National Experts Program

برنامج خبراء الإمارات

COP28 white paper

Energy Transition, The Hydrogen Story

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COP28 White Papers

In preparation for COP28, the third cohort of the National Experts Program (NEP 3.0) developed two white papers with the support of the Boston Consulting Group; one on Food Security and another on Financing the Transition to a Hydrogen Economy.

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Executive Summary

The global energy transition is evolving with the advance of technology. Renewable sources including wind and solar have seen generation efficiency soar and the cost per until fall significantly.

Hydrogen is now emerging as a versatile and clean energy carrier and has the potential to become an important part of the fuel mix in a net zero future.

This report explores the potential of hydrogen as an accelerator of the sustainable energy shift. We evaluate a range of hydrogen fuel types, their applications, and the short- and long-term benefits. This report has a specific focus on the United Arab Emirates (UAE) and its partners in the development of a hydrogen energy ecosystem.

Some eye-catching statistics underpin the allure of hydrogen in a sustainable future. The Hydrogen Council believes hydrogen can contribute **20%** of total abatement needed to get to net zero. Between now and 2050, hydrogen can help avoid **80** gigatons (GT) of cumulative CO2 emissions resulting in an annual abatement potential of **7** GT.

Governments, industries, and individuals seeking alternatives to fossil fuels in their climate change mitigation strategies are increasingly turning to hydrogen. However, substantial financial support will be required to capitalize on hydrogen's potential.

The Energy Transition Commission (ETC) estimates the world needs to invest up to **$15** trillion in hydrogen between now and 2050, for infrastructure development, research, production scalability, and distribution network expansion. The deployment of effective financial mechanisms and incentives can attract both private and public investments, stimulate innovation, and create an ecosystem conducive to market expansion.

The COP28 climate conference, presided over by the UAE, will be a pivotal moment in the global response to climate change. The event will witness a Global Stocktake that will measure progress towards the Paris Agreement goals. The outcomes will inform future strategies on climate action. One of the central pathways for action is doubling hydrogen capacity, with **60%** coming from low carbon by 2030, as announced by COP President Designate, H.E. Dr. Sultan Al Jaber.

One of the challenges of building a robust hydrogen ecosystem is the diversity of production processes. Hydrogen comes in a number of forms-gray, blue, and green-all made using different methods.

Green hydrogen is produced by electrolysis in a process powered by renewable energy. This is a clean and sustainable production option with zero carbon emissions. However, production costs are high and, at present, there appears to be no economically viable way to scale green hydrogen.

Blue hydrogen, derived from natural gas with carbon capture and storage (CCS), offers a transitional solution with lower emissions. While CCS captures a substantial amount of CO2, the process lacks maturity and remains expensive.

With the momentum behind hydrogen growing, an increasing number of countries, including the UAE, are adopting hydrogen strategies within their broader energy policies. However, faster action is required to create demand for low-emission hydrogen and unlock investment to accelerate scale-up and bring down costs.

In conclusion, hydrogen's potential as a clean energy catalyst demands strategic financial investment. COP28's focus on the doubling of hydrogen capacity by 2030 aligns with global climate goals, underscoring hydrogen's centrality to a sustainable future. Understanding and investing in hydrogen's potential is vital if we are to deliver a successful energy transition.

1. Introduction

A successful energy transition will require a range of fuels to power our homes, workplaces, transportation, and energy grids. The early stages of the net zero transition have been led by renewables such as solar and wind and the emergence of electric vehicles.

Now a new fuel is emerging-hydrogen-and it has the potential to play a significant part in helping achieve the climate targets that will top the agenda at COP28 in the UAE.

Hydrogen has vast potential as a clean and versatile energy carrier in the transition. The Hydrogen Council believes it can contribute **20%** of the total emission cuts required, and help avoid up to **80** GT of cumulative CO2 emissions between 2021-2050. After 2050, hydrogen has an abatement potential of **7** GT per year.

However, delivering on hydrogen's potential will require huge investment. Analysis from the World Bank shows a global financing need of around **$30** trillion between now and 2050. This translates into around **$1** trillion per year.

Only with the correct financial mechanisms and incentives in place, will the hydrogen industry be able to attract private and public investment. This will fund technological innovation, infrastructure development, and the scaling of production capacity needed to create a viable hydrogen ecosystem that will drive market expansion.

This paper is intended to inform the COP28 vision on hydrogen systems of the future. It takes a deep dive into every aspect of the hydrogen value chain to examine how the industry must evolve to play its full part in the global energy transition.

2. COP28 Vision, Doubling of Hydrogen by 2030

The UAE's presidency of COP28 will be a critical moment in the global energy transition. The conference will host the first Global Stocktake-a reality check on the world's progress in meeting the goals of the Paris Agreement, which has a final deadline of 2050.

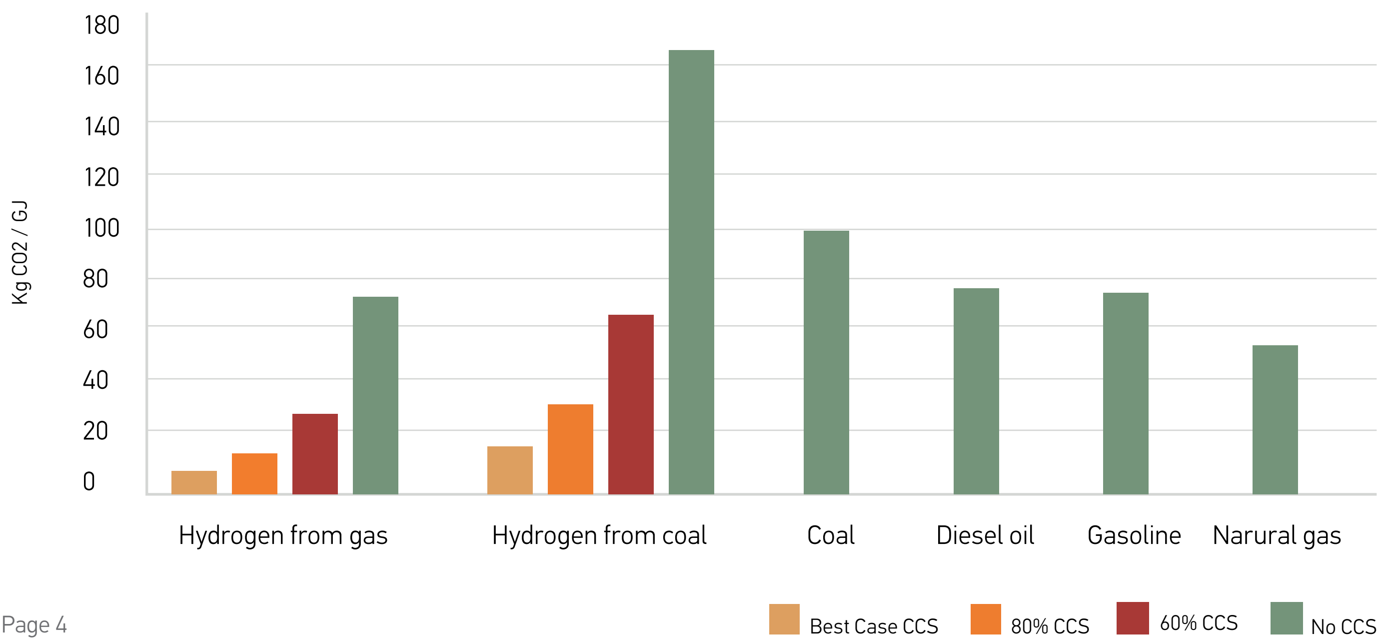
The Global Stocktake will help align efforts on climate action, including measures required to unlock blocks to progress and accelerate momentum toward achieving our climate goals. The UAE's presidency of COP28 is also an opportunity to ensure the world responds to the Global Stocktake with a clear plan of action, uniting the world on bold, practical, and ambitious solutions to the most pressing global challenge of our time.

One of those solutions is to ramp up capacity for hydrogen production and use. This was a key message from COP President Designate, His Excellency Dr. Sultan Al Jaber, during his speech at the 2023 Petersberg Climate Dialogue. In his address, he called for a doubling of hydrogen production to **180** million tons per year by 2030. His Excellency also urged governments to introduce policies to jump-start the hydrogen value chain.

3. What Are The Types of Hydrogen And Why Do They Matter?

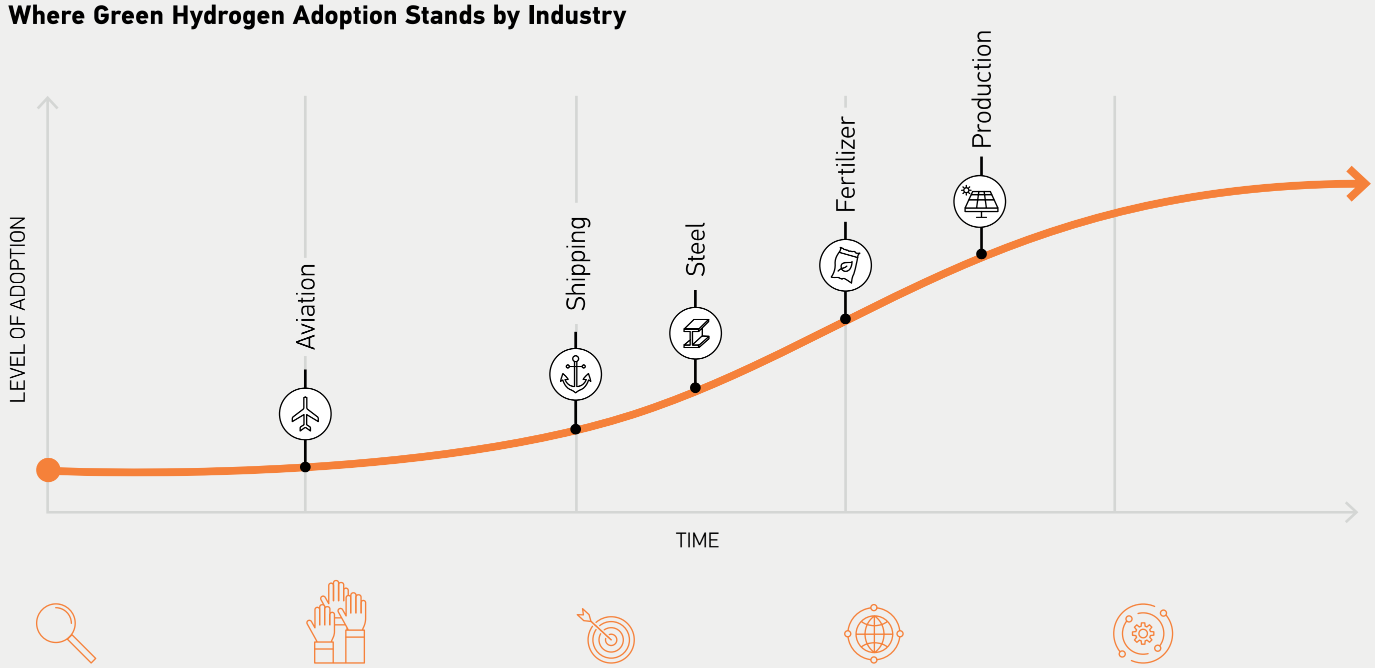
Producing hydrogen is complex. There is no standard production technique but a range of methods that deliver products known as green, blue, and gray hydrogen. Each process comes with its advantages and drawbacks.

Emission Intensity of Different Fuels



Green hydrogen is produced using renewable energy sources, such as solar, wind, or hydro. They power the electrolysis process that splits water into hydrogen and oxygen. This process results in zero carbon emissions and is considered the cleanest and most sustainable way to produce hydrogen fuel. However, the cost of producing green hydrogen is currently **4-6** times higher than making regular hydrogen, and therefore not economically viable for many applications.

Where Green Hydrogen Adoption Stands by Industry



Solution Search
Early-stage research drives development of new solutions

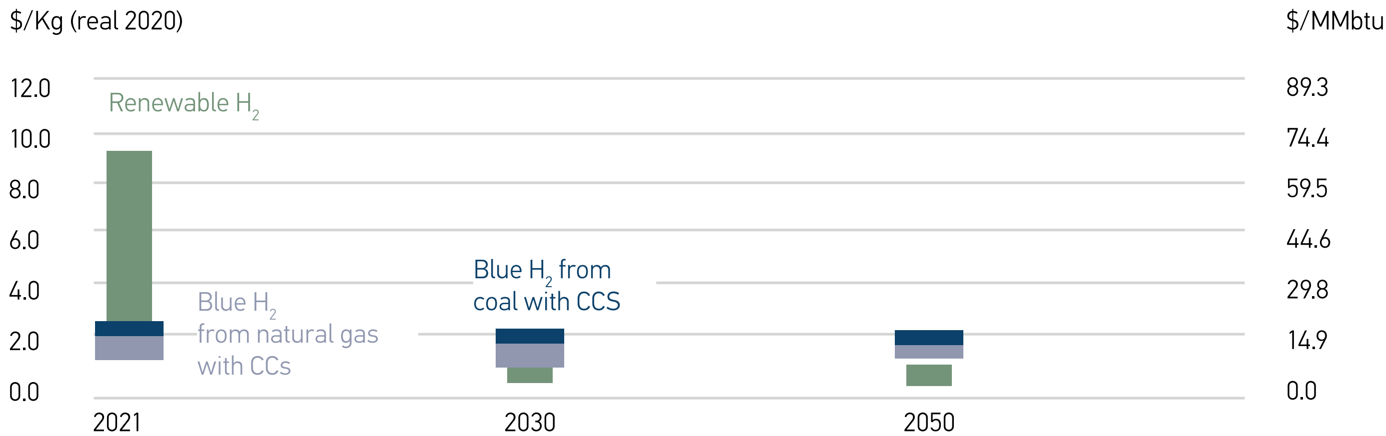
Proof of Concept
Innovations are being piloted, often through public private parterships

Early Adopters
Innovations are scaled by frontunners and established in niche market

System Integration
Frontunners push to build up the enabling environment

Market Expansion
The innovation reaches scale and is widley adopted/ met with broad compliance

Production Costs: Green vs Blue Hydrogen



Note: Assumes our optimistic electrolyzer cost scenario.
Source: Bloomberg NEF.

Blue hydrogen, on the other hand, is produced using natural gas as a feedstock. To clean up the production process, CCS technology is looped into the system.

The process involves the Steam Methane Reforming (SMR) of natural gas, which releases CO2 as a byproduct. The CO2 is then captured and stored underground, preventing it from entering the atmosphere.

Blue hydrogen is considered a transitional solution that can help reduce carbon emissions in the short term, giving time for technological advancement to bring down the cost of green hydrogen.

Gray hydrogen is produced from fossil fuels, typically natural gas, through SMR.

The production of gray hydrogen releases significant amounts of CO2 into the atmosphere, contributing to greenhouse gas emissions and climate change, hindering progress towards carbon neutrality and a low-carbon future.

These hydrogen variants, all versatile energy carriers, serve a multitude of critical functions in today's evolving energy landscape. Hydrogen excels in energy storage and transport, enabling the capture of surplus renewable energy for later use or efficient long-distance transmission.

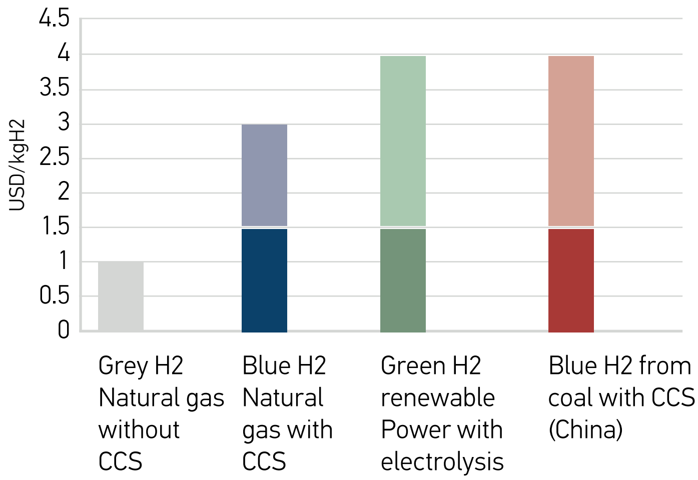
Hydrogen's functionality also extends to powering fuel cells in electric vehicles, offering extended ranges and rapid refueling, thereby aiding in the transition to zero-emission transportation.

In heavy industry, hydrogen's potential is evident in replacing carbon-intensive processes. It can be used as a reducing agent in steel production, helping to lower emissions. Furthermore, it plays a pivotal role in ammonia synthesis for fertilizers, fostering greener agriculture. These diverse applications underscore hydrogen's significance in our pursuit of sustainable and clean energy solutions across industry sectors.

In essence, green and blue hydrogen could each play vital roles in the transition to a low-carbon economy. The choice between green and blue hydrogen would likely be determined by regional factors such as local availability and cost of renewable energy or natural gas, infrastructure, and environmental policies.

As the technology matures and costs fall, it is expected that green hydrogen will become more prominent in the long term. However, blue hydrogen serves as an important stepping stone, providing a way to transition away from carbon-intensive energy sources, while still leveraging existing infrastructure and technologies.

Costs of producing blue versus gray and green hydrogen.



Notes: Blue and green hydrogen presented with both high and low estimates. High estimate represents current cost and low estimates represent the potential future cost.
Source: based on IEA 2018, 2019, 2020, Cappellen et al 2018, Lua et al 2019.

4. Geopolitical significance of low-carbon hydrogen:

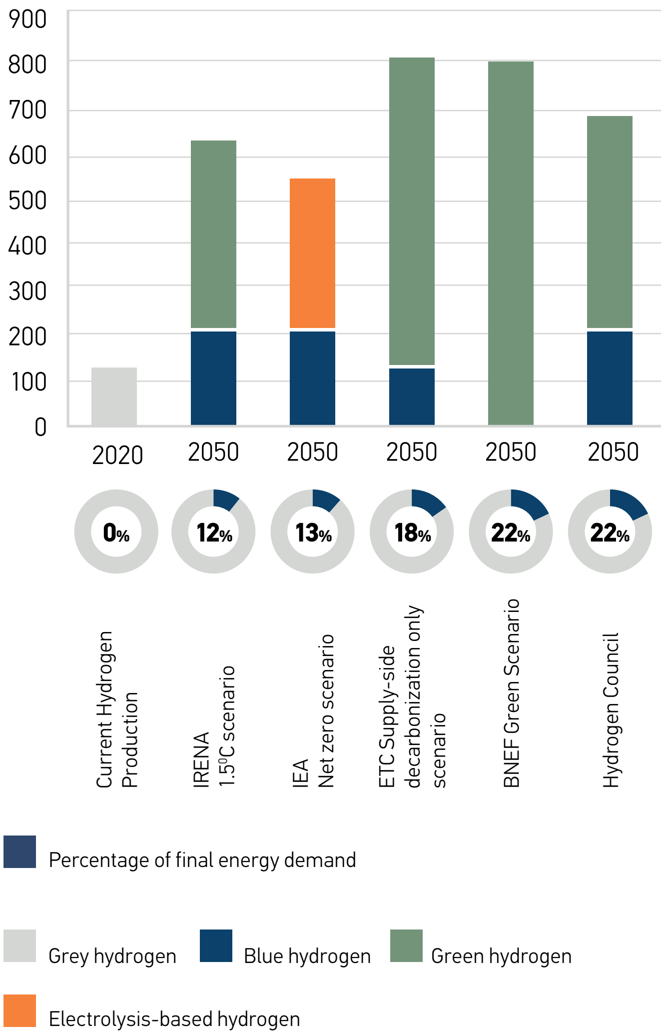
In a world fractured by geopolitical tensions, energy security is a top priority for countries around the world. Hydrogen has been identified as a potential clean solution to energy instability. It also gives nations lacking natural energy resources the potential to become major producers and exporters.

More than **30** countries have established or are developing national hydrogen strategies. Those countries are mainly located in Africa, the Americas, the Middle East, and Oceania. A race to become a global leader in the market is developing. This acceleration of hydrogen strategies should see a rapid increase in production capacity. Current sales have already exceeded liquefied natural gas with an estimated market value of **$174** billion. Forecasts suggest the global market value of hydrogen could reach **$600** billion by 2050, which makes it a very attractive national investment opportunity.

One of the crucial elements for hydrogen production at scale is the availability of the required infrastructure and countries are moving to ensure they can deliver. For example, Chile has launched a strategy to produce **25** GW by 2030 and aims to become one of the world's top three hydrogen exporters by 2040. Several neighboring countries are following suit.

This activity in the energy sector has created a new form of diplomacy between nations. Germany, Japan, the Netherlands, and the Republic of Korea are strengthening and establishing ties with hydrogen-producing countries to secure their energy needs. Other nations might look for opportunities to reduce the energy import dependency and add local clean hydrogen production to their energy mix.

Hydrogen production (Million tonnes)



Source: IRENA (2022), Geopolitics of the Energy Transformation: The Hydrogen Factor, International Renewable Energy Agency, Abu Dhabi.

5. Transitional pathways-net zero

Hydrogen plays a vital role in transitional pathways towards a more sustainable and low-carbon future that aligns with the global net zero 2050 strategy. It offers several key advantages that make it a valuable component of the energy transition:

Decarbonization of Hard-to-Abate Sectors: Hydrogen can be used as a clean energy carrier in sectors that are challenging to decarbonize, such as heavy industry, aviation, transportation, and heating. By replacing fossil fuels with hydrogen, emissions of greenhouse gases can be significantly reduced, helping to achieve climate targets.

Energy Storage and Grid Balancing: Hydrogen can be produced through electrolysis when there is excess renewable energy generation. This allows for the storage of surplus energy, which can later be converted back into electricity or used for other applications when there is insufficient renewable energy supply. Hydrogen therefore facilitates grid balancing and enables greater integration of intermittent renewable energy sources into the energy system.

Renewable Energy Integration: Hydrogen can serve as a means to store and transport renewable energy over long distances. It can be produced from renewable sources, such as wind and solar power, through electrolysis. This enables the utilization of excess renewable energy for hydrogen production, which can then be transported and used in various sectors.

Fuel Cells and Zero-Emission Mobility: Hydrogen fuel cells offer a clean and efficient alternative for transportation as they emit only water vapor, making them a zero-emission option. Hydrogen fuel cells can be used in cars, buses, trucks, and even trains, helping to reduce emissions in the transportation sector.

Energy Resilience and Security: Hydrogen diversifies energy sources, reducing dependence on fossil fuels and enhancing energy resilience. It can be produced locally, using a variety of sources, including renewable energy, natural gas, or biomass. This versatility helps mitigate energy supply risks and enhances energy security.

Industry and Job Creation: The development and deployment of hydrogen technologies open up new opportunities for industries, fostering innovation, and creating jobs. The hydrogen value chain, including production, storage, transportation, and utilization, can generate employment across different sectors, contributing to economic growth and development.

By leveraging the unique properties of hydrogen, transitioning toward a hydrogen economy can contribute significantly to reducing greenhouse gas emissions, integrating renewable energy, and achieving the Sustainable Development Goals. However, it is important to ensure hydrogen production is sourced from renewable energy to maximize its environmental benefits and contribute to a fully sustainable energy transition.

The global hydrogen market is on the cusp of a significant evolution, with international certification schemes at its core. For the market to truly flourish, there is a pressing need for a universally accepted method to verify, track, and recognize the characteristics of every kilogram of hydrogen produced. A major focus of these certifications is the sustainability aspect. This encompasses the carbon footprint, which measures greenhouse gas emissions per production unit, factors in land and water usage, as well as the broader social impact. By establishing a consistent and reliable international standard, trust is fostered between hydrogen importers and exporters. This trust is pivotal in promoting global trade in hydrogen and its derivatives, with sustainability credentials as a key differentiator.

6. Certification Schemes

Hydrogen certification schemes are pivotal in monitoring the sustainability, quality, and traceability of hydrogen production, distribution, and usage. Implementing standards, guidelines, and verification procedures will bolster market confidence and encourage hydrogen to be utilized as a clean energy source. These certification schemes can be divided into three main categories: Green Hydrogen, Sustainability, and Carbon Certification.

The absence of standardized hydrogen certification and the lack of mutual recognition among trading nations are significant barriers to global hydrogen trade. Without harmonized standards, ensuring hydrogen purity and sustainability across borders becomes challenging, increasing costs and creating inefficiencies. For hydrogen to realize its full potential in the global energy mix, unified standards, and mutual recognition are essential.

Green Hydrogen Certification is instrumental in validating the "green" credentials of hydrogen, which is produced from renewable energy sources. For instance, the Renewable Hydrogen Certification Scheme, developed under the Renewable Energy Directive, focuses on hydrogen generated using renewable electricity. This certification ensures transparency and traceability by tracking renewable aspects and preventing double-counting of these renewable energy sources.

Sustainability Certification measures the environmental, economic, and social aspects of hydrogen production. The Global Sustainable Biomass Program and the Roundtable on Sustainable Biomaterials (RS issue certifications for hydrogen generated from sustainable biomass resources. These schemes look at a variety of factors including land use, biodiversity, greenhouse gas emissions, and social impacts to ensure the sustainable production of hydrogen.

Carbon Certification verifies the carbon content and emissions related to hydrogen production. This certification examines the carbon intensity of hydrogen, aiding in distinguishing it among various forms of hydrogen, such as gray, blue, or green hydrogen. It provides transparency and accountability concerning carbon emissions, promoting the use of low-carbon and zero-carbon hydrogen.

India, as part of its G20 proposal, has put forward the development of global standards for low-carbon hydrogen, as per the report by the International Renewable Energy Agency (IRENA). These standards would aim to ensure the uniformity and comparability of low-carbon hydrogen across different regions, thus facilitating global trade and application of this clean energy resource. This initiative would also contribute to global efforts in combating climate change and accelerating the transition to a more sustainable energy landscape.

In essence, hydrogen certification schemes are critical for promoting transparency, accountability, and market trust. As the hydrogen sector continues to evolve, these certification schemes must adapt and align with international standards and best practices, ensuring the integrity and credibility of the hydrogen market. It will also play a key role in facilitating informed decision-making among stakeholders, enabling trade, and supporting the transition toward a sustainable hydrogen economy.

7. Finance

Role of multilateral development banks and international financial institutions in funding hydrogen projects

As highlighted in the final agreement of COP27, an annual investment of **$4-6** trillion in renewable energy was the minimum requirement to meet the net-zero emission targets by 2050 (United Nations Environment Program, 2022). This level of investment emphasizes the need to look beyond government funding and expand the role of multilateral development banks and international financial institutions.

Despite the global consensus on emission mitigation, funding for renewables is still some distance from where the world needs to be. In the five years following the signing of the Paris Agreement, the top **60** commercial banks have financed up to **$3.8** trillion in fossil fuels (Clifford, 2021). This level of commitment to fossil fuel energy reiterates the urgent need for large financial institutions to both diversify and increase investment in renewable energy.

While there is still a need for significant further investment, some financial institutions are making efforts toward funding climate change programs. To address the ever-growing risk to poorer countries and vulnerable groups, the World Bank Group has committed to investing around **$200** billion in climate change programs around the world between 2021 and 2025 (World Bank, 2023). Similarly, the Asian Development Bank has pledged a contribution of **$100** billion to combat climate change between 2019-2023, as has the African Development Bank-committing to increase access to climate financing of $25 billion to low-income African countries.

This increased commitment and investment in commissioning projects has seen a direct impact on low-emission hydrogen production, which increased by 9% in 2021 (Bermudez, Evangelopoulou, Pavan, 2022). However, renewable energy-based hydrogen output still only accounts for 1% of the global average (IRENA, 2022). Despite current electrolyzer capacity limitations within hydrogen facilities, the additional capacity in future plants will increase the demand for green hydrogen considerably by 2050. This increase in demand is also associated with the expected reduction in the cost of hydrogen production (PWC, 2023).

To further support the drive toward the carbon emission target and to meet the supply of the projected growth in the demand for hydrogen, financial institutions will need to play a major role.

Three key areas are identified as initial steps to increasing financing for hydrogen. These are:

- **Increase flexibility within their project risk criteria.** A study by Boston Consulting Group (BCG), suggests banks can gain a strong competitive advantage by prioritizing the development of risk assessment and management capabilities within institutions. Financial institutions with a larger risk appetite today will likely stand to benefit in the long term with the evolution of this industry, says BCG.
- **Reduce fossil fuel investments.** In line with the International Energy Agency's (IEA) declaration that there is a 50% chance of reaching net zero by 2050 if no further oil and gas fields are developed after 2021, more financial institutions need to start phasing out investments in fossil fuel-based projects. HSBC, NatWest, and Lloyds Bank are already reducing such investments. This decrease in investment in fossil fuel energy can free up capital to invest in hydrogen.
- **Attracting more investors to green financing models.** Climate financing schemes must remain attractive to potential investors. Scaling up green bonds, which are expected to exceed a value of $1 trillion by the end of 2023, could attract further investment in hydrogen. Interest rate discounts are another way of attracting investment.

Any hope of reaching net-zero global emissions rests on decarbonizing hard-to-abate sectors such as power, heavy industry, heating, and transportation. In addition, emerging solutions will need to play a pivotal role.

These solutions come at a significant cost. BCG estimates that up to $13 trillion of private-sector investment in hydrogen and CCUS will be required to achieve the IEA "net-zero emissions by 2050" scenario. Until now, banks have not provided the debt financing necessary for these two technologies to scale up.

Despite the misalignment between current financing opportunities and the estimated $13 trillion deficit, staggered approaches to addressing this can be put in place. Firstly, enablers must be introduced that support the growth of the hydrogen ecosystem, such as sustainable infrastructure, utilities, and transportation. These enablers are key to encouraging participation and investment in addressing climate change, which will drive innovation and efficiency.

Current list of initiatives (government, private, multilateral development banks, international organizations) that work on hydrogen projects

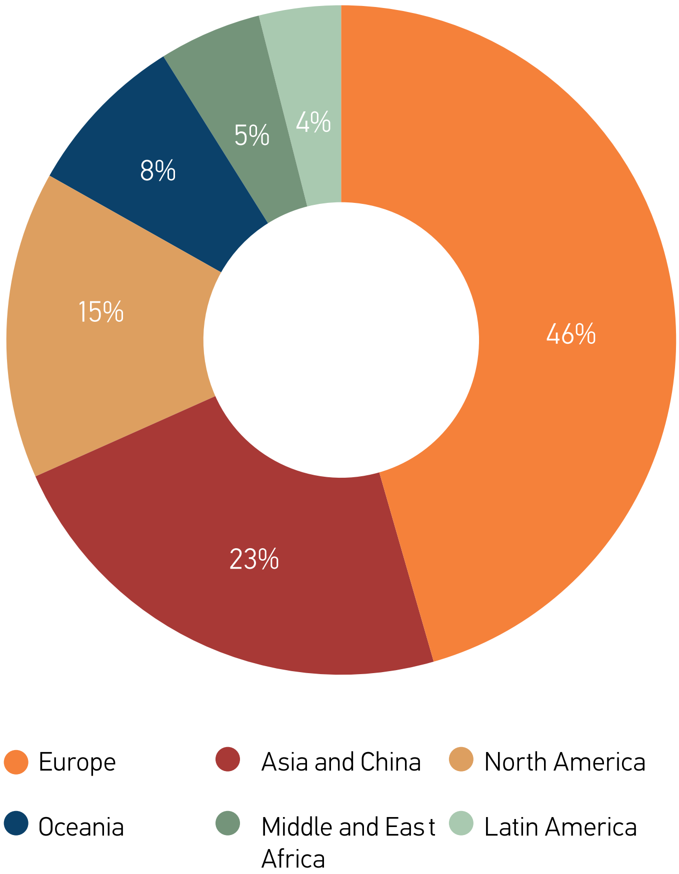
684 large-scale hydrogen projects have been announced globally, amounting to $240 billion in direct investments[1].

Project Type	Number of Projects	Examples
Gigascale production	61	Renewable H2 projects, 1 GW, low-carbon H2 projects, 200 KT per annum
Large-scale Industrial Usage	332	Refinery, ammonia, methanol, steel, and industry feedstock
Integrated H2 economy	78	Cross-industry and projects with different types of end uses
Transport	150	Trains, ships, trucks, cars, and other hydrogen mobility applications
Infrastructure	63	H2 distribution, transportation, conversion and storage

Europe's announcement of 314 projects (46% of the total projects) makes the continent the biggest contributor to meeting decarbonization targets. Its focus is on industrial applications, transportation, and power generation. China accounts for half of the announcements made in Asia, with a major focus on the transport sector (Exhibit 1) [2] .

[1] https://www.mckinsey.com/capabilities/sustainability/our-insights/five-charts-on-hydrogens-role-in-a-net-zero-future
[2] https://www.mckinsey.com/capabilities/sustainability/our-insights/five-charts-on-hydrogens-role-in-a-net-zero-future

Exhibit 1: Announcement MW-Scale Projects



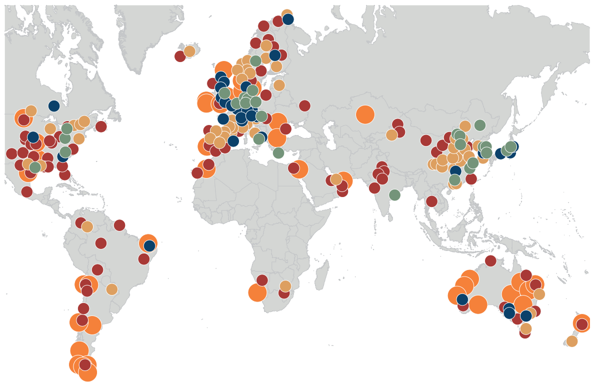
While the number of proposed hydrogen projects is accelerating, implementation is stuck in first gear. Out of the $240 billion investments announced, only 10% ($22 billion) have been approved for final investment (Exhibit 2)[3].

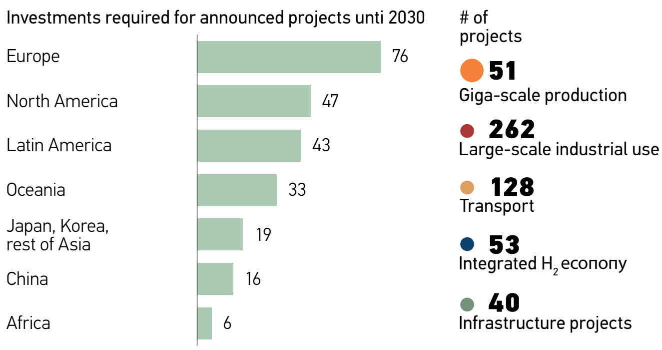
Out of the 684 projects, 534 aim to fully or partially commission through 2030. About 30% of those 534 projects are undergoing feasibility and front-end engineering design studies, and only 10% have reached a final investment decision.

In terms of investment share, Europe is leading the way at around 30% or $76 billion. However, strong government support has seen other countries and regions surpass Europe in terms of project delivery. China has deployed 200 MW of hydrogen electrolysis compared to 170 MW in Europe. North America is leading the implementation of projects with 80% of the operational global capacity of low-carbon hydrogen.

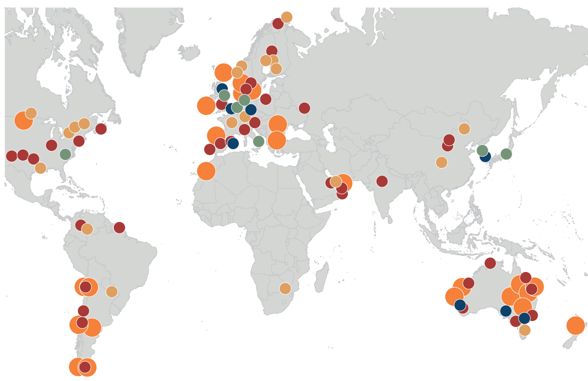
Exhibit 2: Global Hydrogen Project Announcements

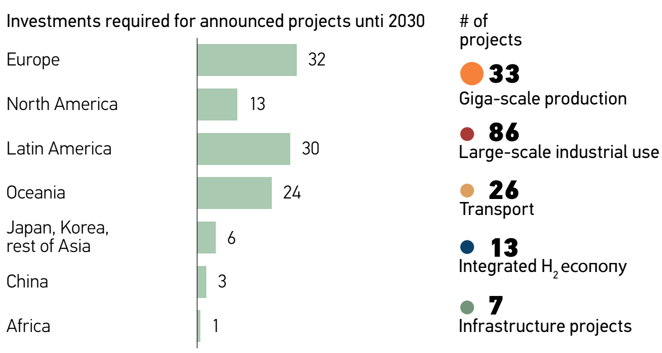
Out of 534 large-scale projects worth "$240 billion announced globally...





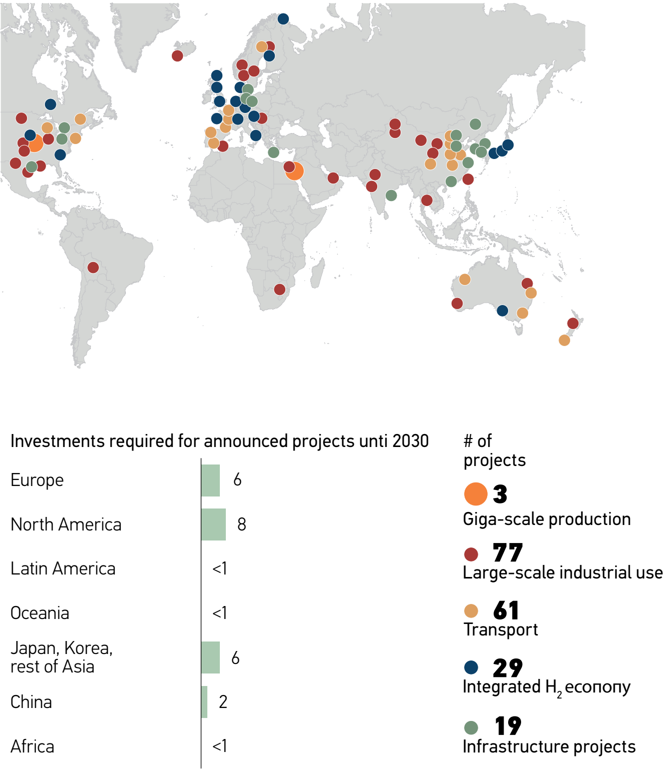
...165 - about one third - are undergoing feasibility and FEED studies ...





[3] https://hydrogencouncil.com/wp-content/uploads/2022/09/Hydrogen-Insights-2022-2.pdf

... and only about 10% of investments have achieved final investment decision.



Despite the positive increase in project proposals, final investment decisions are lacking. While it is essential to have ambitious plans, executing those plans through actual investment and implementation is crucial to bringing about meaningful progress in addressing climate change.

One of the main challenges for project developers in the current environment is the lack of clarity on demand projections. Many are anticipating the establishment of regulatory frameworks and funding to commit to long-term hydrogen supply contracts.

The bulk of the committed investment is seen in North America, at **35%**, followed by Europe and Asia, each at **25%**. North America's investments are mainly due to low-carbon hydrogen projects, whereas Europe's investments are due to clearer regulatory environment and industry decarbonization targets [4].

To reach the target of achieving net zero emissions, there is a need to focus on investing in well-established hydrogen projects. Unfortunately, the current level of commitment towards this objective is not enough, as only **$240** billion was announced versus a required investment of **$700** billion [5].

The investment gap of $460 billion is broken down into three categories:

Category	Investment Gap	Significance
Production	$150 billion	Requires the largest amount of investment
Transmission, distribution, and storage	$165 billion	Enables access to cost-competitive hydrogen supplies globally
End-use applications	$145 billion	To meet projected demand in end-use applications, including steel production and transportation

The $100 billion goal and how much of it is going to hydrogen

At present, most climate finance comes from the public sector but private-sector engagement will be crucial in mobilizing support for climate mitigation and adaptation.

The goal of mobilizing **$100** billion per year by 2020 was established during the United Nations Climate Change Conference (COP15) held in Copenhagen in 2009. Developed countries made this commitment to support climate action in developing nations. The objective was to provide adequate financial resources to assist developing nations in mitigating greenhouse gas emissions and adapting to the impacts of climate change.

The **$100** billion annual goal was seen as a crucial step in addressing the climate finance gap. The funds were expected to come from a variety of sources, including public finance from developed countries, private investments, and innovative financial mechanisms.

The latest analysis by the OECD indicates that while progress has been made, the goal of mobilizing **$100** billion per year was not fully achieved by 2020, with a shortfall of **$16.7** billion.

To respond to the present and future climate risks there is a pressing need to significantly increase the scale of adaptation finance, from all sources. Finance should also be predictable. By 2025, a new, collective quantified goal on climate finance will be set, starting from a floor of **$100** billion per year.

[4] https://hydrogencouncil.com/wp-content/uploads/2022/09/Hydrogen-Insights-2022-2.pdf
[5] https://www.mckinsey.com/capabilities/sustainability/our-insights/five-charts-on-hydrogens-role-in-a-net-zero-future

Climate finance is distributed through various channels and mechanisms. The specific distribution of climate finance depends on factors such as funding sources, recipient countries, and the type of climate action being supported. The distribution of climate finance falls largely into the following categories:

- **Bilateral and Multilateral Channels:** Developed countries provide climate finance through bilateral channels.

- **Adaptation and Mitigation:** Climate finance is divided between adaptation and mitigation activities, which include projects that reduce GHG emissions.

- **Priority Countries and Sectors:** finance directed toward countries and sectors based on criteria such as vulnerability to climate change, development needs, and emissions levels-such as Least Developed Countries and Small Island Developing States.

- **Public and Private Finance:** Climate finance includes both public and private funding. Public finance comes from government budgets and the private sector, including businesses, institutional investors, and impact investors.

- **Geographic Concentration:** Climate finance has been criticized for being concentrated in a few high-emitting countries.

As mentioned in the section above, the specific contribution of hydrogen energy in climate finance has not been explicitly detailed. Climate finance commitments and allocations are generally broad and cover a range of sectors and activities related to climate change mitigation and adaptation.

Engagement of the private sector in hydrogen funding

A key factor in ensuring the sustainable growth of the hydrogen market is private investments. It has been proven time and time again across multiple sectors and geographies that, in the long run, sectors with higher private investment experience higher rates of sustainable growth. Therefore, it is important to understand the key drivers in enabling and accelerating private-sector investment.

First and foremost, we need to acknowledge that the main investment consideration around this new industry is risk. It is the foundation of any investment and should be front and center of any discussions about attracting private investors.

Deal structures and arrangements to de-risk investment in these projects are not widely available today. This includes access to long-term renewable energy secured via a Power Purchase Agreement, robust offtake agreements for end-use applications that carry low technology risk and performance guarantees for equipment that does not yet have a long performance track record.

As a result, most of the hydrogen-related projects today are financed by the state or large gas or energy producers. These are the only institutions capable of assessing, managing, and taking on such risks. The four main risks include:

- A lack of long-term offtake agreements with good quality counterparties (offtake risk)
- Immature production technologies (technology risk)
- No consistency in regulation and industry standards (policy risk)
- A lack of established markets to sell to. (merchant risk)

To find the right way to mobilize private finance, the Accelerating Clean Hydrogen Initiative and the Financing the Transition Initiative identified concrete approaches that could help solve the challenge of access to finance for clean hydrogen projects. Below we look into examples that illustrate the challenges and opportunities.

The first example explores co-investment in projects led by credible industrial sponsors and developers. This model helps address most concerns raised by financiers and is gaining traction.

This is mainly because it is focused, not on backing a winning technology but, instead, on picking a credible industrial sponsor or developer for investments. At this initial stage of commercialization, the credibility and creditworthiness of the sponsors involved are critical. Investors and financial institutions can rely on a sponsor's knowledge of the industry, ways to mitigate technology risks, and ability to identify offtakers and ship the end product.

Masdar, a renewable energy developer based in the UAE, operates such a model. Investors in Masdar, which has been active in renewables since 2006, gain exposure to the sector while relying on the company's expertise, and extensive network of strategic partners and co-investors for projects across the world. Furthermore, the fact that Masdar is sponsored by the government of Abu Dhabi, which enjoys an AA credit rating, will give investors a greater sense of comfort.

The second example focuses on the contracts and the public sector's support for these projects. Uncertainty around a hydrogen project's future revenues due to the non-existence of a liquid market for clean hydrogen today, remains a big hurdle to bankability. While financial institutions prefer long-term, credible, offtake contracts as a starting point, offtakers today are generally unwilling to enter into long-term agreements at the current high prices for green hydrogen.

This is where the public sector can step in to underwrite these risks. Long-term contracts for difference (CFDs) have been an effective tool used by governments to help bridge the green premium that exists between low- or no-emission products and their gray or brown alternatives. In Europe, this approach was included in the 2022 RePowerEU Plan.

To support hydrogen uptake and electrification in industry, the European Commission is expected to roll out carbon CFDs, enabling a full switch of the existing hydrogen production from natural gas to renewables and the transition to hydrogen-based production processes in industrial sectors such as steel production.

Furthermore, when used in conjunction with financing instruments to blend public and private capital, e.g. the Connecting Europe Facility, which pays grants for the construction of hydrogen refueling infrastructure that is conditional on additional financing from a financial intermediary, the reduced risk can help boost investor confidence and spur project financing.

We have seen examples of this in other renewable energy alternatives such as solar power. We saw a direct correlation between exhaustive government incentives and acceleration of the advancement and adoption of this technology. This, in turn, attracted a surge of private investment in solar energy. There is reason for optimism in the future of the hydrogen market, and scope for clean hydrogen projects to become just like any existing financial instrument today. First, we must remove the investment roadblocks, establish policy frameworks, and enable measures that will build the confidence needed to unlock the investment market in clean hydrogen.

Case study-Africa

An Overview of the African Continent Hydrogen Potential

Africa has great potential to develop a strong green hydrogen ecosystem given the abundance of renewable energy resources in such a strategic location. The potential of green hydrogen in Africa is about **$1.08** trillion (**€1** trillion). Below, we discuss seven hydrogen-ready countries on the African continent: South Africa, Egypt, Morocco, Mauritania, Kenya, Zimbabwe, Namibia, and South Africa.

Hydrogen Projects in Africa

South Africa is poised to be a significant player in the hydrogen production arena, thanks to its rich reserves of platinum-group metals and abundant renewable energy resources. These assets are crucial for establishing a robust hydrogen project infrastructure. The country has already initiated four major projects to boost its hydrogen production capabilities. These include the South African Hydrogen Valley (also known as the Platinum Valley Initiative), the CoalCO2-X Project, the Boegoebaai Special Economic Zone, and the Sustainable Aviation Fuels Project.

However, there is a challenge that needs addressing. South Africa tends to export a significant portion of its platinum-group metals, which could hinder the full potential of hydrogen production from these minerals. To counter this, the country needs to implement local policies and incentives to retain these valuable resources.

A recent study has spotlighted Napier City as an ideal location for green hydrogen production, primarily due to its abundant wind resources. With wind turbines operating at a capacity factor of **28.05** in Napier, the city could generate **8,298** GWH of energy. This translates to a cost-effective hydrogen production rate of as low as **1.4 $/kg**.

By combining wind and PV systems, South Africa can further optimize hydrogen production. By 2030, the country could potentially ship hydrogen in the form of ammonia to both Japan and Europe at a competitive rate of **3 $/kg**, assuming a weighted average cost of capital of **6%.** Plus, this ammonia can be efficiently converted back to hydrogen at the same rate, offering a sustainable and cost-effective energy solution.

Egypt is making significant strides towards establishing a hydrogen-driven economy. In early 2021, Siemens Germany expressed its support for Egypt's hydrogen ambitions, starting with a letter of intent. Their goal? To foster a long-term hydrogen industry in Egypt by promoting investments, transferring technologies, and launching hydrogen projects powered by the country's abundant renewable energy.

By August 2021, the Egyptian Electricity Holding Company and Siemens Energy had solidified their partnership with a memorandum of understanding. The aim was to kickstart a pilot project for hydrogen production, targeting an electrolyzer capacity of **100-200** MW.

That same year, Egypt joined forces with the Belgian dredging company, DEME Group, to initiate hydrogen production. Egypt's rich energy resources, robust onshore and marine infrastructure, and skilled workforce spurred this collaboration.

The momentum did not stop there. In May 2021, Egypt received six proposals from international companies across the UK, US, Germany, Japan, Italy, and China, all vying to set up green hydrogen production projects. By July, major players like the Egyptian Natural Gas Holding Company, Egyptian Electricity Holding Company, and Eni's International Egyptian Oil Company were onboard, signing a memorandum of understanding to explore both green and blue hydrogen projects. Their focus? Assessing the economic and commercial viability of these initiatives.

October saw another significant partnership. Fertiglobe, an Egyptian-Emirati firm, teamed up with the Norwegian Scatec renewable energy company to produce both green and blue hydrogen in Ain Sokhna, Egypt.

In 2022, Egypt unveiled an ambitious **$40** billion hydrogen strategy, developed in collaboration with the European Bank for Reconstruction and Development. This strategy envisions producing an extraordinary **1.4** GW of hydrogen by 2030. Furthermore, Egypt proudly hosted the UN Climate Change Conference (COP27) that year.
However, the journey is not without its challenges. Financial, regulatory, and resource constraints hinder large-scale hydrogen production. Egypt's goal to boost renewable energy in electricity generation could potentially compete with its hydrogen ambitions. To truly realize its energy transition vision, Egypt needs a robust regulatory framework and dedicated certification institutions.

Given Europe's anticipated shortage of **10** million metric tons of green hydrogen by 2030, Egypt is well-positioned to become a major hydrogen exporter, meeting this growing demand.

Morocco has a target of 2025 to produce green hydrogen from a **100 MW** renewable energy plant, the result of a **$324.06** Moroccan-German agreement in 2020.

The French Total Eren energy group has initiated a **$10.6** billion green hydrogen and ammonia production plant from a **10 GW** solar and wind power plant in Guelmim-Oued Nour in Morocco. In June 2020, Morocco partnered with IRENA to accelerate the development of renewable energy and green hydrogen.

Morocco would need a long time to reach the stage of being capable of exporting hydrogen, besides the challenge of water shortage and prioritizing the supply for small-scale agriculture.

Therefore, Morocco is considering water desalination to overcome such a challenge. Morocco is still believed to be among the countries of potential for Hydrogen production given the huge **$ 896.57** million (**€830** million) directed by the German development bank (KfW), for constructing the Noor Solar plant. A techno-economic assessment for producing hydrogen from various solar systems revealed that hydrogen can be produced annually at a rate of **4,500** tons/year given **9%** solar efficiency. The levelized cost of hydrogen was estimated as **5.57 $/kg**.

Mauritania is emerging as a significant player in the renewable energy sector, particularly in solar and wind energy. This positions the country as a potential hydrogen exporter, with ambitions to achieve this by 2030 or even earlier, according to their national three-phase hydrogen strategy. Two notable projects have propelled Mauritania's green hydrogen initiatives. The first, is the **30 GW** Aman Power-to-X project, a collaboration between the Mauritanian government and CWP. This project harnesses both solar and wind energy to produce hydrogen using electrolysis. Following this, the **10 GW** green hydrogen "Project Nour" was announced in 2021. This venture, a partnership between the Mauritanian government and the African energy company Chariot, operates both onshore and offshore, employing resources similar to the Aman project. However, the country faces market challenges, including improving yet inadequate infrastructure, unclear tax regulations, and intricate labor rules. Despite these hurdles, by 2030, the cost of producing green hydrogen in Mauritania is projected to be around **$1.5/kg**.

Kenya is actively paving the way for a hydrogen-driven future. The nation is in the process of shaping its hydrogen development program, with a focus on producing green hydrogen. The strategy? To harness the excess capacity in Kenya's electrical grids, especially during periods of low electricity demand.

Committed to a cleaner energy transition, Kenya has forged significant partnerships. One such collaboration is between the Kenya Private Sector Alliance and Fortescue Future Industries, a leading green energy company. This partnership aims to foster large-scale green energy projects. It offers a platform for both parties to engage with the private sector and public stakeholders, ensuring swift project mobilization. Additionally, Kenya's collaboration with the German Development Cooperation underscores the country's potential in the green hydrogen sector. This partnership is set to launch pilot projects by 2025, with the Coast region, Rift Valley, and the broader Nairobi area identified as prime locations for green hydrogen production and potential market hubs. However, progress to a hydrogen-rich future is not without challenges. Currently, Kenya lacks a comprehensive political framework to oversee hydrogen generation, storage, and distribution.

Zimbabwe is making significant progress in the green hydrogen sector. Thanks to a collaboration between Hydrogène de France and the Zimbabwe Electricity Transmission and Distribution Co., the country is set to launch its first large-scale green hydrogen plant. This facility is expected to produce **178** GWh of electricity, powered by a **114** GW electrolyzer.

Zimbabwe is also working on an even more ambitious project, boasting an electrolyzer capacity of **197,574.6 MW**. This initiative has garnered support from major international development institutions, including the World Bank. Adding to Zimbabwe's hydrogen infrastructure, AFC Energy has unveiled a new ammonia cracker platform. This innovative system has the potential to produce multi-million tons of hydrogen annually. Such a development could position Zimbabwe as a significant key player in the global green hydrogen landscape.

Namibia is entering the green hydrogen sector, with significant backing from the German government. The country has invested **$32.41** million (**€30** million) to fund four pioneering hydrogen pilot projects. Some of the beneficiaries of this funding include TransNamib, the University of Namibia (Unam), the Namibian Ports Authority (Namport), and the Ohlthaver & List Group.

In November 2021, the Namibian government showcased its commitment to this green initiative by selecting a preferred bidder for a green hydrogen project. If the ongoing feasibility study proves successful, the project is set to commence operations by 2026. This ambitious **$ 9.4** billion venture aims to produce **0.3MT** of green hydrogen by 2030, with the southwestern Tsau Khaeb National Park as its base. However, the path to a hydrogen-rich future is not without its challenges for Namibia. The country struggles with issues like the emissions-heavy desalination process required to supply water for the electrolysis process. Additionally, the absence of regulatory policies governing hydrogen activities poses another hurdle.

Given these challenges, there are concerns about Namibia's ability to contribute effectively to the global **1.5**-degree Celsius climate goal. However, there is a silver lining. The German government is actively engaging with Namibia, exploring the possibility of importing hydrogen, either directly through international gas networks or as hydrogen-derived products. This collaboration could pave the way for a brighter, greener future for both nations.

While international climate finance aims to support Africa, funding between 2014-2018 fell short of the estimated costs, amounting to less than **$5.5** billion annually. This shortfall, coupled with challenges like a low grant-to-loan ratio, rigid funding rules, and co-financing requirements, has hindered the full deployment of adaptation projects.

However, collaborations are on the horizon. The European Investment Bank and its African counterparts are joining forces to tap into renewable energy, aiming to produce hydrogen efficiently and at scale.

Achieving these goals requires a robust political framework, substantial investments, incentives, and dedicated research. An estimated **$20-25** billion is needed annually, along with long-term regulatory frameworks to scale hydrogen technologies. Europe and Africa's collaboration is crucial to realize the potential economic, social, and environmental benefits of this transition.

On the research front, initiatives like the NATO Sahara Trade Winds to Hydrogen project are supporting academic institutions in collaboration with the industry to advance green hydrogen production.

Various policy recommendations have been made to bolster hydrogen production in Africa and transition to a hydrogen-centric economy. These suggestions span the technology, infrastructure, industry, and shipping sectors. For instance, technology-focused policies include setting capacity targets and offering loans, while infrastructure policies emphasize international trading collaborations and energy conversions.

In summary, as hydrogen generation costs decrease globally, Africa is poised to become a competitive hydrogen exporter to Northern Europe within the next seven years. The continent could potentially produce hydrogen at an impressive rate of **5,000 MT** annually, priced at under **$2/kg**.

8. Public Perception of Clean vs Renewable Hydrogen

Public sentiment leans more favorably toward green hydrogen, largely due to its environmentally friendly reputation. Blue hydrogen, despite its reliance on fossil fuels, is acknowledged for its role in transitioning to a low-carbon economy. Its compatibility with existing gas infrastructure gives it an edge, as green hydrogen demands substantial infrastructure investments.

Public opinion can shape policy. To shift perceptions about blue hydrogen, there is a need for comprehensive education on its benefits for a sustainable energy future. This change demands collaboration between governments, businesses, and individuals to highlight blue hydrogen's advantages and promote its widespread adoption. Globally, while some countries have made significant strides toward renewable energy, others remain tethered to fossil fuels. Altering these perceptions demands a holistic approach, combining education, communication, and public engagement.

The UAE is championing this cause, leveraging local and international forums to spotlight the benefits of hydrogen energy. The media can play a pivotal role in this, broadcasting accurate data and success stories. Through consistent efforts, the UAE aims to reshape global understanding and inspire other nations to invest in hydrogen.

The upcoming COP28 climate summit is a prime opportunity for the UAE as hosts to advocate for clean hydrogen. This event will allow the region to influence global policy, urging governments to create conducive environments for hydrogen adoption. As a gathering of influential nations, COP28 can also catalyze global collaboration for clean energy.

Changing public perception is undeniably challenging, but with persistent engagement, clear communication, and trust-building, it is attainable. Beyond the environmental benefits, nations stand to gain economically from new projects and investments. Crucially, shifting public opinion is vital to secure the necessary financing for these endeavors.

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