AUDA-NEPAD
AFRICAN UNION DEVELOPMENT AGENCY

The African Continental Power Systems Masterplan

Support Studies – Green Hydrogen

African Union

THE AFRICA-EU PARTNERSHIP
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Introduction

Development of a continental master plan

The African Union (AU) has articulated a vision for a continent-wide interconnected power system (the Africa Single Electricity Market (AfSEM)) that will serve 1.3 billion people across 55 countries, making it geographically the biggest electricity market in the world. Interconnection offers immense technical and economic opportunity[1], while a fully integrated and competitive market will accelerate development and energy access across the continent. Increasingly, the enhanced system flexibility and resilience of an interconnected power system is also an imperative for a modern power system able to navigate the developments impacting global energy systems. This includes growing shares of low-cost variable renewable energy; commitments to climate change and decarbonisation, decentralisation and democratisation of energy; intelligent grid infrastructure and digitalisation of the energy sector; infrastructure resilience in the face of climate risks; and the rise in energy storage technology and electric vehicles.

Concrete steps have been taken towards realising the broader vision described by the AfSEM together with the AfDB's new deal for energy and clean energy corridor concepts. Among these is the development of a Continental Power System Masterplan (CMP) expected to create the framework conditions that will allow countries to trade electricity to leverage national and regional surpluses and deficits through cross border power exchanges and inter power pool trade. This harmonized platform will aid optimised project decision-making regarding the location, size and timing of generation and transmission infrastructure investments.

The CMP is being developed under the governance structure of AUDA-NEPAD (African Union Development Agency) with direction from ministerial committees to ensure political and technical alignment. Development of the CMP spans two phases (Figure 1) and is implemented over several years, with targeted completion of the first draft by the end of 2023.

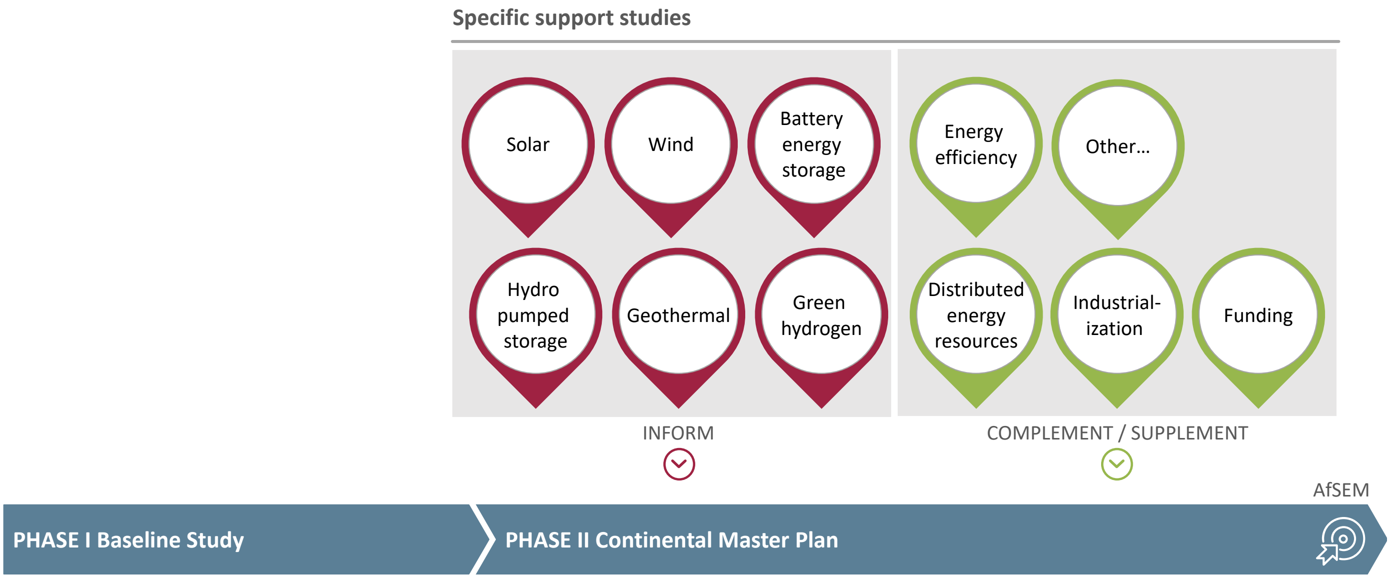


Figure 1: CMP development phases with input from specific support studies

[1] Benefits include increased system reliability; access to more diverse generation resources; enhanced security of supply; improved system flexibility, redundancy, and resilience; reduced or deferred capital investments; diversified loads and improved load factors; and operational and maintenance efficiencies gains, among others.

In parallel, several studies are being developed to help refine and enhance the CMP (Figure 1). These specific support studies (SSS) aim to inform or complement the planning of the CMP, providing a clearer understanding of the potential contribution to the continental power system or the potential for adjacent developmental opportunities.

Green hydrogen as part of the energy generation mix

This study focuses on the findings of the green hydrogen power SSS which was developed with support from the European Union Technical Assistance Facility (EU-TAF) for Sustainable Energy. It provides an overview of the identified resource potential, opportunities, barriers or challenges and recommendations to achieve an optimal contribution to the CMP.

Global electricity generation under IEA's Stated Policy Scenario

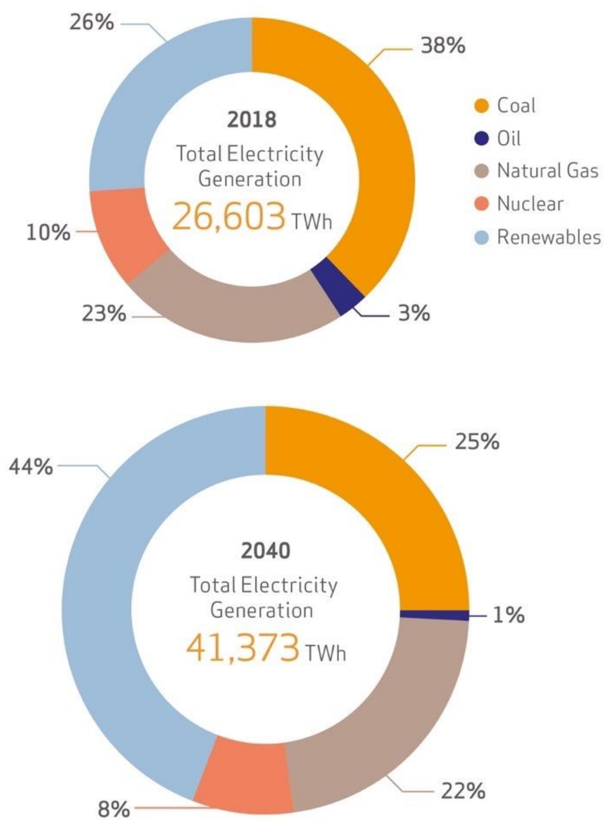


Figure 2: Changes in the global electricity mix, 2018 – 2040 (measures in TWh)

Global projections to 2040 recognise renewable energy as a critical part of a diversified electricity mix to meet the power needs of the world (Figure 2). Green hydrogen is not considered in these projections which are limited to electricity production. It however provides evidence of the overall energy transition.

Similarly, the CMP being developed for the African continent does not consider green hydrogen in the electricity mix planned for 2040, and this would be additional (Figure 9).

Current planning for the future diversified energy mix should support the transition of hydrogen to green hydrogen, and especially in countries that currently use hydrogen (Egypt and South Africa) and / or those with a high export potential.

Africa electricity production share per technology 2023–2040

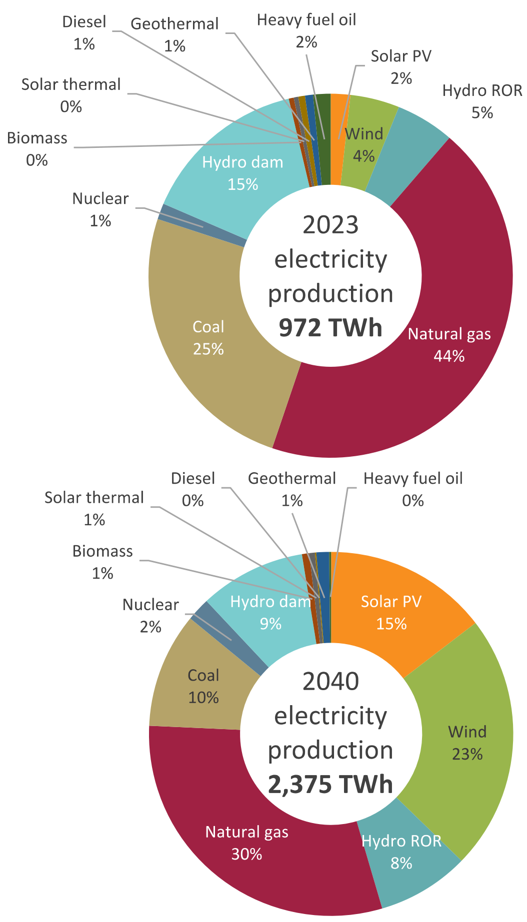


Figure 3: Africa electricity production share per technology 2023–2040

Overview

Hydrogen is a well-established gas that has been used by industry for many decades, primarily in petroleum refining and fertilizer production. In 2020 close to 90 million tons (mt), or 11 Exajoules – EJ, was produced globally, most of which was produced from natural gas or coal (China and South Africa). Consequently, it has a high carbon and water content. A switch to more sustainable fuel sources (Figure 4) coupled with new applications for hydrogen highlights the versatility of GH2 as it can be used to replace existing hydrogen usage and/or as a 'fuel switch' in sectors that are difficult to electrify, so called hard to abate of long haul and heavy transport (rail, shipping, trucks, aviation); steel; cement; and the chemical industry. GH2 can also provide support to the power sector as it increases the flexibility of the electricity sector through 'Power to X'[2] technologies that offset RE variability and intermittency by providing an energy storage system.

	Terminology	Technology	Feedstock/ Electricity source	GHG footprint*
PRODUCTION VIA ELECTRICITY	Green Hydrogen	Electrolysis	Wind | Solar | Hydro Geothermal | Tidal	Minimal
	Purple/Pink Hydrogen		Nuclear	
	Yellow Hydrogen		Mixed-origin grid energy	Medium
PRODUCTION VIA FOSSIL FUELS	Blue Hydrogen	Natural gas reforming + CCUS Gasification + CCUS	Natural gas | coal	Low
	Turquoise Hydrogen	Pyrolysis	Natural gas	Solid carbon (by-product)
	Grey Hydrogen	Natural gas reforming		Medium
	Brown Hydrogen	Gasification	Brown coal (lignite)	High
	Black Hydrogen		Black coal	

*GHG footprint given as a general guide but it is accepted that each category can be higher in some cases.

Figure 4: Hydrogen by production source

In 2020, low-carbon hydrogen comprised less than 1% of global hydrogen production. This is set to grow significantly as the world decarbonizes to meet net zero emission scenarios. Thus, it is forecast that total low carbon hydrogen production will rise to 17 EJ by 2030 (33% in the power sector, 25% in industry, 15% hydrogen-based fuels, and the balance in buildings and transport) – this production is expected to be equally split between electrolysis (RE) and fossil fuels with carbon capture utilization and storage (CCUS). By 2050, production will rise to 60 EJ (420 mt), where transport's (hard to abate) share dramatically increases to 25%. Production from electrolysis will account for two thirds, displacing fossil fuels. Importantly, the electricity required for low carbon hydrogen production in 2050 is greater than the current combined demand in the US and China, and 25% of global natural gas supply. These ambitious targets can only be achieved if early action is taken by industry and government.

Hydrogen usage in Africa has been growing steadily and in 2020 accounted ~4% of total global consumption, where 55% was used for ammonia and fertilizer production, 30% for refining, and the remainder for methanol and other uses. By 2030, the compounded annual growth rate is set to increase from 3% to 4%, increasing the continent's consumption by 1mt to 4mt. Usage is concentrated in North Africa (67%), followed by South Africa (13%), and the remaining 20% across the rest of the continent.

[2] Power-to-X (also known as PtX or P2X) is a collective term for conversion technologies that turn electricity into carbon-neutral synthetic fuels, such as hydrogen, synthetic natural gas, liquid fuels, or chemicals. These can be used in sectors that are hard to decarbonise or, unlike electric power, be stored for later use.

Potential GH2 Applications, Technology and Price

Market Opportunities

Africa's RE potential for power generation is very large and mostly untapped, as detailed in the individual SSS reports and thus not repeated here. However, as a point of reference it is estimated that there is 1 000 GW of solar; 350 GW hydroelectric; 110 GW wind; and 15 GW of geothermal potential.

Water resources, given that many regions in Africa suffer from acute shortages is an important consideration as hydrogen production requires large quantities of water. The smallest water footprint is from electrolysis (9 kg per 1 kg H2), whereas natural gas requires almost double (13 - 18 kg per 1 kg H2). Hydrogen production in high RE but water stressed areas, presents the opportunity for desalination plants whose financial viability is anchored to the plant but also serves the community. The associated cost is deemed low at just $0.01-0.02/kg of H2. Significant research is currently underway to overcome the challenges of seawater corroding equipment and the by-product of chlorine.

A major consideration is the continent's generation and electrical interconnection transmission infrastructure, as hydrogen production is very energy intensive (as detailed above). However, GH2 is considered a demand or load that requires RE for its production but, at the same time, can be grid independent. Importantly therefore, the uptake of GH2 need not negatively affect continental electrification objectives but, on the contrary, could bolster RE deployment whilst reinforcing and/or deploying electricity grids, including areas with limited access.

Moreover, given the growing global urgency to decarbonize demand for GH2 (and its derivates such as ammonia, methanol and others) is increasing and many countries that are unable to produce the required quantities domestically are seeking to establish partnerships with potential suppliers. Here, several announcements and joint cooperation agreements with Africa have been made, including North African countries (due to existing gas infrastructures connected to Europe), Namibia and South Africa. On this basis the applications where GH2 could and is likely to play a role in the local and or regional economy must be weighed up against planned export projects. Initially, although still not proven at scale, GH2 will be competing with CCUS to decarbonise specific sectors. The most prevalent continental applications are: i) Industrial heating - specifically cement, iron and steel production, and oil refining, and, ii) Production of chemicals - specifically ammonia and its derivatives, and methanol.

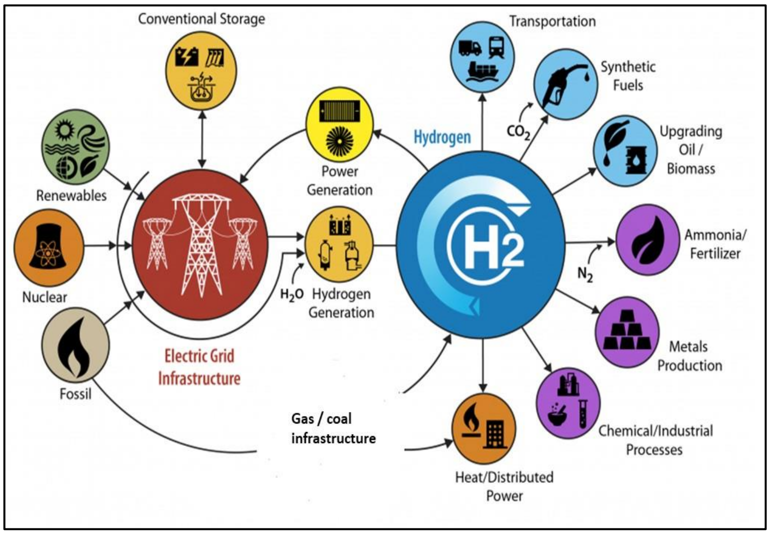
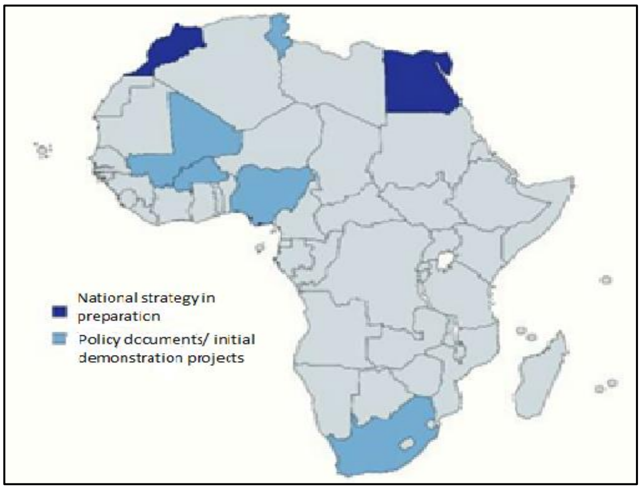


Figure 5: GH2 Energy system

GH2 is a nascent industry, and as such very few countries in Africa have to date developed a national strategy and roadmap (Figure 6). To overcome this challenge and identify the countries (by power pool) with the greatest GH2 production and use, a multi criteria analysis was undertaken. This was based on the above-mentioned criteria, as well as any identified supportive national policy and actions. The top candidates include:

- COMELEC Morocco, Algeria, Mauritania
- WAPP Nigeria
- EAPP Egypt, Kenya, Tanzania
- CAPP Congo (DRC)

- SAPP South Africa, Namibia



Source: World Energy Council

Figure 6: GH2 Strategies and projects

Figure 8: Existing LNG terminals for export

Technology

GH2 is produced from RE and uses different technologies. This study limits itself to the water electrolysis process. The most problematic aspect of hydrogen, however, is its storage and transportation. The most common form is compressed gas or cryogenic liquid, but both come at a significant financial and energy cost, prompting the use of alternate carriers (ammonia, methanol, synthetic fuels) which are obtained from Power to X processes, and therefore of interest to several African countries with high GH2 potential and access to ports for exports (Figure 7). The use of existing gas pipelines between North Africa and Europe places these countries at an advantage, as the EU is expected to be the world's leading importer of GH2 by 2030 (Figure 8).

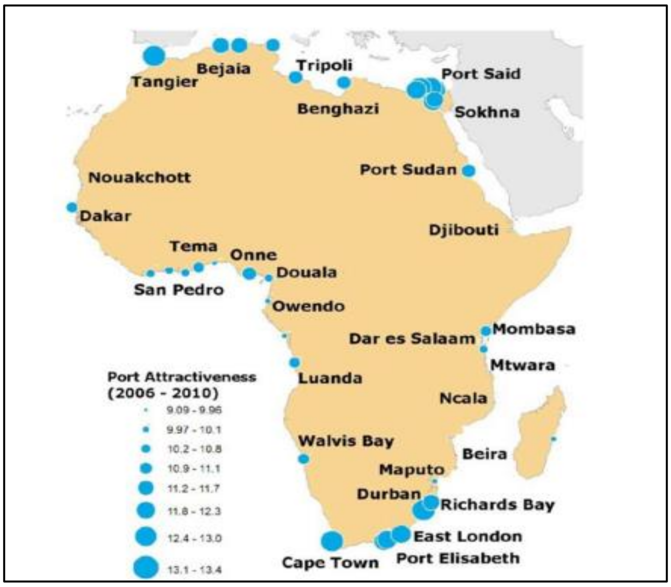


Figure 7: Port attractiveness index

The value recognition of GH2 is recent, and very few targets or incentives to promote its use and related products exist. Consequently, the global GH2 market is still limited due to low demand and on this basis forecasting exports is fraught with assumptions. Transitioning to GH2 at the national or regional level can rely on existing manufacturing and usage data, increasing its confidence levels.

Table 1: Estimated continental GH2 demand (Mt H2)

Sector	Year		
	2030	**2035**	**2040**
Transport	0.61	1.97	5.5
Industry	2.07	4.12	15.19
Buildings	-	-	-
Total w/o power	**2.7**	**6.1**	**20.7**
Power	0.08	0.36	2.38
Grand total	**2.8**	**6.4**	**23.1**

Continental demand for GH2, within and across African countries, to replace fossil fuel-based hydrogen is estimated to rise significantly, as shown in Table 1. These estimates assume that production costs will range between $1.5 to $3/kg by 2030 in order to be competitive, as well as a conducive policy and regulatory environment and other important enabling factors are in place – discussed in the next section. The increased infrastructure capacity required to meet the estimated demand is truly significant, as shown in Figure 9, underscoring the need for countries seeking to produce GH2 to incorporate it into their energy planning at the soonest opportunity. Currently, global GH2 production costs are too expensive, and for it to become commercially viable the price must drop to under $2/kg, this is less than half the current cost levels.

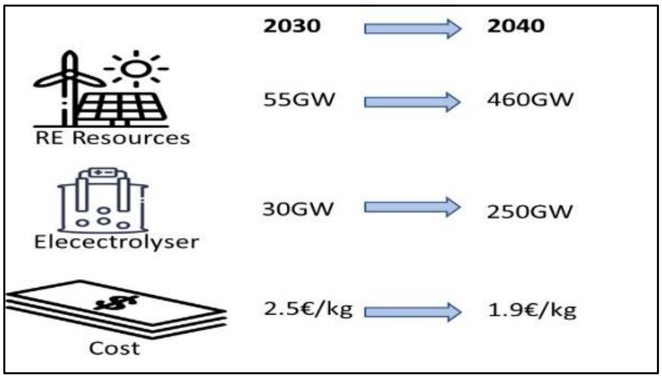


Figure 9: Capacity increases

Barriers, Challenges and Opportunities

Notwithstanding the continent's high RE potential, energy production remains fossil fuel based. Globally, GH2 is currently not cost competitive due to its high production costs when compared to hydrogen produced from fossil fuels. Undoubtedly many production challenges will be reduced through technological advances and economies of scale. For Africa, the following technical and non-technical (regulatory, legal, finance, environmental, safety) barriers will need to be considered and addressed to unlock the still small, but growing applications and seemingly insatiable future international demand for GH2.

High production costs. The ever-decreasing costs of RE and electrolysers allows for GH2 to increase its cost competitiveness. However, the end user cost is still too high. Notably demand is being driven by sectoral decarbonization imperatives rather than cost efficiencies. This positive development must be maximised through the development of supportive policy and regulatory frameworks.

Infrastructure development. To date hydrogen is produced close to where it is used due to the lack of dedicated infrastructure. – Globally, the pipeline network is only about 5 000 km and has just 470 refuelling stations, making the existing infrastructure insufficient to support its envisioned growth. In Africa, most countries have an energy supply and infrastructure deficit, and with just ~4% of global total hydrogen usage the continent's existing infrastructure (electricity distribution and transmission networks, roads and pipelines) is insufficient. This constitutes a major barrier to future economic development. However, it also offers an opportunity that newly built infrastructure will support and enable future hydrogen developments and the overall transition to a low carbon economy.

Enabling policy. Collectively there are many GH2 applications, which if coordinated creates the economies of scale needed to reduce costs and increase investment. Enabling national and international policies, such as the removal of fossil fuel subsidies, will accelerate these actions. Three stages of policy support are identified: i) technology readiness; ii) market penetration; and iii) market growth. Internationally, most sectors find themselves in the first stage but some sectors (and countries) have advanced more than others.

Policy and regulatory requirements. Noting the high capital costs and infrastructure requirements, countries seeking to travel the GH2 road must develop an integrated policy approach. This starts with a national strategy and regulatory framework of the targeted sectors with consideration given to the full GH2 supply chain of production, storage, transport, and importantly environmental considerations as the ultimate driver of exports is decarbonization. This activity is largely work in progress for almost all countries, and Africa should enter at this early stage to gain maximum benefit and influence international decision making and attract interest.

Technical norms and standards. Integrity is key. Certification is likely to demand guarantees of origin for imported hydrogen that will need to comply with the principle of additionality.

Investment challenges. To build new infrastructure and / or to upgrade existing infrastructure for the hydrogen sector will be costly, and not feasible without private and public long-term investment commitments. Countries in Africa will face significant competition from other potential exporting countries (Middle East, Australia, South America) and private sector financing will pursue regions with the most conducive technical and policy support mechanisms.

Technology requirements: Electrolyser technology, apart from the economic aspects, still has great potential for improvement but given its capabilities, it also shows great potential for long term applications such as grid support services. However, it is important to note that a large connection of electrolysers to the grid can give rise to both positive and negative impacts and detailed assessments must be made for the appropriate design and planning of each project.

Definitions: Countries developing a GH2 for export should consider the definitions of the markets they are targeting as these may differ. What is acceptable to the Japanese market may not qualify in the EU and vice versa.

Conclusion

The competitiveness of GH2 can be assessed by its cost, as it can be compared to its fossil-based competitors – see Figure 1. Its demand will thus depend on technological and non-technological aspects to increase its cost competitiveness, such as a premium being paid to accelerate decarbonization. For now, GH2 projects must be analysed on a case-by-case basis to carefully analyse important aspects such as the plant configuration; technologies; plant management; and numerous local factors (available RE sources, grid infrastructure, demand for GH2, regulated electricity markets, etc.). Collectively these will determine the costs and final viability of the project.

Countries that develop a comprehensive GH2 strategy, which identifies priority sectors (local consumption applications and / or exports) which is then used to create an enabling environment will benefit. GH2s investment potential, coupled with job creation, export earnings and direct access for products to countries that may impose carbon border adjustments tariffs are significant. But so too is the uncertainty. Careful, considered and collaborative planning is undoubtedly the first task.

The clean energy needed to produce GH2 is additional to a country / region / continent's power requirements. And notwithstanding there are some synergies do exist between GH2 production and the grid, the high capital investment and long lead time needed necessitates long-term strategy development with consistent oversight.