REPORT

Integrated Africa Power

AFRICA IN THE GLOBAL HYDROGEN ECONOMY

THOUGHT COLLECTIONS

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1. Green Hydrogen – a background

1.1 What is hydrogen and what can it be used for?

Hydrogen is on the road to be the energy carrier of the future. If it is produced from renewable power sources, it is climate-friendly and frequently called "green hydrogen". and Due to its ability to being transportable over long distances and storable over long periods of time, hydrogen has the potential to contribute to the energy transition away from fossil and towards renewable sources. Green hydrogen can also be used as a feedstock for the production of chemicals like ammonia (from which fertilisers are derived), synthetic fuels or in steel making. In this way hydrogen might become the basis for climate-neutral mobility, industry and electricity and heat supply. The molecular form of hydrogen, which is of interest as an energy carrier and feedstock, is the diatomic molecule H2 which is a gas at mild ambient conditions. Hydrogen can be challenging to store and transport. It must generally be compressed to high pressures, liquified at very low temperatures, or stored within a porous material. It may leak more readily than current gaseous infrastructure fuels like natural gas or propane. It can also embrittle some current infrastructure materials such as pipeline steels, posing challenges for their immediate use for hydrogen without refurbishing

1.2 What hydrogen production pathways and types of hydrogen are there?

Main hydrogen production pathways: Hydrogen can be produced using multiple processes and energy sources. Color codes are used to differentiate between different processes. The figure below give an overview of the color code, respective production processes and energy sources used for these processes. Grey hydrogen is produced by steam methane reforming (SMR) or gasification of coal.

Blue hydrogen is produced by SMR or coal gasification including carbon capture and sequestration (CSS) technology. Turquoise hydrogen is obtained-through pyrolysis of methane. Green hydrogen is produced through electrolysis of H2O (water) using electricity from renewable energy sources. In this process, water is split into hydrogen and oxygen. The focus of activities conducted throughout the underlying stakeholder consultation process is laid on green hydrogen.

1.3 How can hydrogen help enabling the energy and industry transition?

Hydrogen can be used for generating electricity with the help of so-called hydrogen fuel cells where electric energy is created by burning hydrogen together with oxygen to create water. The electric energy produced in this process can, for example, be used in stabilizing a grid or for transportation. These properties make it a powerful enabler for the energy transition, with benefits for both the energy system and end-use applications:

- Enable large-scale, efficient renewable energy integration
- Distribute energy across sectors and regions
- Act as a buffer to increase system resilience – energy storage
- Decarbonize transport especially long-haul trucks, aviation, shipping
- Decarbonize industry energy use, especially high temperature heat
- Serve as chemical feedstock using captured carbon
- Help decarbonize building heating.

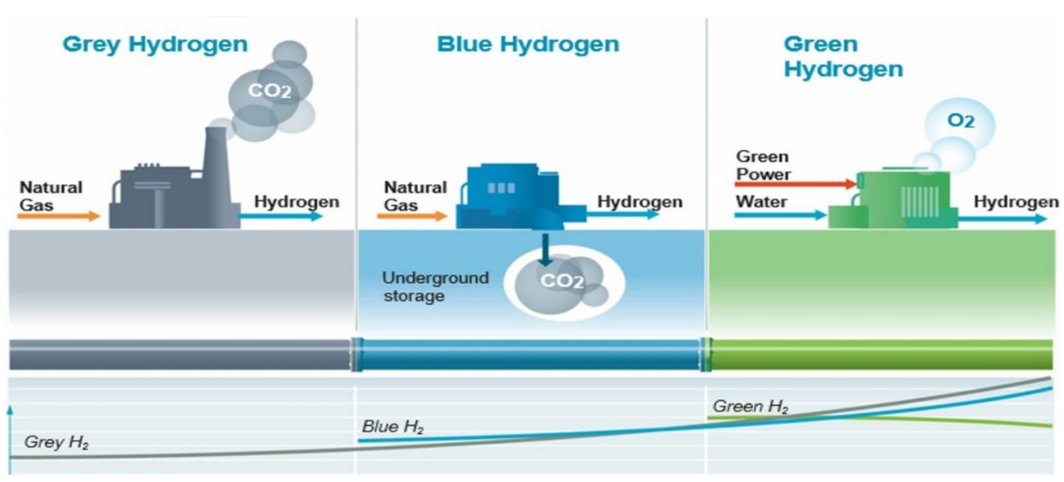

Figure 1. - Forms Of Hydrogen

1.4 Why are green hydrogen partnerships on the (political) agenda?

To counter climate change, governments and industries are driving the energy transition to adopt various measures to reduce their climate impacts while maintaining the stability of their economy. Green hydrogen technologies are one of the upcoming central topics in the energy and green feedstock transition. Three main reasons are driving different nations to pursue the development of a green hydrogen economy: (1) decarbonisation, (2) export potential and (3) energy security. Like the fight against the climate crisis and advancing the energy transition, the development of a green hydrogen economy and trade is a global challenge: this is because green hydrogen cannot be economically produced to the same extent everywhere. Green hydrogen will be most economically produced in locations that have an optimal combination of abundant renewable resources, available land, access to water and the ability to transport and export hydrogen and hydrogen products to large demand centres. Currently, the development of green hydrogen partnerships is widely discussed at the political level, with Europe and the U.S. as prospective importing countries and many countries of the global South as potential exporting countries. Green hydrogen can act as a catalyst for accelerating clean energy investment, market development, energy access, cost digression and leapfrogging towards 100 % renewable energy globally.

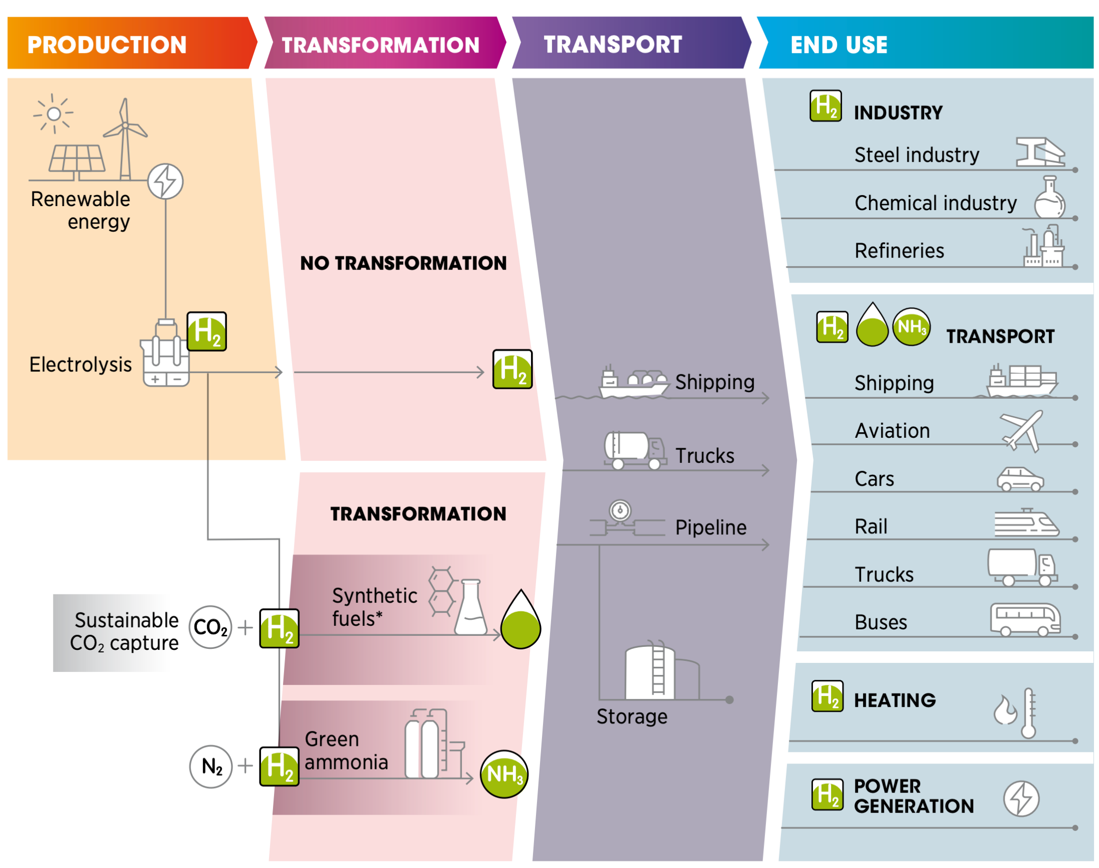

Figure 2. - Green hydrogen value-chain, processes and various uses (IRENA, 2020).

2. Green hydrogen of Africa – an Interview

Africa's size and its abundance of renewable energy and mineral resources make it ideal for green hydrogen production. Indeed, some large scale projects are already in the making. But will green hydrogen become just another exploited African resource? pv magazine Global recently sat down with Chigozie Nweke-Eze, founder of Integrated Africa Power (IAP), to discuss the green hydrogen opportunity for Africa and whether resources can be used for export industries when domestic needs are so high.

Chigozie Nweke-Eze
CEO, Integrated Africa Power (IAP)

Green hydrogen is being touted as Africa's next great resource – and therefore, as history wil tell us, it's next great export, too. The continent has no shortage of sun and wind – what else will it need to develop green hydrogen at scale in this decade?

Africa has abundant energy resources for green hydrogen development, but it will also need enabling conditions, huge financing, and technical supports to be able to leverage these potentials for the production and transportation of green hydrogen competitively

Several African countries, especially around the Northern and Southern Tropics, have excellent solar (average daily potential of 4.49 kWh/kWp) and wind resources (180,000 TWh per year) for potential green hydrogen production. Africa also has large untapped hydropower potential, estimated at over 250 GW, mainly located along the Congo and Nile rivers. Countries like South Africa and the DRC have an abundance of mineral resources essential for producing clean hydrogen and other renewable energy technologies. South Africa's unique endowment in platinum group metals an important mineral for manufacturing electrolyzers gives it a particular advantage in the growing green hydrogen mar ket. However, despite these abundant renewable energy resources many countries in Africa still face daunting energy related challenges. More than 640 mil lion. Africans have no access to electricity, placing the velectricity access rate on the continent at just over 40% the lowest in the world. Per capita consumption of energy in sub-Saharan Africa (excluding South Africa) stands at just 180 kWh, compared to 13,000 kWh per capita in the US and 6,500 kWh in Europe. Moreover, renewables remain at an early stage of development, accounting for only 20% of the African power mix (consisting of 15% hydropower and 5% from other renewable energy sources). Given this reality, any capacity additions for the production of green hydrogen raise the question of whether they are coming at the expense of expanding access to renewable energy supply for local users, both to meet socio-economic needs and enable clean industrial development on the continent. Furthermore, the production of green hydrogen comes with significant demand for water. Given the increasing levels of water scarcity across large parts of Africa, this raises additional questions regarding the sustainability of green hydrogen production in these regions.

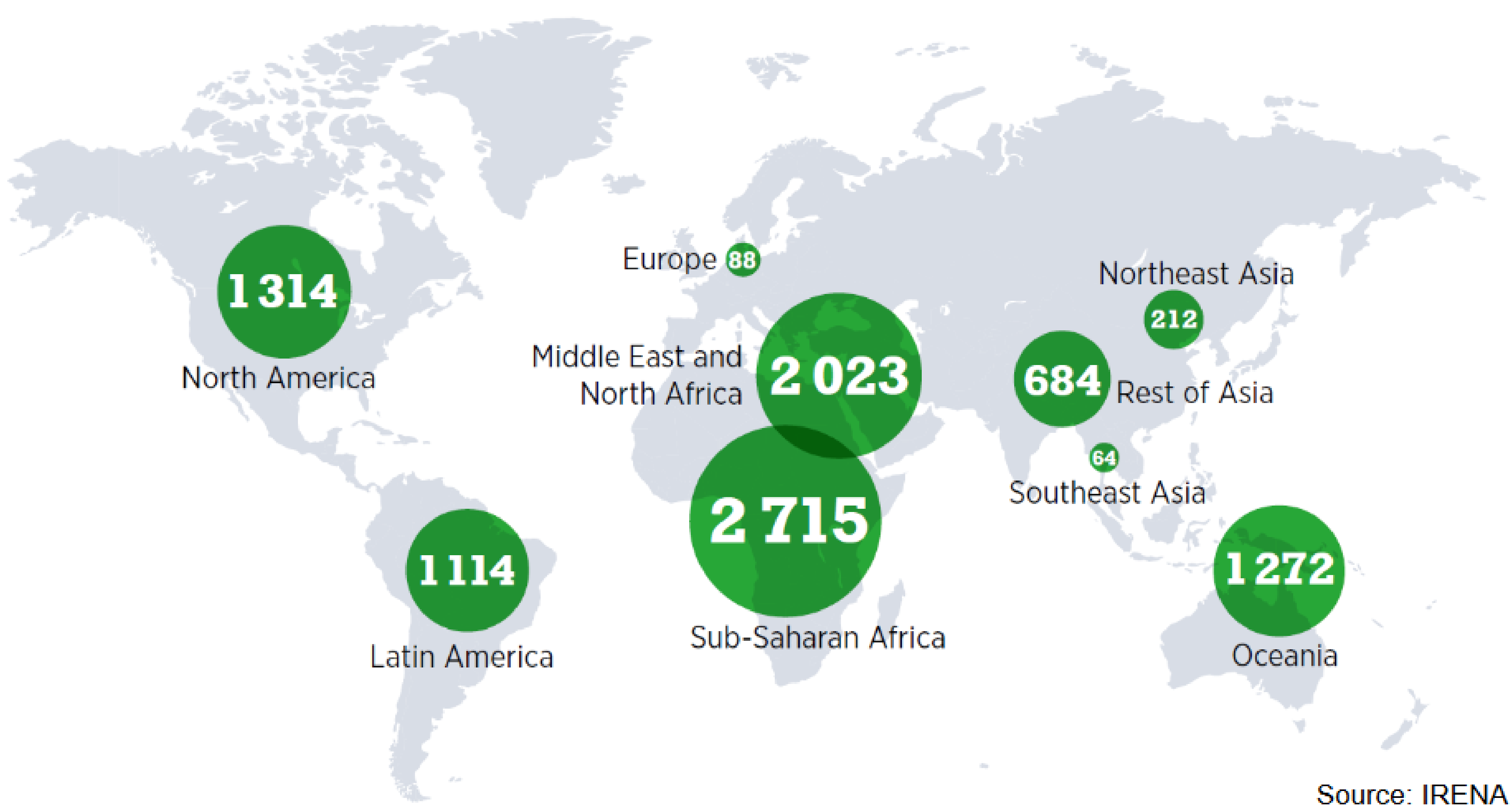

Figure 3. - Technical Potentials of Green Hydrogen Production, with Sub-Saharan Africa and MENA region taking lead. (IRENA 2020)

How far along are the promising projects?

Most of the potential green hydrogen projects are in the feasibility study and planning phases (in the case of South Africa, Morocco and Egypt) or in early stages of project development (in the case of Namibia and Angola). To give a few specific examples, we can look at the $10 billion Hyphen Hydrogen Energy project in Namibia, – an investment equivalent to the country's annual GDP. At full capacity, the project is expected to generate 300,000 tons of green hydrogen per annum for domestic use and for export. The large scale project will require 5 GW to 6 GW of renewable generation capacity and 3 GW of electrolyzer capacity, estimated to cut 5 to 6 million tons of CO_2 every year.

A similar project in Angola from the state-owned oil company Sonangol in conjunction with German companies Conjucta and Gauff Engineering is looking to develop 280,000 tons of green ammonia for export to Germany by 2024. Germany is also expecting production of green hydrogen and its derivative products from projects in the works in Morocco. South Africa published its hydrogen society roadmap in early 2022. The country aims to deploy 10 GW of electrolyzer capacity by 2030, producing 500,000 tons of green hydrogen every year. Hopefully, the commitment of $8.5 billion from the US, UK, France, Germany and the European Union at the recent COP26 in Glasgow will spur developments in the green hydrogen sector. In Mauritania, a framework agreement was signed between the government and Chariot Ltd to guide the next steps for the ambitious 10 GW green hydrogen project known as Project Nour. Chariot has already signed an agreement with the Port of Rotterdam in the Netherlands for the import of up to 600,000 tons of green hydrogen per annum from the proposed project.

With so many Africans lacking access to electricity, is green hydrogen looming as yet another valuable African resource to be exploited and exported?

There is a risk of relegating energy access pursuits in the race for green hydrogen production in Africa. African countries should see that the role of green hy drogen for climate neutrality is secondary to direct electrification based on renewables deployment. It is important that the green hydrogen projects are not developed at the expense of progress in energy, water and food access in the continent. Green hydrogen projects should be additional, in the sense that they add value to already existing pursuits of energy security and transition, along with improved water supply through desalination for others' use in agriculture, drinking and sanitation. Certain percentages of produced green hydrogen also be used domestically to advance energy security and green industrialization.

Namibia seems to have taken a strong export perspective. Its SCDI Hydrogen Project is one of the continent's most ambitious. Will the global market be ready for it?

Countries like Germany have expressed interest in importing about 50% of their green hydrogen needs. Such countries who are ready and willing to import green hydrogen can be a ready market for Namibia's green hydrogen. It is however important that the production of green hydrogen in African countries is both cost effective and sustainable so as to compete favourably with potential green hydrogen export from other countries like Chile.

Key to transporting green hydrogen over long distances is pipeline infrastructure some natural gas pipelines between North African nations and Europe currently exist. Are there plans for more?

Yes, there were plans for the construction of the Trans-Saharan gas pipeline which was supposed to be an extension of the West Africa Gas Pipeline (WAGP) to Europe (Spain) through Algeria. But this plan did not work out, so the pipelines are now planned to remain in the continent, but not to reach Europe. In its replacement, the Nigeria-Moroccan Gas Pipeline is currently underway to transport gas from Nigeria to Europe through Morocco. The pipeline is still under construction and is expected to be finished in 2046. It makes sense to construct the pipelines to be able to transport hydrogen to Europe as well.

In May, Kenya, South Africa, Namibia, Egypt, Morocco and Mauritania founded the Africa Green Hydrogen Alliance to make the continent a front-runner in the race to develop green hydrogen. What role will intra-African collaboration play in this market?

It will allow for complimentary cooperation in green hydrogen projects. Such collaboration will also allow for sharing of know-hows and best practices for green hydrogen production in the African context. Further, countries could cooperate to balance out peculiar risks for green hydrogen production at competitive prices. For instance, countries with huge solar potential but with water constraints or political instability (like Niger and Mali) could partner with neighbouring countries with more abundant water supply and security.

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https://www.pv-magazine.com/magazine archive/green-hydrogen-of-africa/

3. The promise of African clean hydrogen exports: Potentials and pitfalls

Abundant energy resources in many parts of Africa position the continent as a potential location for the production and export of climate friendly hydrogen, based either on renewable electricity (green hydrogen) or natural gas in combination with carbon capture and storage technologies (blue hydrogen). Green hydrogen is produced via electrolysis by splitting water molecules into their component parts using renewable electricity, while blue hydrogen is produced by splitting natural gas into hydrogen and CO2—after which the CO2 needs to be captured and stored.

Several African countries, especially around the Northern and Southern Tropics, have excellent solar and wind resources. Africa also has large untapped hydropower potential, mainly located along the Congo and Nile Rivers. Countries like Nigeria, Algeria, and Angola have some of the largest gas reserves in the world. Blue hydrogen has been suggested as a low-carbon option for these countries as they seek to diversify their fossil fuel-dependent economies. This large resource potential has spurred political engagement by a number of European countries, most notably Germany. The German government has partnered with several African countries to develop a Hydrogen Potential Atlas and has committed $45.7 million to the National Green Hydrogen Development Strategy of Namibia. Germany and the Democratic Republic of the Congo have taken up discussions that could see the country relaunch the controversial Inga Dam III project. Germany has also set up so-called Hydrogen Offices in Angola and Nigeria to facilitate dialogue with these fossil fuel-exporting economies.

3.1 The Politics and Economics of Hydrogen in Africa

But how realistic are these ambitions, given a number of factors complicating the region's pursuit of this energy carrier?

First, hydrogen development cannot be separated from Africa's broader energy landscape. More than half of the African population lacks access to electricity. Per capita lconsumption of energy in sub-Saharan Africa (excluding South Africa) stands at 180 kWh, compared to 13,000 kWh per capita in the U.S. and 6,500 kWh in Europe. Renewables also remain at an early stage of development: In 2018, the continent generated approximately 180 TWh of renewable power—approximately 20 percent of electricity generation and less than 0.02 percent of its estimated potential.

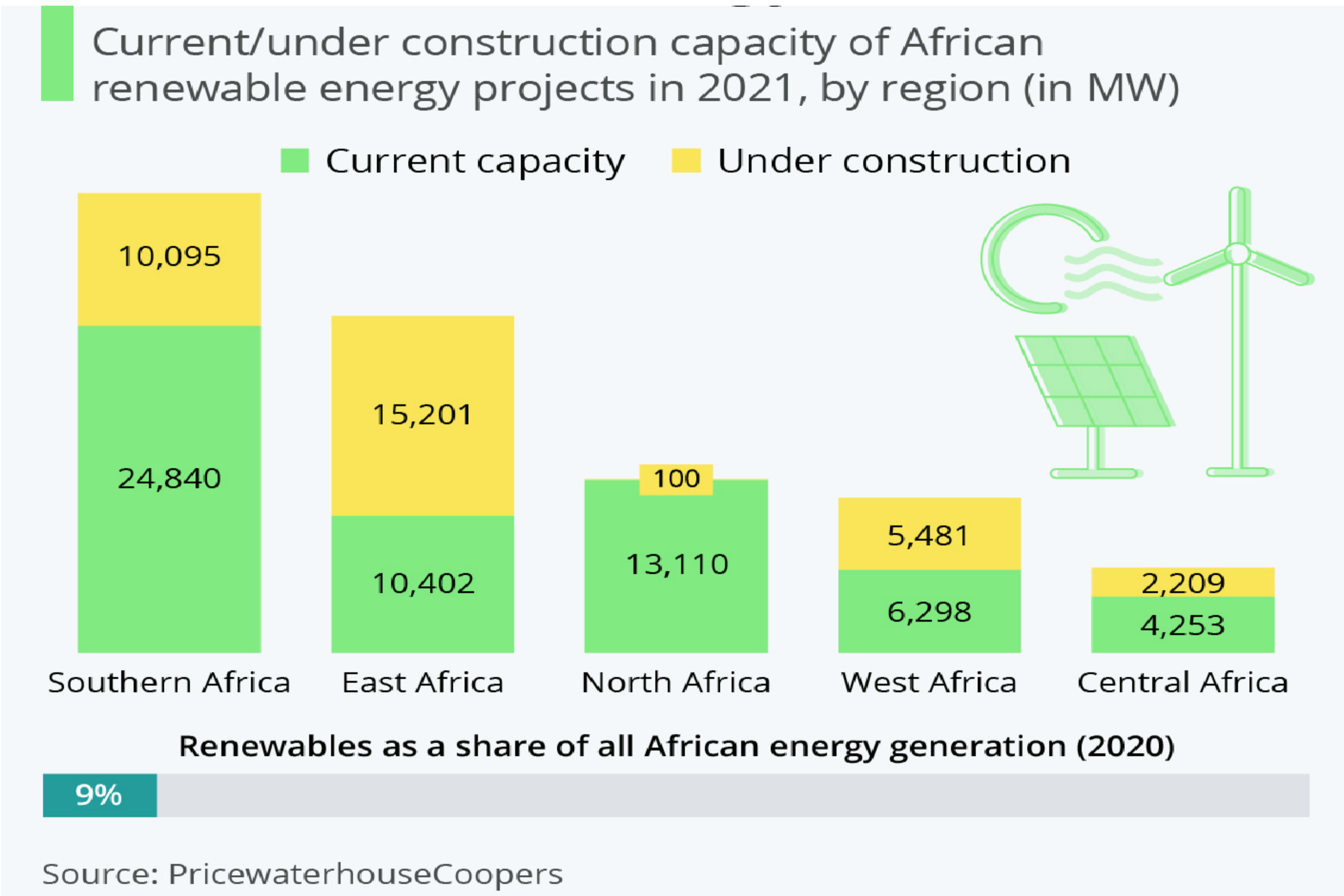

Figure 4. - Renewable Energy In Africa. Source: PricewaterhouseCoopers

Despite the large potential, capacity additions for the production of green hydrogen raise the question of whether they are coming at the expense of expanding local access to renewable energy to meet socioeconomic needs, to ena able clean industrial development, and to meet domestic climate targets within the context of the Paris Agreement. Furthermore, the production of green hydrogen comes with a significant demand for water at a time of increasing levels of water scarcity across Africa especially in the northern and the Sahel regions. Similarly, the prospect of blue hydrogen as a climate-friendly energy carrier remains highly uncertain, due to residual greenhouse gas emissions, the need for safe CO2 storage sites, and controversy related to the viability of carbon capture and storage technologies.

West Africa alone could produce approximately 120,000 TWh of green hydrogen per year at a price of less than $2.63/kg, assuming no water constraints. However, the cost of transporting hydrogen hampers this competitiveness. Maritime shipping, considered the most cost effective for distances over 3,000 km, would add an estimated $1 to $2.75/kg. For shorter distances, the cost of pipeline transport could be considerably lower, estimated at $0.18/kg per 1,000 km for new hydrogen pipelines and $0.08 for retrofitted gas pipelines.

Though such infrastructure investments carry high costs and are frequently hampered by delays, current pipelines, when repurposed, could offer a starting point for Africa's hydrogen trade. Current international pipeline infrastructure in Africa mainly consists of pipelines transporting natural gas from Northern African countries to Europe as well as connections between Egypt and the Middle East. In addition, the West African Gas Pipeline (WAGP) network, which currently transports gas from Nigeria to neighboring countries Benin, Togo, and Ghana, also offers potential for transporting hydrogen. It is the starting point for the recently launched Nigeria-Morocco Pipeline project, which could potentially be further extended to Europe. If constructed as "hydrogen ready," the WAGP could be repurposed for the export of hydrogen from West African countries. However, its success will depend on the interests of the Nigerian and Moroccan governments.

3.2 Hydrogen Development in Africa's Green Energy Front-runners

In addition to export-oriented ambitions, African countries are pursuing different, local applications of green hydrogen and related industrial development opportunities. For example, Morocco, a major exporter of fertilizers, plans to replace imports of conventional ammonia with domestic green ammonia, with its first project to start construction in 2022. Similarly, Egypt is investing in a facility for the production of 1 million tons of green ammonia annually.

South Africa has launched a strategy aimed not only at the production of hydrogen but at the domestic manufacturing of hydrogen-related technologies and products. Building on its endowment in platinum-group metals—a key metal for the production of hydrogen technologies, the South African government is promoting an industrial corridor stretching from the Limpopo mining region through Johannesburg's industrial district to Durban. The country's chemicals and energy giant, Sasol, has launched an initiative for landmark green hydrogen projects, aimed at greening existing materials and chemical value chains.

Whether ambitions to export large quantities of hydrogen from Africa to Europe will be feasible remains an open question, given the constraints around transport infrastructure, water access, as well as crucial climate-related considerations. Moreover, any strategy to develop hydrogen exports will have to take into account the industrial policy ambitions of important players on the continent or risk losing the goodwill of these key allies.

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4. Africa has what it takes to supply green hydrogen to the world – but what must be considered?

4.1 The World needs green hydrogen supply from more competitive sources

As the global pursuit of carbon-neutrality targets intensifies, the production of green hydrogen, has emerged as a key pillar for fostering a transition to climate-neutrality. Green hydrogen, produced through splitting water molecules into its constituent parts via green-powered electrolysis, is seen as a pathway for reducing the carbon footprint of today's CO2-intensive hydrogen production. It is particularly seen as an energy vector for decarbonizing the hard-to-abate sectors, as well as a possible long-term storage medium in a future energy system dominated by variable renewable energy sources. In the advent of the recent Russian war and the subsequent shortage of gas supply to the European Union, many countries have increased efforts in its pursuit of other energy options, by turning to green hydrogen development. Countries like Germany has stated that it is willing to import up to 50% of its total green hydrogen needs from countries with more competitive sources, and has subsequently earmarked EUR 2 billion to support green hydrogen projects.

The country created H2-Global to facilitate and catalyze green hydrogen and Power-to-X (PtX) products importation in Europe. It also set up the International Hydrogen Ramp-Up Program (H2-UPPP) to support SMEs (small and mid-size enterprises) in developing and emerging countries in pilot projects development. In Africa, countries such as Namibia, Morocco, South Africa, Egypt, and Angola are already pursuing green hydrogen and ammonia projects in different scales. In May 2022, Kenya, South Africa, Namibia, Egypt, Morocco and Mauritania, came together to form the Africa Green Hydrogen Alliance, with aim to make the continent a frontrunner in the production and supply of green hydrogen through collaboration and sharing of best practices.

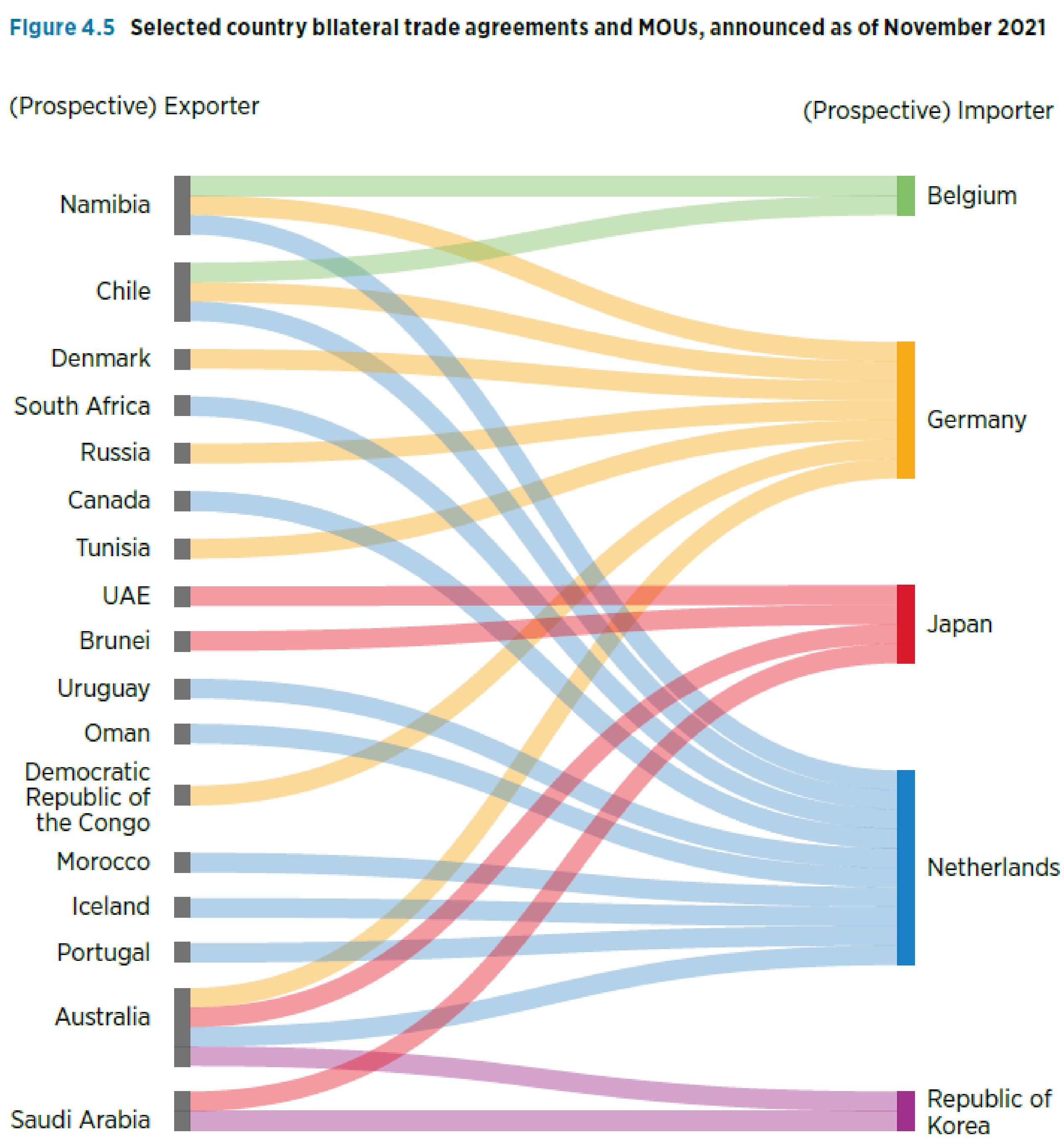

Figure 5. - Bilateral trade agreements and MoUs (IRENA 2021)

4.2 Africa has what it takes

African countries are promising partners for producing cost-competitive green hydrogen for the German market due to Africa's abundant resources in renewable energies, coupled with its low population density and large-scale availability of non-arable land.

Several African countries, especially around the Northern and Southern Tropics have excellent solar (average daily potential of 4.49kWh/kWp) and wind resources (180,000 TWh per year) for potential green hydrogen production.

Africa has an installed hydropower capacity of over 38 gigawatts (GW) and the highest untapped potential across the world, utilizing only about 11% of its capacity. Countries in North African as well as Namibia, South Africa, Angola, and Botswana, have extensive non-arable land and proximity to ports. Countries like

South Africa and the Democratic Republic of Congo, have an abundance of mineral resources essential for producing solar panels, wind turbines, electric motors, batteries, electrolysers and biological carbon. All of these potentials position Africa as a viable supplier of green hydrogen and Power-to-X (PtX) products at competitive costs.

Notwithstanding these fitting conditions, developed countries' bid to import hydrogen and African countries readiness to supply it could have disadvantages, if not well planned and managed.

Firstly, more than half of Africa's population has no access to electricity. Therefore, green hydrogen production in the continent should be planned in such a way that it gives the producing African countries the opportunity to improve their energy supply in a climate neutral way, while also seizing the global market opportunities to export excess outputs to the global market. As such, green hydrogen should be produced in line with the additionality principle, such that they add value to already existing pursuits for energy security and transition in the region.

In addition, green hydrogen should also be produced in ways that it does not compete with demand for other resources like water and arable land for agriculture and other domestic uses. Since most of the viable areas for green hydrogen production in Africa, particularly in the northern and Sahel regions, also face water scarcity, efforts should be made not cause additional stress. Green hydrogen production in these sites should increase fresh water supply, through desalination and provision of other water infrastructures.

Furthermore, with its long value chain, a hydrogen economy also offers significant potential for job creation and for attracting international investment into the region of its production, thus contributing to economic growth and development. These benefits should be optimized in the African context through policies, regulations and quotas, such that solving energy crisis goes in tandem with creating jobs and improving inclusive economic growth and development. These benefits can be enhanced when most of the value chain of green hydrogen and Power-to-X production remain within the continent.

Finally, achieving a sustainable green hydrogen production in the African conti nent will generally require adequate consultation among all stakeholders, cou pled with local level awareness and sensitization so as to optimize benefits and achieve a win-win situation in green hydrogen production and trade cooperation, among African countries and the rest of the world.

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