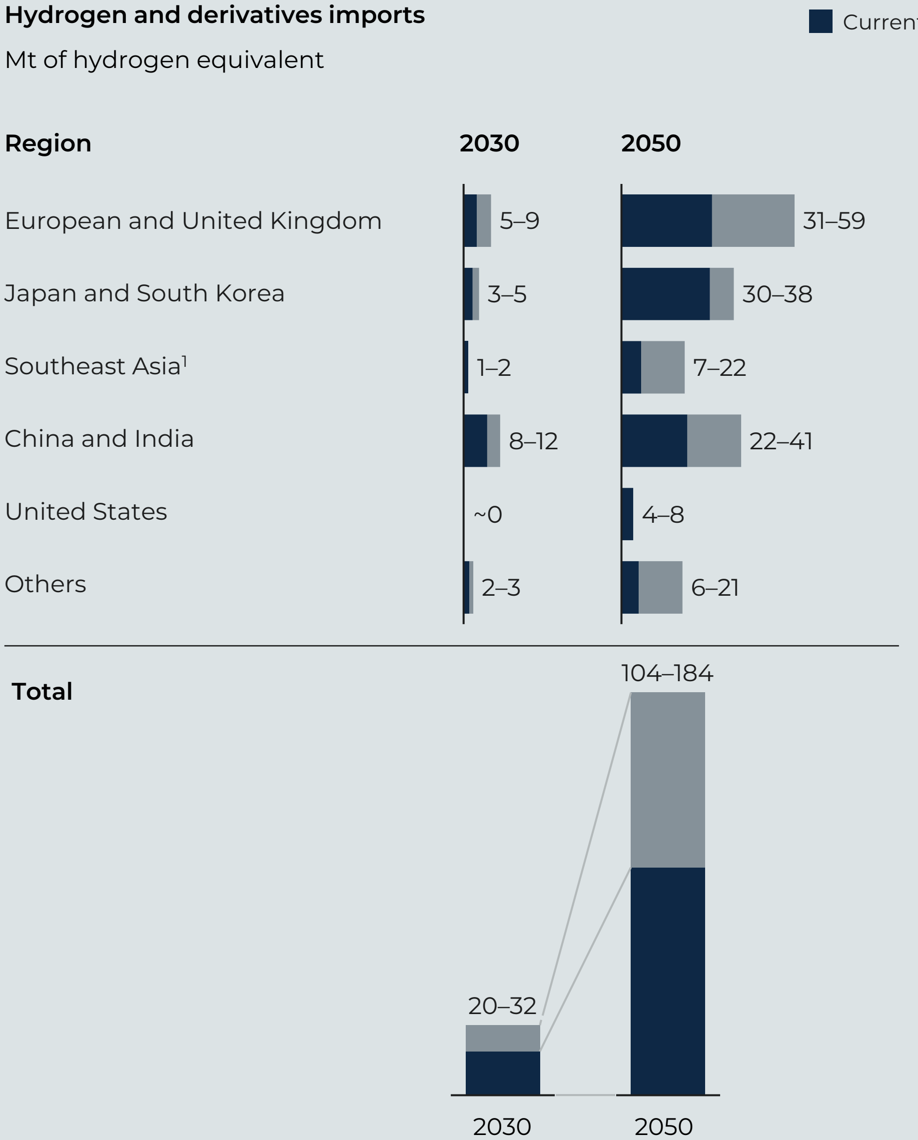
Transportation is a critical cost component, and landed costs will contribute to determining which production location is likely to have an advantage. As such, cost competitiveness will be a major driver for the selection of suppliers. In addition, it may be necessary for export countries to establish themselves as credible suppliers—for example, by investing in reliable infrastructure and skills development—if they wish to succeed in the long term (**Exhibit 5**).

Exhibit 5

International cross-border trade for hydrogen and its derivatives is expected to reach 100–180 Mt by 2050

Hydrogen and derivatives imports

Mt of hydrogen equivalent



Comments

- International cross-border trade is expected to grow **5–6x** between 2030 and 2050
- Europe, Japan, South Korea, and Southeast Asia could account for ~65% of the import market by 2050 in the Achieved Commitments scenario
- Hydrogen and ammonia import demand could largely be driven by Europe, Japan, and South Korea
- Synthetic fuel demand is expected worldwide

[1] Malaysia, Singapore, Thailand, and Vietnam.

Source: McKinsey and Hydrogen Council: Global Hydrogen Flows

Unique renewable energy endowments could put some African countries in a competitive position

Renewable hydrogen could be an especially viable proposition for many African countries, because the continent's renewable energy endowment—notably for wind and solar—is among the best in the world. Therefore, the continent could be highly competitive in supplying green hydrogen globally.

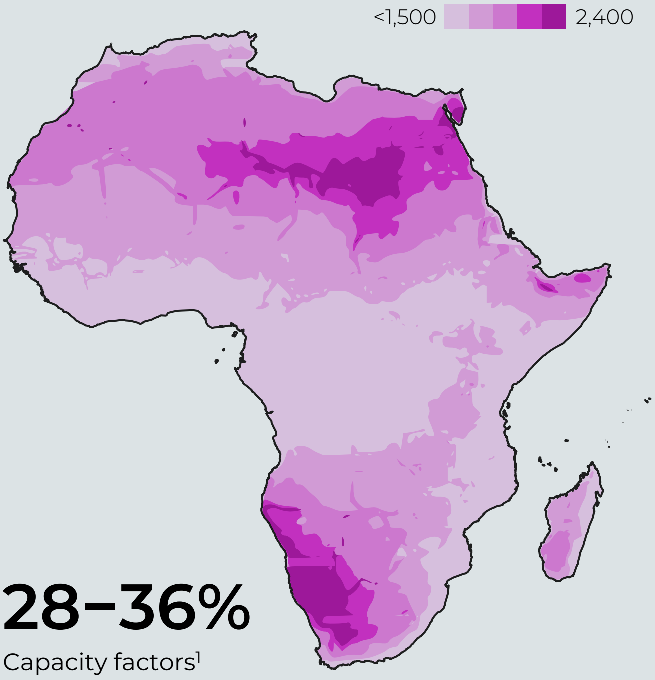
Africa has immense renewable potential from both solar and wind (**Exhibit 6**). Many African countries, especially those in the north and south of the continent, are well suited to tap into this potential, as they have complementary load profiles for wind and solar. There are plenty of remote or stranded locations with very high renewable endowment that could be used for large-scale deployment of renewable energy. Such

Exhibit 6

Africa is well equipped to tap the hydrogen opportunity with immense renewables endowments

Renewables potential in Africa

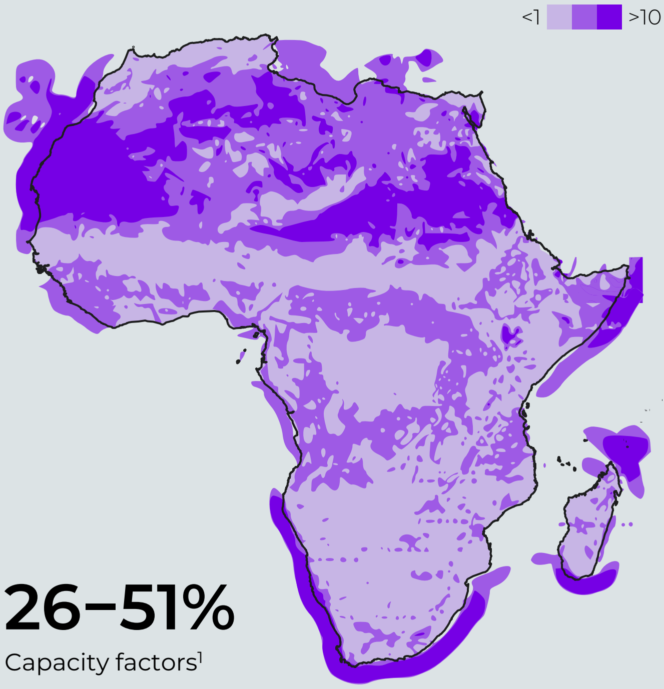
Solar power potential, kW hours/kW peak



28–36%

Capacity factors[1]

Wind power potential, m/second



26–51%

Capacity factors[1]

Key insights

Africa has immense renewables potential from both solar and wind.

Countries in the north and south of the continent are especially **well-suited for renewable hydrogen production** based on complementary load profiles.

Based on hybridization and optimal system sizing, **even higher load/capacity factors can be achieved, thus lowering the levelized cost of energy.**

Low levelized cost of energy is a strong foundation for competitive levelized cost of hydrogen, considering energy costs account for >60%[2] of hydrogen production costs.

[1] Global range is 10–21% for solar and 23–44% for wind.
[2] 2030: >60%; 2050: >55%.

Source: Global Solar Atlas; Global Wind Atlas; McKinsey Hydrogen Cost Optimization Model deployment, combined with hybridization and optimal sizing solutions in these areas, could mean that even higher load and capacity factors could be achieved, further lowering the levelized cost of energy. This, in turn, would be a critical factor in helping to drive down the costs of renewable hydrogen production, as energy costs account for more than 60 percent of hydrogen production costs.[11]

Assuming deployment at scale, the production costs of hydrogen on the continent could drop by around 50 percent between 2025 and 2050, as the levelized cost of energy falls and the electrolyzer supply chain on the continent scales up (**Exhibit 7**). Globally, manufacturers have already announced a planned scale-up to increase capacity to 175 GW by 2030, which is likely to drive down capital expenditure costs.[12]

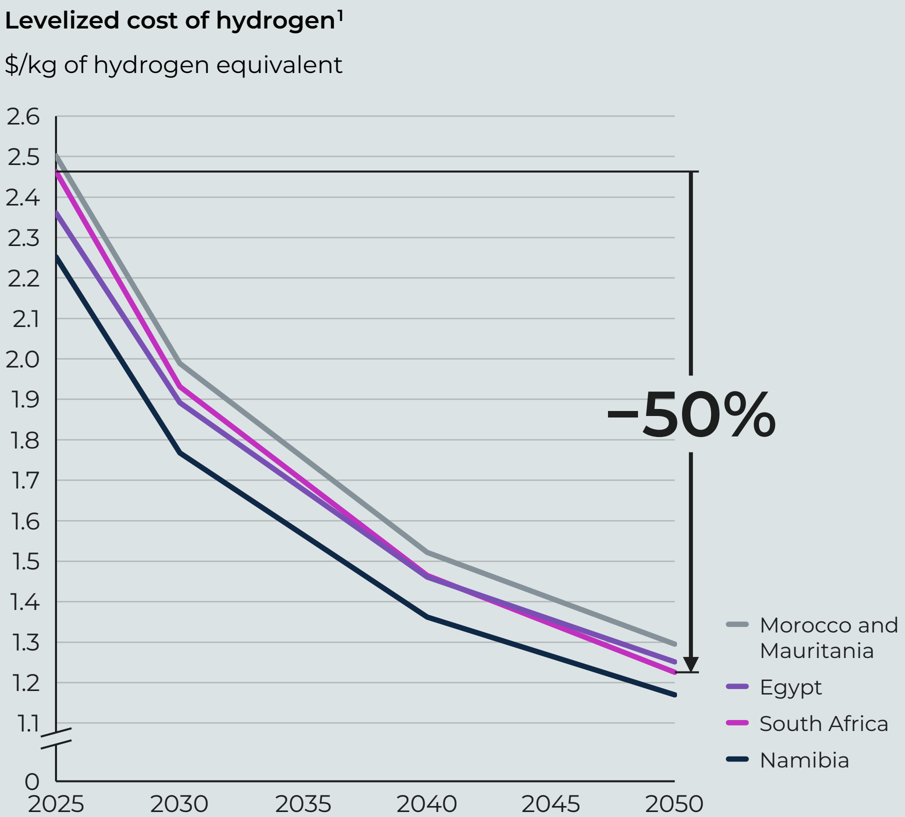
In turn, a lower levelized cost of hydrogen is likely to translate into decreased production costs for hydrogen derivatives, notably green ammonia, methanol, and synthetic kerosene. Green ammonia production costs could fall by around 40 percent on average, in line with the cost reduction share of hydrogen production, although conversion costs are expected to decline at a slower rate or stay flat. The cost of producing synthetic kerosene could potentially drop by about 35 percent from around $3.20 per kg to $2.10 per kg. Methanol is expected to have the smallest production cost reduction of only around 31 to 37 percent, from around $3.75 per kg to $2.50 per kg (**Exhibit 8**).

[11] McKinsey and Hydrogen Council: Hydrogen Insights.
[12] Ibid.

Exhibit 7

Production costs for hydrogen could drop ~50% between 2025 and 2050

Stable, large-scale electrolyzer (>100 MW)



Drivers

- **Lower levelized cost of energy** through at-scale renewables deployment and lower financing costs
- **Declining capex** due to scale-up of the electrolyzer supply chain

[1] Average of production cost for green solar and wind energy with 95% annual firmness.

Source: McKinsey and Hydrogen Council: Hydrogen Insights

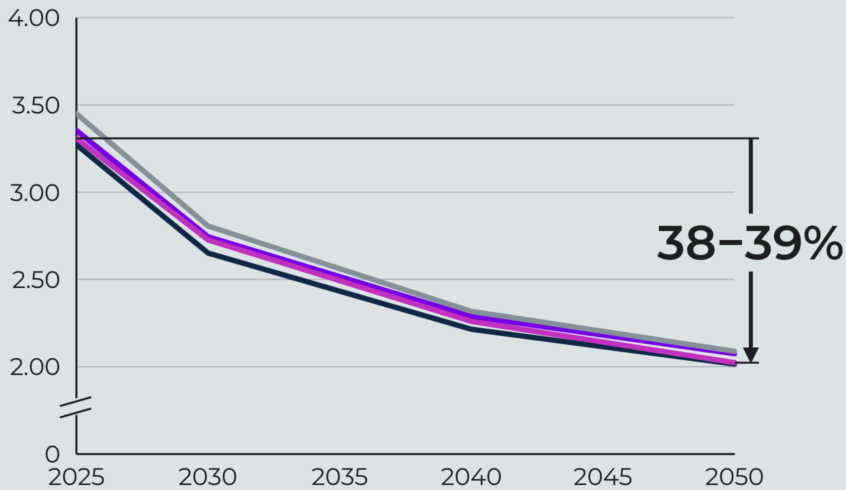
Exhibit 8

Production costs for hydrogen derivatives could decrease ~30–40%, mainly driven by strong reduction in levelized cost of hydrogen

Stable, large-scale electrolyzer (>100 MW), $/kg of hydrogen equivalent[1]

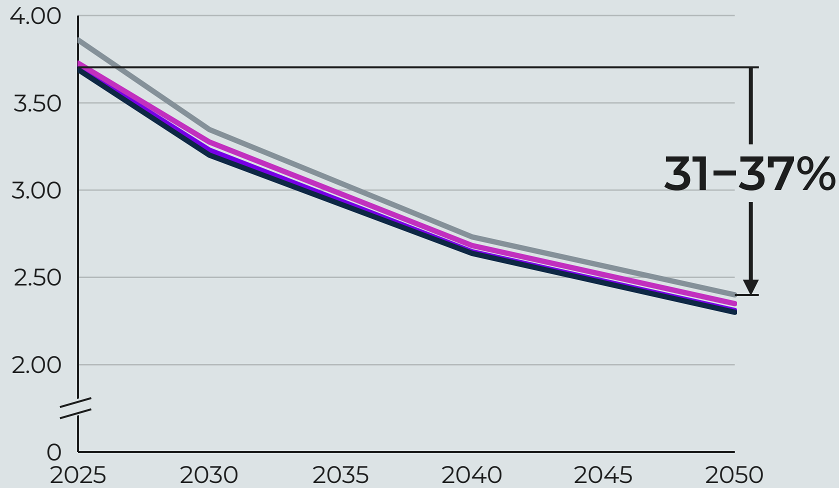
Morocco and Mauritania | Egypt | South Africa | Namibia

Levelized cost of ammonia



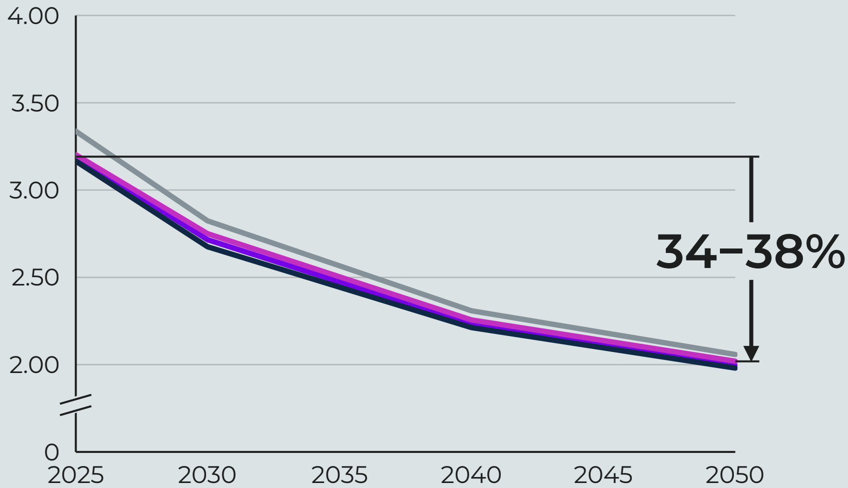
Green ammonia production costs could **decrease by ~40%, strongly impacted by lower levelized cost of hydrogen**, with conversion cost declining at a lower rate or staying flat

Levelized cost of methanol[2]



E-methanol is expected to have the **production cost reduction of ~31–37%,** from ~$3.75/kg to ~$2.50/kg

Levelized cost of synthetic kerosene[2]



Synthetic kerosene could potentially drop by **~35%** from ~$3.20/kg to ~$2.10/kg

1 Based on green hydrogen generated though solar and wind in a tier-1 area.
2 2040–50 development of CO_2-based derivatives is highly uncertain, since increasing demand for CO_2 exceeds supply of biogenic CO_2, and more expensive direct air capture technologies would be required.

Source: McKinsey and Hydrogen Council: Hydrogen Insights

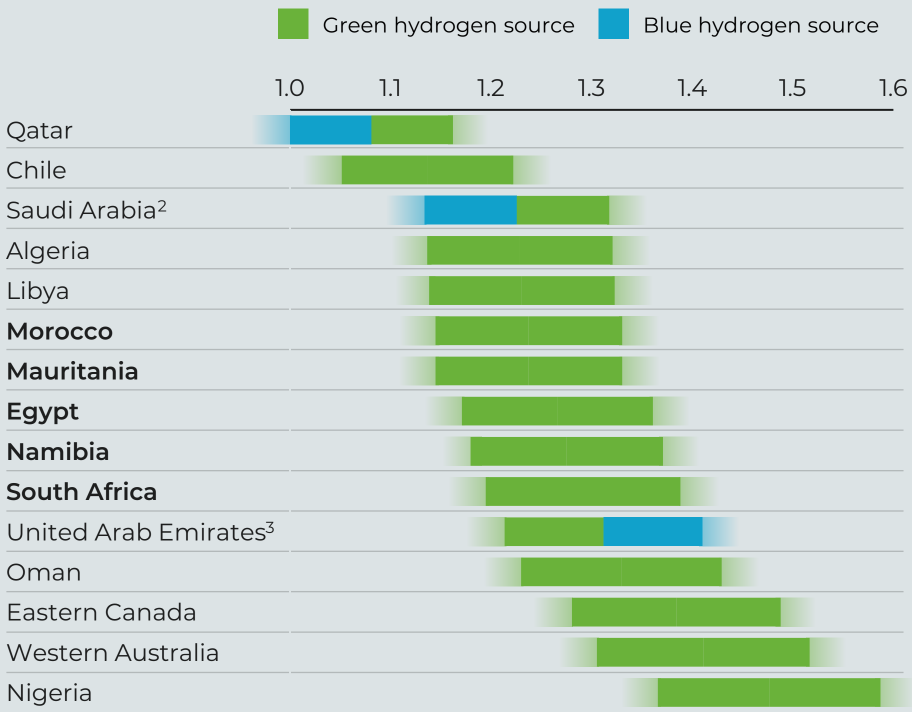
On the basis of landed costs in the demand regions, several African countries could be among the top ten suppliers. Several AGHA members are well within the landed cost range of the potential lowest-cost suppliers. As landed costs are quite sensitive to the cost of capital, AGHA members could further improve their cost base by mitigating project risks and thus accessing low-cost financing. In addition, the importers would likely diversify their supply base, which would further strengthen the positions of several AGHA members as potential suppliers (**Exhibits 9 and 10**).

Exhibit 9

Several AGHA members could be among the top ten seaborne suppliers of ammonia to Central Europe

Ammonia landed cost range[1] to Central Europe, no subsidy, 2050

Indexed



Comments

- Europe could import between 5 and 10 Mt of hydrogen-equivalent ammonia by 2050
- Several AGHA members could be competitive in ammonia shipments to Europe
- **Diversification of supply sources will be key,** and Europe could look at supplies beyond the Middle East
- The market share would therefore not only be dictated by cost competitiveness, but also by the **ability of producing nations to become credible suppliers**

1 Lower bound: weighted average cost of capital + 1%; upper bound: weighted average cost of capital – 1%.
2 Assuming 60% blue, 40% green.
3 Assuming 40% blue, 60% green.

Source: European Commission; McKinsey and Hydrogen Council: Hydrogen Insights

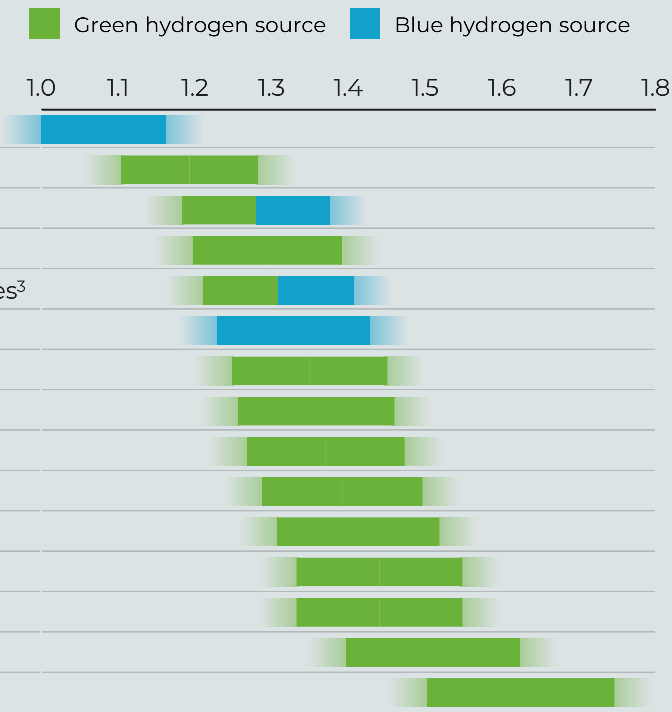
This means that African production of green hydrogen and its derivatives could be competitive from a supply perspective, with clear opportunities for export, especially to Europe and Asia. If Africa can deliver on its potential for low-cost hydrogen and derivatives production, it could capture a significant portion of future global hydrogen trade volumes.

Exhibit 10

AGHA members could become key suppliers of green ammonia to Asia

Ammonia landed cost range[1] to Japan, no subsidy, 2050

Indexed



Comments

- Asia could import between 10 and 20 hydrogen-equivalent ammonia by 2050, with Japan, South Korea, India, and China expected to be key importers
- Several AGHA members could be competitive in ammonia shipments to Asia
- The market share would therefore not only be dictated by cost competitiveness, but also by the **ability of producing nations to become credible suppliers**

1 Lower bound: weighted average cost of capital + 1%; upper bound: weighted average cost of capital – 1%.
2 Assuming 60% blue, 40% green.
3 Assuming 40% blue, 60% green.

Source: McKinsey and Hydrogen Council: Hydrogen Insights

2. POSITIONING AFRICA ON THE GLOBAL HYDROGEN MAP

The coming green hydrogen economy holds significant promise for the African continent. Confronted with a number of interlinked challenges, including climate change, low economic growth, and poverty, AGHA member countries are recognizing green hydrogen as a viable technology choice to help them address these issues concurrently.

Green hydrogen is a potentially zero-carbon industrial opportunity that could help African countries reduce their reliance on fossil fuels while also meeting the growing demand for energy at home, which is needed to boost economic development and create jobs. By harnessing the continent's strong renewable resource potential, key African countries can emerge as front-runners in the creation of transportable hydrogen energy and chemical and value-added hydrogen derivative products, thus paving the way for the development of new industries and export markets that could bring investment and sustainable development to the continent and helping the world reach net zero.

Green hydrogen has a key role to play in sustainably industrializing African economies

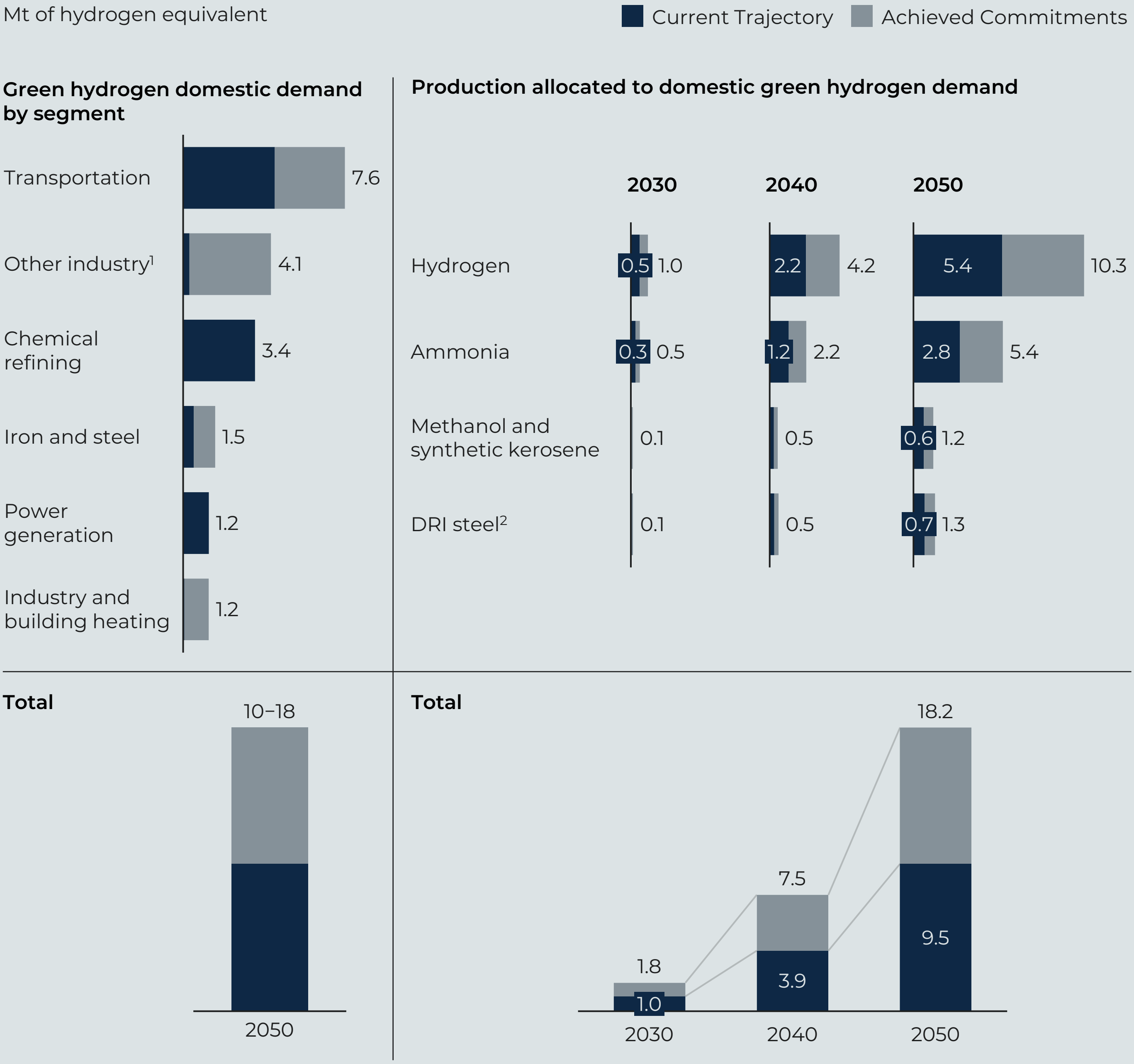
Green hydrogen offers an opportunity to develop clean energy-intensive industries that are competitive in overseas markets, in particular those with high carbon prices. Breakeven of hydrogen technology with incumbent technology would happen in several key applications in the next decade, even without regulatory intervention, and in some instances would provide a clear economic rationale for decarbonization. For example, adoption of hydrogen-powered mining trucks would reduce the carbon footprint of minerals and thus keep these minerals competitive in the global market that increasingly prizes carbon content alongside costs.

African domestic demand is likely to be driven largely by transportation and other industry, which includes cement, nonferrous metals, materials, mining, manufacturing, construction, food and tobacco, and agriculture and forestry. Hydrogen and ammonia are likely to be the major end products—accounting for roughly 85 percent of domestic ambition—with methanol, synthetic kerosene, and direct reduced iron playing smaller but still significant roles.

By 2050, the continent could self-supply its full domestic demand potential of between 10 to 18 Mt of hydrogen equivalent, as production costs in Africa are expected to be significantly lower than the landed cost of importing these products to Africa (**Exhibit 11**). Depending on the state of technology readiness, national ambitions, funding, and available incentives, as well as the actions taken by various African nations between now and 2030, there is potential for this domestic demand to increase even further.

Exhibit 11

Africa's domestic demand for green hydrogen and its derivatives could reach 10–18 Mt by 2050



[1] Cement, nonferrous metals, materials, mining, manufacturing, construction, food and tobacco, agriculture and forestry, and other unspecified industry.

[2] Steel made using direct-reduced iron. Green steel potential in 2050 is dependent on the availability of DRI-grade ore or availability of the technology to process low-grade ore.

Note: Potential estimated above is sensitive to the state of technology readiness, actions by various African nations between now and 2030, national ambitions, and the state of funding.

Source: McKinsey Global Energy Perspective; McKinsey and Hydrogen Council: Global Hydrogen Flows

African hydrogen exports could reach 20 to 40 Mt by 2050

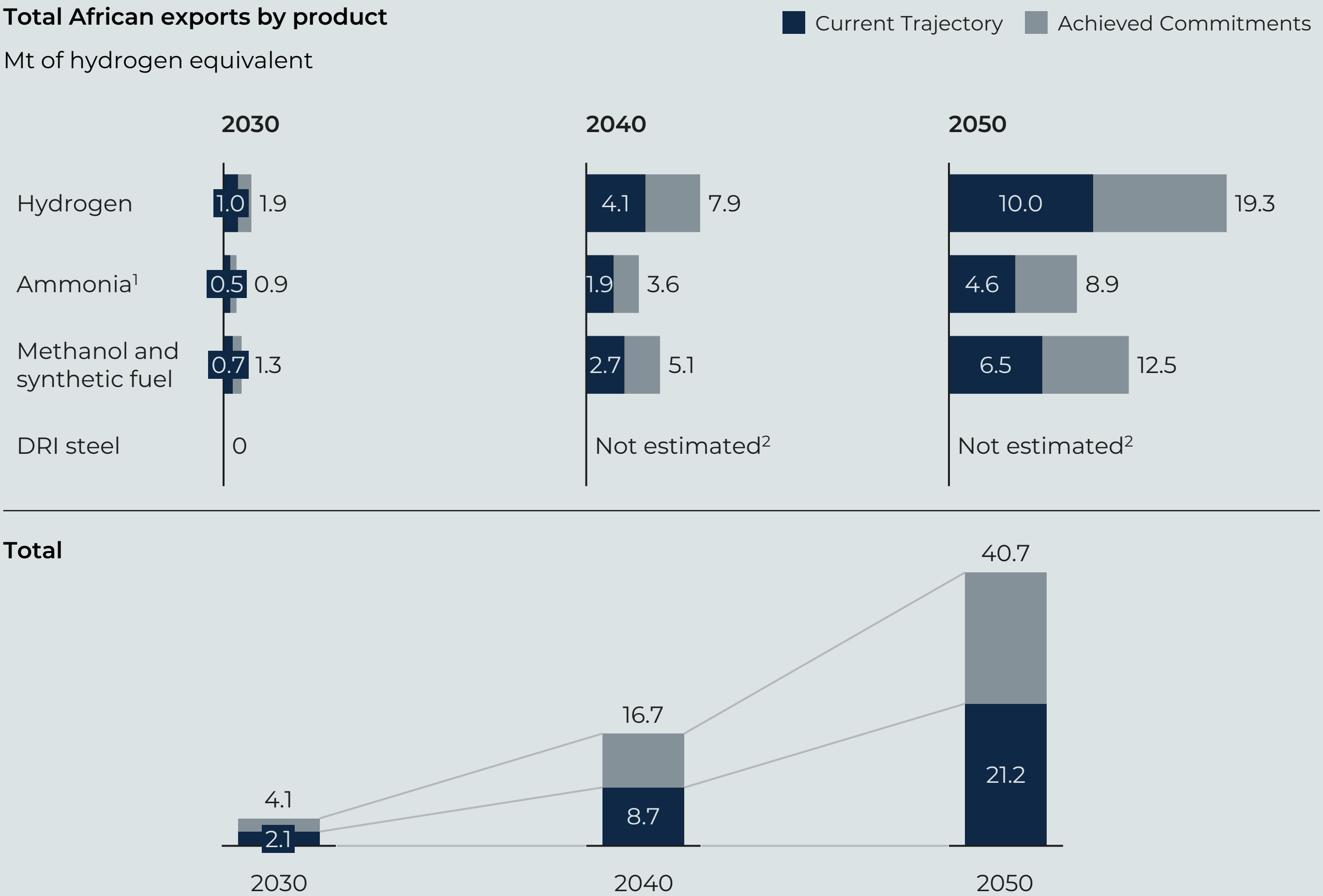
A significant portion of the green hydrogen produced in Africa will likely be destined for global export. As the applications for hydrogen and its derivatives develop, demand across the world is projected to rise sharply. In the Achieved Commitments scenario, the global import market for hydrogen and its derivatives could reach 180 Mt by 2050, with Europe, Japan, South Korea, and Southeast Asia potentially accounting for roughly 65 percent of the import market by 2050.

To meet the rising demand for hydrogen and its derivates from these high-demand centers, the seaborne hydrogen import market is expected to grow fivefold to sixfold between 2030 and 2050, with several countries with abundant renewable energy and relatively lower local demand for hydrogen well positioned to capture this space. Countries with complementary load profiles of wind and solar—of which parts of Africa are notable examples—have the highest potential to capture the full advantage of green hydrogen production to meet domestic demand as well as export it.

If African countries are able to build out low-cost hydrogen production and transportation systems, the continent's exports for green hydrogen and its derivatives could reach 20 to 40 Mt by 2050, with the mix of exported end products depending on several factors, including carrier technology and shipping routes (**Exhibit 12**).

Exhibit 12

Africa's exports of green hydrogen and its derivatives could reach ~20–40 Mt by 2050



[1] Excludes ammonia used as hydrogen storage and carrier.
[2] Export potential exists, for example, in Mauritania; however, the numbers were not quantified in this study.
Note: Potential estimated above is sensitive to the state of technology readiness, actions by various African nations between now and 2030, national ambitions, and the state of funding.

Source: McKinsey and Hydrogen Council: Global Hydrogen Flows

Northern and southern regions could emerge as key exporting hubs

As noted in the previous chapter, Africa offers an opportunity for several big offtakers to diversify their supply base, and could be a credible supplier to key demand hubs, primarily in Europe and Asia. AGHA members in both Northern Africa and Southern Africa could be competitively placed to capture these markets, notwithstanding supply competition from Australia and the Middle East.

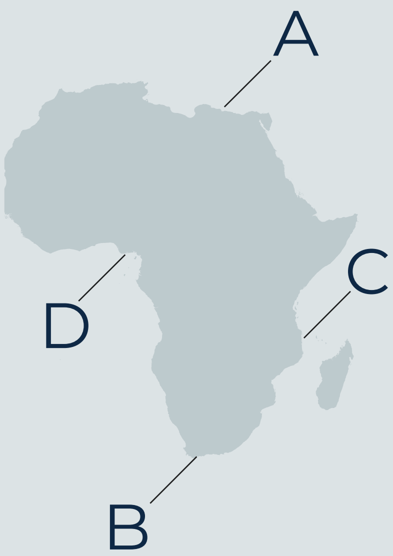
In Northern Africa, pure hydrogen exports are likely to dominate in the long term, and could reach 17 Mt by 2050, driven mainly by exports to Europe through new or existing pipelines. Southern African countries such as Namibia and South Africa could tap into an export market of 10 to 22 Mt of hydrogen equivalent. Methanol and synthetic kerosene exports are likely to dominate from Southern Africa and could reach

Exhibit 13

Northern and southern regions of Africa could emerge as key export hubs

Producing nations will likely see healthy competition among themselves for some derivatives, such as synthetic fuel

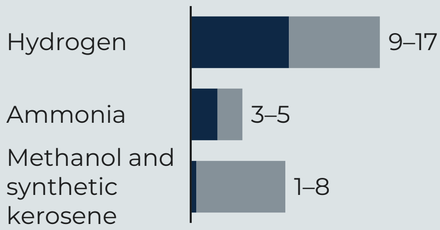
Achieved Commitments | Current Trajectory



A Northern Africa

Exports by region in 2050

Mt of hydrogen equivalent



Northern Africa has a **12–30 Mt of hydrogen equivalent** export opportunity, **mainly driven by delivering hydrogen to Europe** through **new or existing pipelines.**

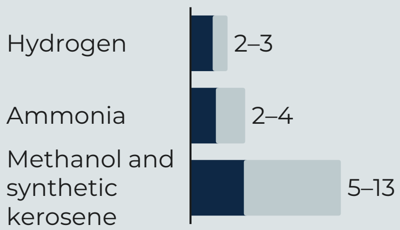
Ammonia exports could be largely directed toward Europe and South Korea.

There is a synthetic fuel opportunity in the Achieved Commitments scenario, supplying to key demand centers across the world.

B Southern Africa

Exports by region in 2050

Mt of hydrogen equivalent



Southern Africa, mainly Namibia and South Africa, could tap into a **10–22 Mt of hydrogen equivalent** export market.

Hydrogen and ammonia shipments are mostly directed to the Japanese, South Korean and Southeast Asian markets

Synthetic fuel presents a strong opportunity to serve global markets

C Eastern Africa

D Western Africa

Solar and wind profiles are less optimized for exports, likely more focused on domestic demand

Source: Expert interviews; McKinsey and Hydrogen Council: Global Hydrogen Flows

13 Mt of hydrogen equivalent by 2050 (**Exhibit 13**).

There may also be opportunities for seaborne exports of both ammonia and hydrogen from Southern Africa to Europe, which will likely want to diversify its supply to boost energy security, especially if low-cost suppliers fail to ramp up.

Finally, while hydrogen and ammonia import demand could largely be driven by Europe, Japan, and South Korea, demand for synthetic fuel is expected to be seen worldwide, with Europe, China, and India emerging as leading demand centers. There is thus a strong opportunity in synthetic fuels, with a possibility for African countries on both ends of the continent. Synthetic fuel exports from Africa could potentially reach 13 Mt by 2050 under the Achieved Commitments scenario.

AGHA's production could reach 30 to 60 Mt by 2050

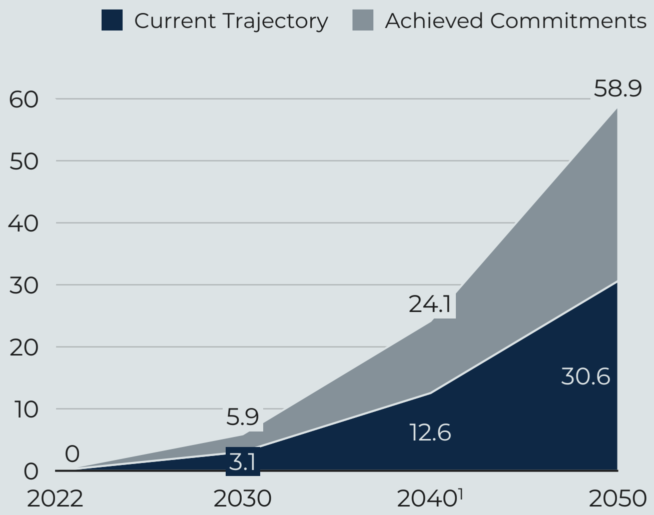
In the drive to meet rising domestic demand and capture key export opportunities, AGHA's production volumes could reach 60 Mt of green hydrogen and its derivatives by 2050 in the Achieved Commitments scenario. This is equivalent to roughly 22 percent of the potential global import market, or 10 percent of total global hydrogen demand (**Exhibit 14**).

Exhibit 14

AGHA's addressable market could reach 31–59 Mt by 2050

AGHA's addressable market for green hydrogen and its derivatives

Mt of hydrogen equivalent



	2030	2040	2050
Renewables capacity[2], GW	~51–97	~208–400	~507–975
Electrolyzer capacity, GW	~29–56	~119–228	~290–560

Underlying hypothesis for AGHA to capture this market

- **Investment attracted to build ~29–56 GW of electrolyzer** capacity and **~51–97 GW of dedicated renewables** capacity by 2030
- Renewable capacity for hydrogen built in such a way that it **supports further deployment of renewables for AGHA members' electrification needs**
- **Early offtake agreements secured**
- **Emerging early adopters** within Africa would lead green hydrogen development
- Demonstrated **cost competitive-ness** and continuous focus on keeping costs in the lower quartile of the global cost curve
- **Strong bilateral ties** with Europe, Japan, South Korea, China, and India
- **Deep technical expertise and funding pool** to steeply ramp up production after 2035

[1] Potential in 2040 is sensitive to the state of technology readiness, actions by various African nations between now and 2030, national ambitions, and the state of funding.
[2] Renewables capacity should be built in remote or stranded locations with tier-1 renewable endowment and deployed in such a way that it could also facilitate the continent's electrification needs.

Source: McKinsey and Hydrogen Council: Hydrogen Insights; expert interviews

Producing 30 to 60 Mt of green hydrogen would require total solar and wind capacity of between 510 to 975 GW, equivalent to ~25 to 50 times current solar and wind installed capacity in Africa,[13] and total electrolyzer capacity of 290 to 560 GW, depending on the decarbonization scenario. To reach this potential, AGHA members would need to take steps now to attract the investments needed to build between 29 to 56 GW of electrolyzer capacity and around 51 to 97 GW of dedicated renewable energy capacity by 2030, with the requirement to ramp up production after 2035, as well as to secure early offtake agreements. The renewable energy buildout should happen in such a way that it facilitates further renewable energy deployment for each member's electrification needs. Additionally, it may be helpful to secure deep technical expertise and funding to drive this ambition, and secure strong bilateral ties with key import markets including Europe, Japan, South Korea, China, and India.

Emerging early adopters within Africa that are leading green hydrogen development on the continent will have a key role to play in demonstrating cost competitiveness and credibility as African countries seek to build their reputation in the emerging hydrogen economy. To be able to compete successfully in the global hydrogen market, African producers would need to keep the cost of production in the lower quartile of the global cost curve.

The stakes are high because the hydrogen economy stands to greatly benefit AGHA members and other African countries that unlock potential opportunities, and could play a crucial role in enabling a just transition for the continent.

[13] Electricity generation and capacity by region, 2021, IRENA.

3. DELIVERING AGHA'S GREEN HYDROGEN AMBITION COULD SUSTAINABLY TRANSFORM AFRICAN ECONOMIES

The green hydrogen economy could create significant economic and social benefits for AGHA member countries and its people, along with environmental benefits that will be felt domestically and around the world.

As mentioned earlier, green hydrogen offers an opportunity to develop clean energy-intensive industries in AGHA member countries that are competitive in the European markets, in particular in those with high carbon prices. Green hydrogen could additionally play a significant role in reducing energy imports, meeting the rising energy needs of a rapidly industrializing economy, and accelerating the deployment of renewables across the continent, thus helping Africa meet its electrification needs.

Most of Africa lags behind the rest of the world in electrification rates[14]. As countries seek to accelerate access to electricity while reducing their reliance on fossil fuels and keeping emissions down, green hydrogen is looking increasingly viable. Investment in infrastructure and training of local workforces as part of green hydrogen projects could reduce the cost and complexity for subsequent renewable-energy-only deployment and help establish renewable energy supply chains. Furthermore, investors drawn to Africa through hydrogen projects could subsequently be more likely to get involved in other renewable energy deployment projects.

By delivering on AGHA's potential for green hydrogen and its derivatives, member countries could help abate about 6.5 Gt of CO_2 globally (equivalent to combined CO_2 emissions of US and Europe in 2021)[15] between now and 2050 in the Achieved Commitments scenario (**Exhibit 15**).

Delivering AGHA's green hydrogen ambition could add up to $126 billion to Africa's GDP and create around 4.2 million jobs by 2050 (**Exhibit 16**). The socioeconomic impacts modeled in this analysis focused on direct and indirect impact through supply chain stimulation of the hydrogen industry, from both one-off investments into new infrastructure and recurring benefits that the operation of these new hydrogen assets could bring.

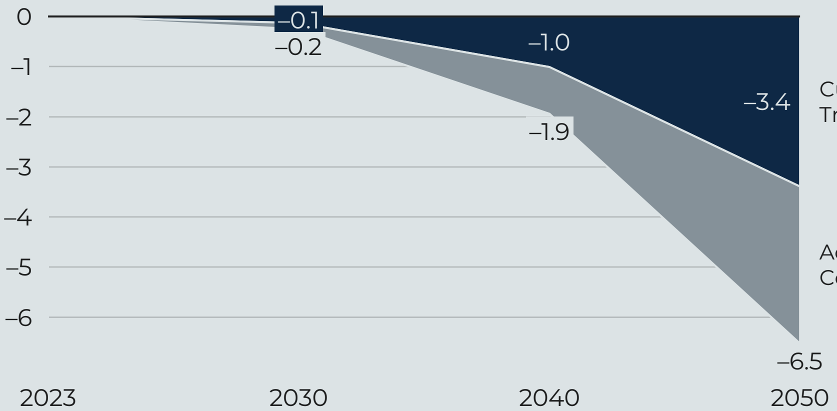
[14] Kannan Lakmeeharan, Qaizer Manji, Ronald Nyairo, and Harald Poeltner, "Solving Africa's infrastructure paradox," McKinsey, March 6, 2020.
[15] IEA global energy review, 2021.

Exhibit 15

Green hydrogen supply from AGHA members could help abate ~6.5 Gt of CO_2 globally

Abatement potential[1] from AGHA green hydrogen and derivatives production

Gt of CO_2 equivalent, cumulative



~0.6 Gt
of abatement in 2050

~6.5 Gt
of cumulative abatement by 2050

1 Emissivity factor based on global energy consumption over time.

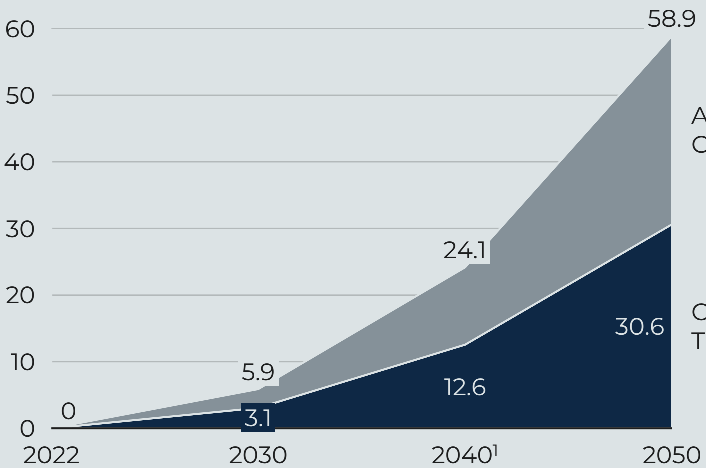
Source: McKinsey and Hydrogen Council: Hydrogen Insights; McKinsey Global Energy Perspective

Exhibit 16

AGHA members' green hydrogen ambition can create huge socioeconomic benefits

Africa's green hydrogen and derivatives production ambition

Mt of hydrogen equivalent



	2030	2040	2050
Gross value added annually, $bn	8–15	32–58	66–126
Jobs created annually, mn	0.2–0.4	1.0–1.9	2.2–4.2

$66bn–$126bn
in gross value added by 2050

2.2mn–4.2mn
new jobs created or sustained by 2050

1 Potential in 2040 is sensitive to the state of technology readiness, actions by various African nations between now and 2030, national ambitions, and the state of funding.

Source: McKinsey I3M model by Vivid Economics

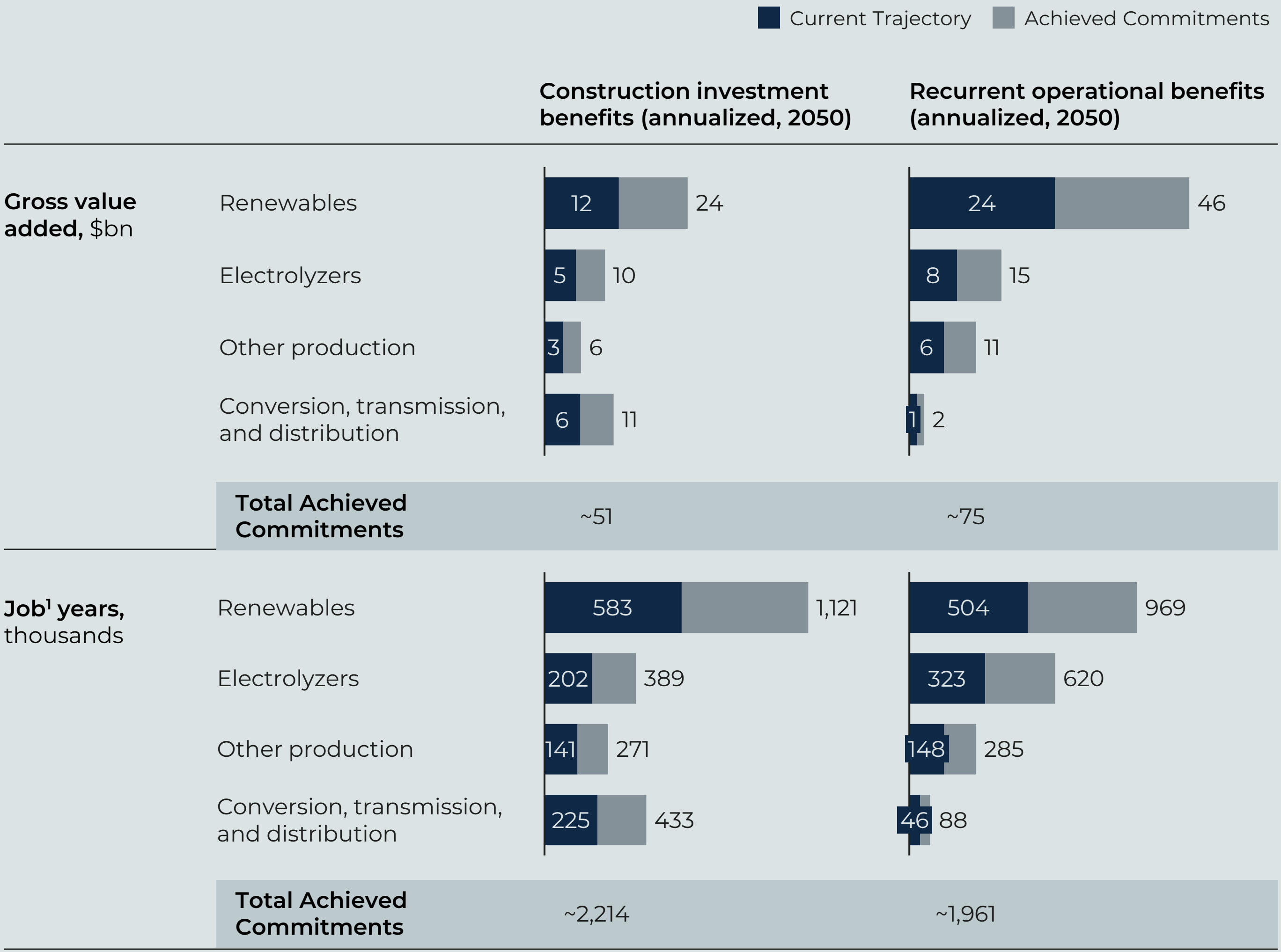
Construction investment would likely bring significant one-off benefits

To build a hydrogen economy, most countries would need to invest in new infrastructure and assets, including new hydrogen and renewable energy infrastructure, the manufacture of electrolyzers, infrastructure to facilitate the conversion of hydrogen to ammonia, and transmission and distribution assets such as pipelines and port infrastructure. This process could help create new supply chains and deliver an economic stimulus for the duration of the construction work.

The greatest economic stimulus by a significant margin would arise from the construction of renewable energy and electrolyzer infrastructure. In the Achieved Commitments scenario, renewable energy–related investments could yield about $24 billion in gross value added and electrolyzer infrastructure about $10 billion in gross value added, adding about 1.2 million jobs and 390,000 jobs, respectively (**Exhibit 17**).

Exhibit 17

Gross value added through recurrent benefits far exceeds that added through one-off benefits



[1] Jobs supported.
Note: "Other Africa" not shown.

Source: McKinsey I3M model by Vivid Economics

Additionally, economic activity would be generated in the associated supply chains that would need to be developed to support the construction of this infrastructure. Overall construction investment could contribute about $51 billion to GDP in 2050 in the Achieved Commitments scenario, equivalent to about 5 percent of the 2021 GDP of AGHA countries.

Operational benefits could far exceed one-off benefits

The operation of assets could bring about new recurring economic activity, including the use, maintenance, and exploitation of assets over their lifetimes, which would support jobs and contribute to overall economic growth and productivity enhancements. Again, this impact is likely to be highest in renewable energy infrastructure, followed by electrolyzer infrastructure—potentially reaching up to $46 billion in GDP contribution from renewable energy and $15 billion in GDP contribution from electrolyzers by 2050, and creating just under 1 million jobs and 620,000 jobs, respectively. An important caveat is that the skills required to operate assets in the hydrogen economy must be developed locally if the benefits are to be accrued by member countries.

Overall, the recurrent benefits of operating new hydrogen and renewable energy infrastructure could support about 2 million jobs and generate up to $76 billion per year in GDP contribution by 2050 in the Achieved Commitments scenario. This is equivalent to around 7 percent of the 2021 GDP of AGHA member countries.

Downstream benefits, which are not included in this analysis, could include greater innovation, the development of new local businesses, cheaper and more reliable energy supplies, increased electrification, and induced impact such as higher household wealth, leading to an increase in overall demand in the economy.

Realizing AGHA's green hydrogen potential will require $450 billion to $900 billion in cumulative investment by 2050

Realizing these socioeconomic and environmental benefits would require substantial investment. Funding would likely need to be made available at the national level to develop critical infrastructure, and access to financing for private ventures would need to be facilitated. As much as 70 percent of the required investments could come from foreign direct investment. In addition, AGHA member countries may also need to ensure that their respective workforces are sufficiently upskilled and able to fill the large number of skilled jobs that are likely to be created.

In the Achieved Commitments scenario, AGHA's hydrogen ambition could require up to $900 billion in cumulative investment by 2050 (**Exhibit 18**). This translates to about $6 billion each year between now and 2030, about $30 billion each year between 2030 and 2040, and about $55 billion each year between 2040 and 2050, which is around 2 percent of the annual total required investment into energy production and electrification components worldwide in the same period to get to net zero.

By far the largest share of capex required—about 70 percent—would go toward constructing renewable energy capacity and electrolyzer capacity. In approaching what will be a significant undertaking, African stakeholders will need to work together to create the optimal conditions to build out a sustainable hydrogen industry that positions the continent as a credible player in the fast-growing hydrogen economy. How they could achieve this is explored in more detail in the next section.

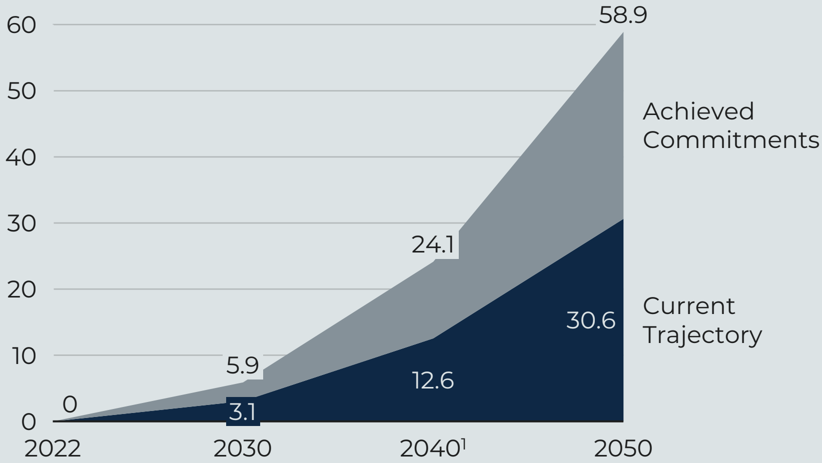
Exhibit 18

The ambition would require $450bn–$900bn in cumulative investment by 2050

70% of the investment is in fact an opportunity for foreign direct investment

Africa's green hydrogen and derivatives production ambition

Mt of hydrogen equivalent



	2030	2040[1]	2050
Cumulative investment, (2020–XX), $bn	~30–55	~175–330	~450–870
Approximate annual investment, $bn	~3–6	~15–28	~28–55

High investment needed

- **~$3bn–$6bn needed annually between now and 2030**
- ~$15bn–$30bn needed annually between 2030 and 2040
- **~$28bn–$45bn** needed annually between 2040 and 2050
  - — Equals ~2–3% of total energy investment needed annually worldwide around the same period to get to net zero
- **~70%** of the total investment in renewables and electrolyzer capacity building

[1] Potential in 2040 is sensitive to the state of technology readiness, actions by various African nations between now and 2030, national ambitions, and the state of funding.

Source: McKinsey and Hydrogen Council: Hydrogen Insights; expert interviews

4. UNLOCKING AGHA'S HYDROGEN OPPORTUNITY

Across the world, rapidly growing demand for hydrogen and its derivatives is creating a large import market that offers African countries a clear opportunity. However, capitalizing on this opportunity would require significant amounts of low-cost funding to scale up renewable energy capacity and hydrogen production facilities to meet burgeoning global and domestic demand by 2030. This, in turn, could create a thriving green hydrogen supply chain that could contribute to broadening economic growth with recurring economic benefits for African economies, including an increase in electrification rates and reduction in CO_2 emissions.

In approaching this opportunity, African stakeholders could work together to prioritize several actions to create the right conditions and establish themselves as leaders in this space.

Five potential steps to realizing AGHA's hydrogen potential

African stakeholders could take a staged approach to unlocking the continent's green hydrogen potential, starting from the basics and building momentum from there (**Exhibit 19**). This analysis outlines five enablers that AGHA member and other stakeholders could consider.

Exhibit 19

AGHA members could consider five key enablers to unlock Africa's green hydrogen potential

Set a national vision and build strategic partnerships
Leading by example in order to signal national commitment to mobilizing resources in support of hydrogen, seeking out support from like-minded national and multilateral partners and seeking buy-in from the wider public

Strengthen regulations
Creating certainty in projects to make them bankable and ensuring that the rules of the game are set in advance and understood by stakeholders

Improve access to low-cost financing
Ensuring that no project fails for lack of financing, especially in countries where risk premiums tend to be higher or countries which may not be fully integrated into global financial markets

Improve critical infrastructure
Enabling integration of value chains to remove physical barriers to generation, transmission, production, and transportation to end users

Support innovation and skills
Addressing skills and knowledge gaps, especially in countries which have not previously integrated downstream value chains

1. Set a national vision and build strategic partnerships

AGHA members could signal national commitment to mobilizing resources in support of the green hydrogen economy, starting with establishing a national vision and a country-level hydrogen road map that lays out commitments, targets, and actions. A clearly articulated vision and road map could play a key role in obtaining support from likeminded national and multilateral partners and getting buy-in from the wider public. For example, Morocco has published a green hydrogen strategy that maps out clear steps and goals for the country over the next 30 years, such as committing to 78 GW of electrolyzer capacity by 2050.

Leading countries are also leveraging bilateral and multilateral relationships to establish hydrogen partnerships to integrate value chains that can help signal their credibility as a supplier to the market. For example, Namibia and Germany signed a partnership in August 2021 to develop green hydrogen, with the aim of putting both countries at the forefront of clean energy innovation.

2. Strengthen regulations

AGHA members could take steps to ensure that clear, transparent regulations relevant to the production and adoption of green hydrogen are implemented in advance and understood by all stakeholders. This could be a game changer that fosters the right conditions for the green hydrogen economy to flourish in Africa and creates certainty around projects, thereby making them more bankable.

Morocco and Egypt are also demonstrating the value of developing and adopting common international standards. Both countries are party to the ISO technical committee that sets standards for the production, storage, transportation, measurement, and use of hydrogen, which could play an important role in harmonizing the global trade of hydrogen and its derivatives.[16]

3. Improve access to low-cost financing

As hydrogen projects are capex intensive, cost of capital is a key determinant of the levelized cost of hydrogen and this competitiveness. Therefore, access to low-cost financing is a critical prerequisite. While sufficient capital exists globally to finance the hydrogen economy, matching this to bankable projects is proving difficult. Concerted action could be required by African stakeholders to create an enabling environment for these international capital flows to help unlock green hydrogen in Africa. Several possibilities exist, including developing consortia and securing offtake agreements, developing public–private partnerships, providing credit guarantees, establishing incentives programs, and tapping into green and development finance institutions. These instruments could help ensure that no project fails for lack of finance, especially in countries where risk premiums tend to be higher, or in countries which may not be fully integrated into global financial markets. Several African countries are already making use of these strategies. For example, Egypt has embarked on a public–private partnership program with the European Bank for Reconstruction and Development to promote renewables. To date, public–private partnerships in Egypt have attracted significant investments, including large-scale solar photovoltaic plants built by Scatec. Mauritania has been able to leverage the carbon credit market to finance the expansion of one of the country's largest solar farms.[17] (See deep dive below for more.)

4. Facilitate deployment of critical infrastructure

Developing upstream and downstream infrastructure to support green hydrogen value chains would be required to build long-term capabilities of the sector on the continent. For example, South Africa is planning to develop a deep-water port in Boegoebaai supported by a 550 km railway line, bulk services, and associated social infrastructure to position the economy for green hydrogen export. Enhancements include constructing green hydrogen and green ammonia production sites, and a 30 GW solar and wind farm with 5 GW of electrolysis.[18]

5. Support innovation and skills

Finally, a thriving green hydrogen economy would not be possible without the relevant skills and innovation capacity to support it. Therefore, developing regional and international research and development

[16] ISO org.
[17] Introducing our solar power project in Mauritania, Klima.
[18] Opportunities in deep-water port development, GlobalAfrica network.

partnerships to support the growth of hydrogen skills on the continent could be key. Stakeholders could invest in local upskilling initiatives; for example, Namibia established the Green Hydrogen Research Institute in October 2021 to act as a national hub for hydrogen R&D, helping upskill Namibians and develop local businesses.[19]

Deep dive: Accessing low-cost financing is key to realizing AGHA's green hydrogen potential

In the Achieved Commitments scenario, an estimated $900 billion of investment may be needed through to 2050 to scale up green hydrogen in AGHA member countries, of which around $55 billion will be needed by 2030. Given the scale of investments required, a mix of public and private capital will be needed through consortium financing arrangements.

In order to secure low-cost capital to develop the green hydrogen industry, AGHA members will need to address different challenges for early- and late-stage financing. During the development phase, starting from the proof of concept all the way to finalizing technical design, some of the key risks are delays in confirming use-case potential, difficulties in securing long term offtake, difficulties in securing sufficient land at a cost consistent with the project risks, regulatory permitting, environmental risks, lack of stakeholder alignment, and counterparty risks. These risks can be largely managed by securing offtake at an early stage, building consortia that share risks and complement capabilities, and creating bilateral agreements that enable business-to-business exchange.

During the construction phase through to initial operations and ramp-up, some of the key challenges are project financing beyond the initial proof of concept, construction and development risk such as cost overruns, asset certification and approval, execution and operations risk, and sufficient revenue generation. AGHA members will need to tap into debt capital from larger pools such as green financing, multilateral or development finance institution funds. In addition, AGHA members will need to ensure that they have access to the required talent, and that key shared infrastructure is in place, the consortium is operating smoothly with clear governance, and the rules of the game are consistent (for example, permitting or tax regimes).

Consortia bring a number of benefits—having an offtaker as a member of the consortium is key

A consortium is a venture made up of two or more organizations that work together to achieve a common objective. As of April 2021, out of the 20 largest announced green hydrogen projects, the average project has six partners. **Exhibit 20** shows some of the roles that need to be filled in a consortium. Several consortia have potential green hydrogen offtakers as members. This allows developers to share part of the development risk in early stages.

Such consortia can provide substantial benefits to AGHA members, such as creating offtake certainty and risk sharing, creating a common front to unlock subsidies and funding, sharing skills and capabilities, and providing regional access. Financial burden and risk sharing could play a key role in reducing capex requirements for individual partners while helping build mutual commitment toward a project. The Asian Renewable Energy Hub has taken this approach to ensure that players along the entire value chain can partner with investors to spread the risk more evenly.[20]

A strong partnership can also enhance efforts to attract investment by providing a common front to unlock subsidies and funding. This could be particularly powerful when different types of partners are involved, such as industry players and local authorities. Partnerships also allow for the sharing of skills and capabilities, including for coordinated R&D. This could help unlock significant synergies, allowing partners to benefit from complementary capabilities and facilitating the transmission of knowledge. For example, in New Zealand, the complementary expertise of an energy player and a chemicals player working together helped build an integrated green fertilizer plant with innovations in direct air capture for CO_2 removal from ambient air using chemical processes.[21]

[19] Namibia Green Hydrogen Research Institute.
[20] *Renewable energy hub in Australia*, BP, 2022.
[21] Engie.

Exhibit 20

There are different roles to be filled in hydrogen consortia

	Role	Typical players
Project development	Develop the initial idea Find members Select and negotiate the site Secure permits Structure financing	Hydrogen developers (Renewable energy companies) *Frequently takes the lead of the consortium*
Electricity generation	Size the electricity generation requirements (eg, studies, designs) Select the OEMs	Renewable energy companies
Hydrogen production – Technology	Supply the electrolyzer technology Integrate technology with the project (eg, generation, transportation)	Electrolyzer OEMs
Hydrogen production – Operation	Operate the hydrogen production facilities	Industrial gas companies Utilities Hydrogen developers
Key infra-structure	Develop key infrastructure (eg, gas pipelines, ports, transmission lines)	Gas companies Ports Utilities
Go to market (offtakers)	Secure hydrogen offtake Trade/distribute the hydrogen	Chemical companies Refineries Gas companies Commodity traders Other hydrogen users

There are other players not directly related to the hydrogen value chain that can play key roles, depending on the project stage (eg, universities, governments, infrastructure funds, engineering, procurement, and construction firms)

And finally, partnerships could open doors, helping to secure market access and ensuring compliance with emerging local safety regulation and standards.

Regardless of the kind of partnership model that is chosen, governments could have a crucial role to play in supporting and encouraging effective partnerships by establishing regulations that help create certainty and enable consortiums to come together to pool capital and expertise.

Collaboration with international players could provide credit enhancement for investors and loan funds

Mobilizing international finance may require both direct and indirect financing to balance risk exposure for investors. Accessing direct financing for developing economies from development finance institutions such as the Green Climate Fund or the International Finance Corporation could help enhance existing private-sector capital (originating either locally or internationally) to overcome financing shortfalls. Indirect financing, such as partial credit guarantees, political risk guarantees, and first-loss provisions, could help manage project financial risks as well as hedge against downside political risks that some investors may perceive.

Bilateral agreements are key to enabling business-to-business exchange

International agreements could help deepen financial, trading, and R&D relationships by facilitating business-to-business exchanges, which could help further develop the African investment environment. Such agreements could help establish a framework for effective cooperation on specific issues such as regulation and supply chains, facilitate the issuing of joint statements and jointly funded research initiatives, and establish clear rules of ownership of intellectual property.

5. AGHA'S ROLE IN BUILDING OUT AFRICA'S GREEN HYDROGEN POTENTIAL

As green hydrogen technology matures and global demand for hydrogen and its derivatives starts to grow, there is a window of opportunity for Africa to establish itself as a first mover in this fast-evolving market. AGHA has a key role to play in fostering pan African collaboration, regional integration and preparing an enabling environment to realize the considerable economic value and social benefits at stake for both the members of the alliance as well as nonmembers.

Immediate actions and initiatives that AGHA could consider

In the next six months, there are a number of immediate actions and initiatives that AGHA could undertake to foster understanding of its green hydrogen potential and build momentum toward green hydrogen in its member countries and beyond (**Exhibit 21**).

Exhibit 21

There are a number of immediate actions and initiatives that AGHA can embark on to foster understanding and conviction

AGHA's immediate actions

- Organize around a set of **core lighthouse initiatives** to bring together members on key enablers
- Encourage members to **develop country road maps** and periodic reviews to maintain momentum
- Coordinate member **communications around major public announcements and investments,** including as part of COP 27
- Secure a mandate to **engage with international and multilateral actors** to facilitate dialogue between member countries

Enabler	Lighthouse initiative
Set a national vision and build strategic partnerships	Provide support to develop bilateral hydrogen partnership agreements
Strengthen regulations	Set up intergovernmental forums for exchange of information on standard setting
Improve access to low-cost financing	Lead work with development finance institutions to facilitate development of financing instruments
Improve critical infrastructure	Facilitate development of infrastructure road maps among AGHA members
Support innovation and skills	Work with training institutions to help develop robust training programs

1. Organize around a set of lighthouse initiatives

To support members at each stage of their green hydrogen journey, AGHA could organize around a set of core lighthouse initiatives. For example, it could assist stakeholders in setting a national vision and help them build strategic partnerships. To help strengthen regulations, AGHA could facilitate intergovernmental forums for the exchange of information on standard setting.

To improve access to low-cost financing, AGHA could work with development finance institutions to facilitate the development of financing instruments. To improve the critical infrastructure needed to support hydrogen production, AGHA could also work to facilitate the development of infrastructure road maps across its member countries. And finally, to support innovation and skills development, AGHA could work with training institutions to help the continent develop robust training programs for relevant hydrogen skills.

2. Build a collaborative and consistent environment

AGHA could encourage its members to develop country road maps and conduct periodic reviews of them to maintain investment and help coordinate member communications around major public announcements and investments, including as part of future United Nations Climate Change Conferences, to help build a collaborative and consistent environment. Such mandates could also support nonmember states in Africa.

3. Facilitate dialogue with international and multilateral actors

AGHA could support members' alignment around the key requests (for example, development aid support instruments, certification standards) and engage with international and multilateral actors to facilitate dialogue with member countries. This could be crucial to allow members to gain access to global markets and raise the necessary financing to build out their green hydrogen industries.

6. CONCLUSION

AGHA's potential for green hydrogen in Africa is big, and it could bring significant value to the continent—and indeed the world. However, realizing this potential will not be easy. The road ahead is likely to require strong leadership, creative partnerships, and the commitment of significant capital to create the enabling conditions and build the infrastructure required to support the necessary green hydrogen production, storage, and transportation for Africa to become a credible supplier in the global hydrogen economy.

In achieving these goals, collaboration will be key; no one country or company can do it alone. The scale and complexity of the transition means that the kind of deliberate collaboration that AGHA champions will be vital to connect all stakeholders working toward a common goal, including private-sector players that have mobilized large-scale capital, governments, which have the unique ability to create an enabling environment, civil society, which is key to ensuring that benefits flow to local communities and secure community buy-in, and industry players along the entire value chain that will be engaged in the day-to-day operation of this new industry.

Collaboration can also help reduce friction, enhance synergies in critical areas such as skills development and R&D, and increase innovation. Through collaboration, Africa can find better solutions faster than by working in silos.

Momentum toward building a green hydrogen economy is growing, but so too is the urgency to scale up global ambitions toward reaching net zero. If AGHA members can navigate the challenges outlined in this report to secure strong partnerships and mobilize the necessary financing, success is within grasp, bringing jobs and enhanced competitiveness to African economies and helping ensure that the continent thrives in the new global energy landscape.

APPENDIX

Methodology

The following five elements informed this analysis:

1. While there are multiple ways to produce hydrogen, ranging from steam methane reforming or autothermal reforming (which produce gray hydrogen; currently the dominant hydrogen production method) to methane pyrolysis and sequestration of solid carbon (which produce turquoise hydrogen), **only green hydrogen**, which is hydrogen made by the electrolysis of water using renewable energy,[22] was considered in building AGHA's ambition. Green hydrogen produces zero emissions if 100 percent renewable energy is used for its production.

2. **Two potential scenarios** were considered from McKinsey's five decarbonization pathways that are centered around the pace of technological progress and the level of policy enforcement: the Current Trajectory scenario and the Achieved Commitments scenario (**Exhibit 22**).

   The Current Trajectory scenario assumes that the current cost trajectory for renewables continues; however, currently active policies remain insufficient to close the gap to the 1.5°C ambition. In this scenario, global temperatures are expected to reach around 2.4°C and the global average CO_2 price required in 2030 and 2050 to fulfill this scenario would be €55 and €130, respectively. Prices were weighted by country and sector emissions, and are holistic in that they include both explicit costs (such as carbon taxes and the EU Emissions Trading System) and implicit costs (such as subsidies and feed-in tariffs) to incentivize abatement.

   The Achieved Commitments scenario assumes that net-zero commitments will be adopted by leading countries and implemented through purposeful policies, thereby further accelerating the transition, though financial and technological constraints remain. In this scenario, a 1.7°C temperature increase is targeted and CO_2 prices needed to fulfill this scenario would be €100 to €180.

   By contrasting these two scenarios, it is possible to get an idea of how impactful policies and actions taken by governments could be, and how African countries could position themselves to grasp the opportunity presented in the more ambitious scenario.

   For the most part, this report presents the numbers relating to the more ambitious Achieved Commitments scenario, although a detailed contrast is offered in most exhibits.

3. To **forecast demand**, expert and asset-based granular modeling was applied to more than 70 energy products, including hydrogen and its derivatives such as ammonia, methanol, synthetic fuel, and direct reduced iron, covering 55 segments, including transportation, industry, and power. Over 146 of the most relevant countries shaping global energy demand were considered. This modeling leveraged more than 20 state-of-the-art McKinsey assets, including the McKinsey Hydrogen Model, McKinsey's Sustainable Fuels Model, the McKinsey Power Model, and McKinsey e-truck Total Cost of Ownership Model.

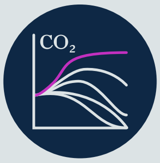
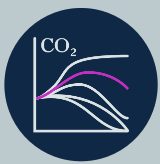
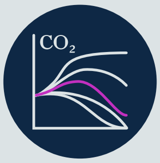
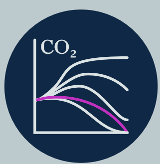
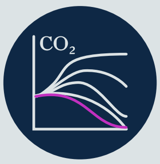
---

[22] Only solar and wind energy was considered in this report.

Exhibit 22

The Achieved Commitments and Current Trajectory decarbonization pathways were used for hydrogen demand and supply modeling

Scenarios center around the pace of technological progress and level of policy enforcement

Speed of energy transition	**Scenario description**			**Required CO_2 price**[1] €/ton of CO_2, 2030–2050	**Global temperature increase linked to expected emission levels**[2]
Slower		**Fading Momentum**	Fading momentum in cost reductions, climate policies, and public sentiment will lead to prolonged dominance of fossil fuels	<50	>2.4°C
		**Current Trajectory**	Current trajectory of renewable cost decline continues; however, currently active policies remain insufficient to close gap to ambition	55–130	2.4°C (1.9–2.9°C) *Included in this work*
		**Further Acceleration**	Further acceleration of transition driven by country-specific commitments, though financial and technological restraints remain	75–140	1.9°C (1.6–2.4°C)
		**Achieved Commitments**	Net-zero commitments[3] achieved by leading countries through purposeful policies; followers transition at a slower pace	100–180	1.7°C (1.4–2.1°C) *Included in this work*
Faster		**1.5° Trajectory**	A 1.5° pathway is adopted globally, driving rapid decarbonization investment and behavioral shifts	>200	<1.5°C

1 Global average CO_2 prices required in 2030 and 2050 to trigger decarbonization investments sufficient to fulfill the scenario. Prices were weighted by country and sector emissions, and are holistic in that they include both explicit costs (eg, carbon tax and EU Emission Trading System credits) and implicit costs (eg, subsidies and feed-in tariffs) to incentivize abatement.
2 Warming estimate is an indication of global rise in temperature by 2100 vs preindustrial levels (range: 17th–83rd percentile), based on Integrated Professional Course assessments, given the respective emissions levels and assuming continuation of trends after 2050, but no net-negative emissions.
3 Excluding international bunkers.

Source: McKinsey Global Energy Perspective

4. **Hydrogen trade flow** was forecast using the Global Hydrogen Trade Model, which optimizes production and trade flows across 1.5 million trade routes. The process considers inputs such as product demand, production costs and limits, transportation costs for pipelines and shipping, and diversification and security of supply constraints. Outputs include country-level production forecasts, volumes by hydrogen carrier technology, landed cost curves, and capex investment cost curves.

5. Finally, **adjustments were made for external factors**. Key importers and exporters were identified, and volume potential was aligned through stakeholder syndication along three key parameters:

   – Historical partnerships and trade ties (such as Northern Africa and Europe for natural gas)

   – Specific country priorities

   – Country capabilities including financial mechanisms for development finance institutions and policies to support renewable energy investments; the availability of technical resources, including research centers, in-house manufacturing expertise, existing hydrogen production pilots, and planned and existing infrastructure; and regulations, including the existence of special economic zones, and stakeholder authorities in the country.

Assumptions

A number of assumptions were made in this research in three key areas:

1. **Demand and Technology**

   – Hydrogen will become one of the key vectors of decarbonization across mobility and other hard-to-abate sectors.

   – Net-zero momentum will persist and several demand centers around the world will continue to support the hydrogen economy via investments, policy alignment, and demand creation.

   – Technological improvements in hydrogen end-use applications will continue to reach competitiveness with incumbent and other decarbonization alternatives.

2. **Supply and cost**

   – The cost of renewable energy will continue to decline, driven by huge uptake around the world.

   – Momentum in the global scale-up of electrolyzers will continue and the required capacity is built up to unlock learning and cost decline.

   – Renewable energy plants and electrolyzers are developed in a coordinated way, solving for optimized, cost-effective design each time and supporting future renewable development for the continent's electrification needs.

   – Hydrogen carriers such as ammonia, liquid hydrogen, and liquid organic hydrogen come of age for shipping and become mainstream by 2030, driven by large-scale investment in shipping infrastructure for liquid hydrogen.

3. **AGHA production**

   – Buyers will sign long-term bilateral contracts to underwrite a stable source of demand.

   – African suppliers will be able to leverage stable demand to raise funding and develop infrastructure.

   – AGHA members will overcome the challenges identified in this study (see Chapter 3), including timely investment into the required infrastructure.

Acknowledgment

We, the Africa Green Hydrogen Alliance (AGHA), carried out this joint research with McKinsey & Company. We would like to acknowledge McKinsey's role as a knowledge and analytical partner, with special thanks to Kartik Jayaram, a senior partner in Nairobi; Kannan Lakmeeharan, a partner in Johannesburg; Amina Kandil, a partner in Cairo; Hauke Engel, a partner in Nairobi; Maurits Waardenburg, an expert associate partner in Brussels; and Ashish Srivastava, a consultant in London.

We are deeply grateful to Rachel Fakhry, green hydrogen sector lead with the Climate Champions Team, for her continuous leadership throughout this engagement. We are also grateful to Inês Marques, director of the green hydrogen development plan at the Green Hydrogen Organisation; Joyce Kabui, Africa manager at the Green Hydrogen Organisation; and Jabri Ibrahim, green hydrogen and youth engagement manager for Africa with the Climate Champions Team for their support in organizing several collaboration sessions with AGHA members, including the Green Hydrogen Summit in Abidjan, Côte d'Ivoire, in September 2022.

A special thanks goes out to Mohamed Hafez from the Egyptian Electricity Holding Company; Ahmed Hafez from Egypt's Ministry of Electricity and Renewable Energy; Eric Mwangi from the Kenyan Ministry of Energy; Khroumbaly Lehbib, Ismail Abdel Vetah, and Hanefy Ahmedou from Mauritania's Ministry of Petroleum, Energy and Mines; Samir Rachidi, Nouhaila Nabil, and Ayoub Hirt from Morocco's Institut de Recherche en Énergie Solaire et Énergies Nouvelles (IRESEN); Frans Kalenga from Namibia's Ministry of Mines and Energy; James Mnyupe, Namibia's Hydrogen Commissioner; Masopha Moshoeshoe from South Africa's Investment and Infrastructure Office; and Mahandra Rooplall from South Africa's Industrial Development Corporation.