GREEN HYDROGEN SOUTH AFRICA

The Potential Benefit of Green Hydrogen for the Republic of South Africa

Policy Paper

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Implemented by:
giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

THE POTENTIAL BENEFIT OF GREEN HYDROGEN FOR THE REPUBLIC OF SOUTH AFRICA

Policy Paper

PUBLICATION: The Potential Benefit of Green Hydrogen for the Republic of South Africa

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LAYOUT AND DESIGN: Studio112

PUBLICATION DATE: September 2023

FUNDED BY: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH 333 Grosvenor Street, Hatfield Gardens, Pretoria, South Africa

RESPONSIBLE INSTITUTIONS

Green Hydrogen South Africa (GHSA): GHSA is a multi-stakeholder initiative that promotes South Africa as a leading green hydrogen producer and investment destination of choice. It is led by The Presidency of South Africa and home of the South African Green Hydrogen Summit (SAGHS).

H2.SA: H2.SA is a project of the German Development Cooperation with South Africa. It is commissioned by the German Federal Ministry for Economic Cooperation and Development (BMZ) and implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH in close cooperation with The Presidency of South Africa. H2.SA's main objective is to promote a South African green and sustainable hydrogen economy. Working closely with its partners from Government, private sector, and civil society, H2.SA provides expertise, resources, and builds capacity for a secure and sustainable energy future that holds opportunities for all South Africans.

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ACRONYMS

NDC	Nationally determined contribution
CO_2	Carbon dioxide
BEV	Battery-electric vehicle
HCV	Heavy commercial vehicles
XHCV	Extra-heavy commercial vehicles
PGM	Platinum group metal
AGHA	Africa Green Hydrogen Alliance
JET IP	Just Energy Transition Investment Plan
RCS	Regulations, codes and standards
GHG	Greenhouse gases
ERA	Electricity Regulations Act
H_2	Hydrogen
HSRM	Hydrogen Society Roadmap
ICE	Internal combustion engines
UNFCCC	United Nations Framework Convention on Climate Change

1. Introduction

South Africa is a signatory to the Paris Agreement, which aims to reduce greenhouse gas (GHG) emissions through the nationally determined contribution (NDC). Generally, South Africa's power sector contributes the most; it is one of the most carbon-intense among the G20 nations and its GHG emissions are 1.2 times higher than the G20 average of 7.5 [1]. The second-largest contribution to GHG emissions is the transport and hard-to-abate industrial sector. The updated NDC targets the power sector and the hard-to-abate sectors which aim to reduce GHG emissions to a target range of 420–350 Mt CO_2-eq by 2030 and by a further 45% by 2050. This is a clear and bold statement that indicates South Africa's intention to move away from a hydrocarbon-based economy to a sustainable low-carbon economy. While these ambitious targets may seem formidable, South Africa has compiled a Just Energy Transition (JET) plan which has identified priority sectors to decarbonise the economy in line with the NDC targets.

For more than a century, hydrogen has been used extensively in the hard-to-abate sector as a chemical feedstock. The current use of hydrogen as an energy carrier gained significant momentum due to the need to decarbonise the energy system across the entire value chain. This approach has largely been driven by global consensus that hydrogen and power-to-X (PtX) products can play an integral role in facilitating decarbonisation of sectors such as long-haul, heavy-duty transport, commercial aviation, maritime transport, and industrial sectors. More importantly, the production of hydrogen must also be decarbonised, which requires carbon-free energy as the source to break water into hydrogen and oxygen molecules at least cost.

South Africa has several competitive advantages in the green hydrogen space, primarily attributed to abundant, cost-competitive, and renewable resources; land availability; and mineral endowment resources such as platinum group metals (PGMs) that are used in producing electrolysers and hydrogen fuel cells. More importantly, South Africa has experience in the industrial-scale Fischer-Tropsch process used to produce power fuels, as well as existing port infrastructure and prime shipping access to the rapidly growing international hydrogen market.

The objective of this policy brief is to provide recommendations on potential opportunities relating to the green hydrogen economy in South Africa, taking advantage of the abundant renewable and mineral resources.

2. Technology landscape

South Africa has abundant renewable energy resources, especially solar and wind, that can be used to produce green hydrogen at a competitive cost [2]. The country also has a strong industrial base and expertise in hydrogen-related technologies, such as fuel cells, electrolysers, and synthetic fuels [2]. South Africa is well placed to adopt the manufacturing of green hydrogen, which could provide much needed benefits in creating employment opportunities, energy generation, balance of payment inflows, and many other economic benefits [2]. The country possesses many of the resources to become a world leader in green hydrogen [2].

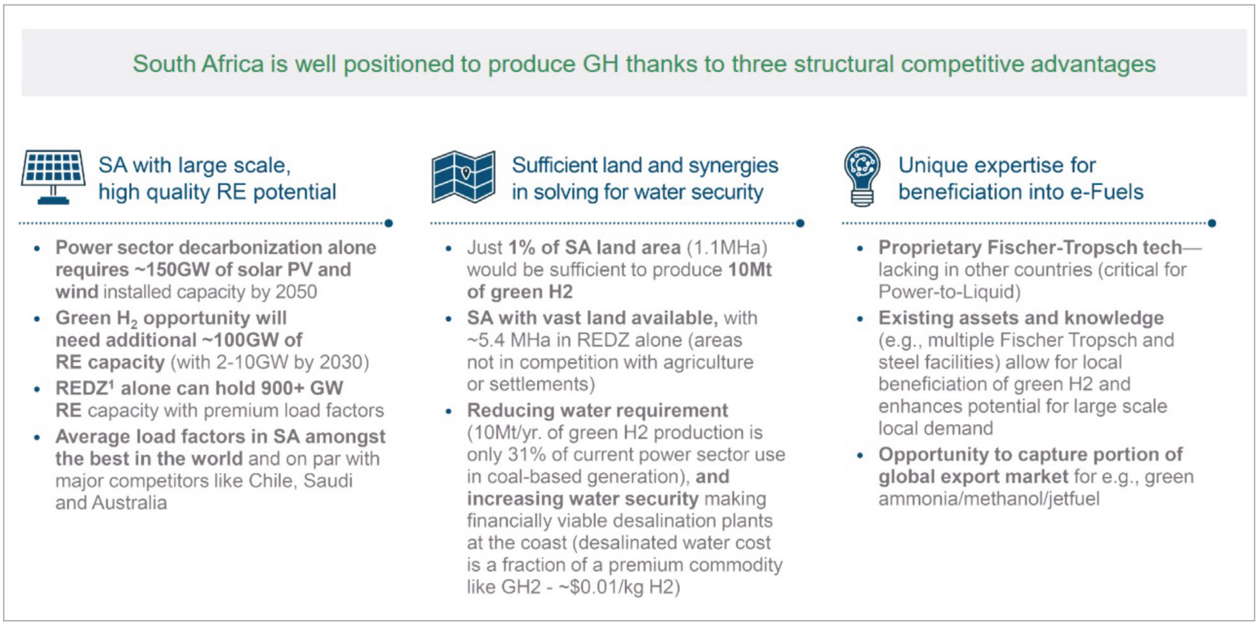

Figure 1: The three structural competitive advantages of South Africa [2]

2.1 Technology infrastructure and supply chains

As the country continues to grow and revolutionise its status quo, South Africa aims to use its mineral endowment, renewable energy assets, and land and water resources to produce green hydrogen. This is evident as the country has already benefitted from the start of nineteen (19) green hydrogen projects that have been identified for development, nine of which have been formally registered with Infrastructure South Africa [3]. These projects and similar future projects will provide potential benefits to the country, as infrastructure will stimulate economic growth, provide opportunities for investment in new markets, and create jobs [4]. Adapting green hydrogen infrastructure provides a unique situation for the country to create strategies for re-skilling the current workforce and educating the future workforce to ensure sustainability of the green hydrogen infrastructure and its supply chain (see Annex 6.1).

Along with projects that support green hydrogen infrastructure, other end-users may prosper by using green hydrogen directly or indirectly in their supply chains. In particular, the greening of production supply chains of any industry assists in obtaining the sector's GHG emission restrictions and striving for net zero. This will contribute to South Africa's decarbonisation obligations, as it is a signatory to both the United Nations Framework Convention on Climate Change (UNFCCC) and the 2015 Paris Agreement [5].

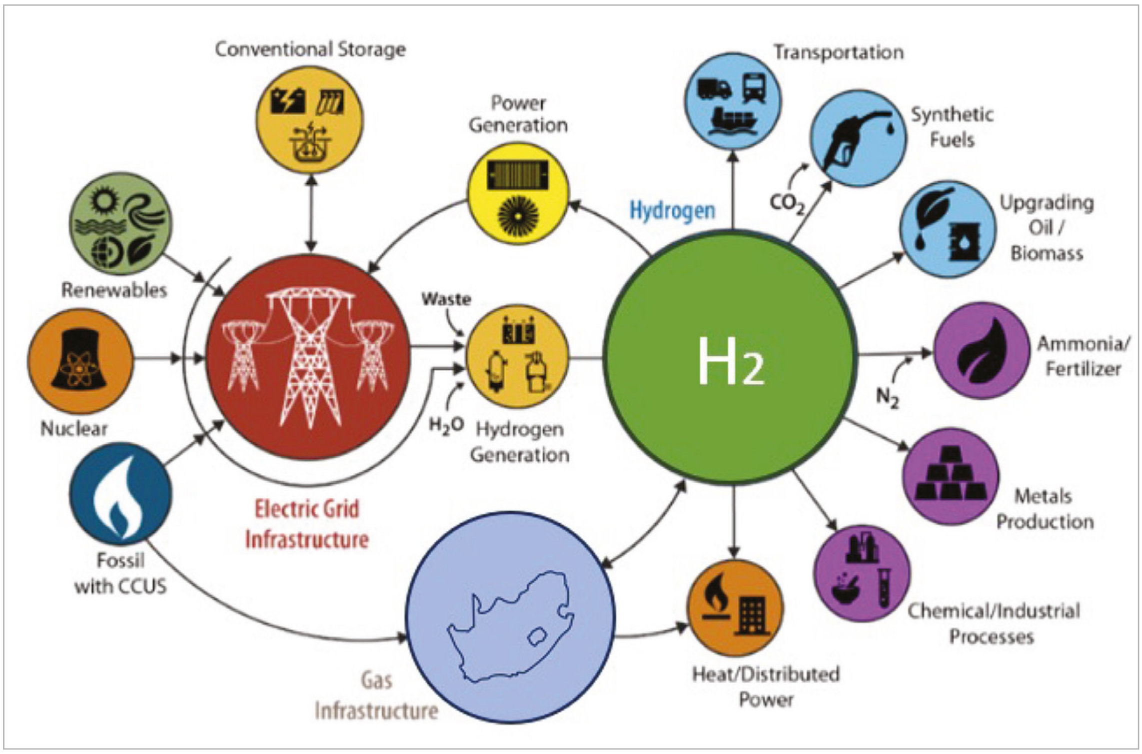

Figure 2: Hydrogen-envisioned end-users and green hydrogen up-takers

2.1.1 Potential benefits for the mining sector

Using green hydrogen in mining operations could reduce carbon emissions and improve air quality. For example, Anglo American Platinum has already started using green hydrogen fuel cells in its mining operations in South Africa [6]. Thus, application of green hydrogen could help mining companies reduce their carbon footprint while also meeting their sustainability goals [6].

2.1.2 Potential benefits for the transport sector

For heavy-duty and long-range transport applications, hydrogen powered vehicles are expected to be more cost-effective than battery electric vehicles (BEVs) in the short term [7]. Table 1 below shows the expected time frame for various hydrogen powered vehicles to reach total cost of ownership (the purchasing and running costs of the lifecycle) compared to internal combustion engine vehicles (ICEVs) and battery electric alternatives. Longer time frames (indicated by shades of red) suggest less suitability for hydrogen power as battery electric alternatives become more established. Heavy commercial vehicles (HCVs) and extra-heavy commercial vehicles (XHCVs) show the greatest potential to reach cost competitiveness with ICEVs and BEVs.

Table 1: Total cost of ownership of hydrogen powered vehicles versus ICEVs and BEVs [7]

Type of vehicle	Usage	Range	Year of parity with ICE	Year of parity with BEV
Small PV	Short range	200 km	2035	2050
Large PV (i.e. SUV)	Long range	600 km	2030	2030
LCV	Long range	650 km	2030	2025
MCV	Short range	300 km	2025	2030
HCV	Long range	500 km	2025	2020
XHCV	Long range	600 km	2025	2020
Buss	Short range	150 km	2025	2040
Buss	Long range	450 km	2025	2025
Coach	Long range	500 km	2025	2025

Table 2: Total cost of ownership of hydrogen powered vehicles versus ICEVs and BEVs
* Shades of green indicate greater competitiveness and shades of red indicate least competitiveness.
Source: Prepared by TWIMS using data from Hydrogen Council (2020, pp. 33-41)

Green hydrogen directly benefits the South African transport sector by encouraging the modal shift of passenger transport from passenger transport [8-10], where it is encouraged to allow for reduced road traffic and costs associated with maintaining national and urban roads. Intrinsically, this allows resources to be redirected to environmentally sensitive upgrades of rural road infrastructure and further transport development for the country.

2.1.3 Potential benefits for the electrical grid sector

A study by IRENA reveals that Africa's systematic shift away from fossil fuels to a renewable energy system could lead to 6.4% higher GDP, 3.5% more jobs across the economy, and a 25.4% higher welfare index throughout the forecast period 2020–2050 [11]. In South Africa specifically, renewable power, heat, and fuels could provide 23% of the country's total final energy consumption by 2030, compared to only 9% overall in 2015 [12]. The benefits of renewable energy in South Africa are not limited to environmental sustainability but also include closing the energy supply capacity gap that has resulted in a prolonged energy crisis.

The green hydrogen supply chain can address national challenges, such as South Africa's energy crisis, by supplying surplus renewable energy to the grid, helping overcome industrial and national challenges.

In summary, introducing green hydrogen will potentially benefit South African technology infrastructure by:

1. Enabling decarbonisation solutions to be realised in multiple hard-to-abate sectors.
2. Spearheading green hydrogen infrastructure to be developed.
3. Providing an economical option to reduce the current and future infrastructure operating carbon footprint and support decarbonisation goals.
4. Creating new job opportunities in the green economy sector.
5. Generating platforms to reskill the current workforce and create job opportunities that require new knowledge and technical know-how.
6. Attracting national and international funders to invest in the green hydrogen supply chain.
7. Decarbonising hard-to-abate sectors with green hydrogen can access financial incentives and reduce carbon taxes by integrating it into supply chains, promoting its development and use in the country.
8. Allowing for economic growth and sustainability in a new economic sector, while retaining and revolutionising other hard-to-abate sectors.

2.2 Research and development of green hydrogen products

Green hydrogen provides a platform for research and development (R&D) of new technologies and processes. R&D allows the efficient usage of resources to provide the green hydrogen molecules produced here. Historically, South Africa has a well-known platform of organisations that provide world-leading technology innovation. The potential benefit of R&D can be summarised as follows:

> "Our resource endowment has to be translated into a competitive advantage for value-added manufacturing that can contribute to job creation, investment, the export of hydrogen and platinum-based fuel cells."

Ebrahim Patel, Minister of Trade, Industry and Competition of South Africa.

Among innovations, green hydrogen R&D will potentially benefit the development of electrolysers, fuel cells, and dual fuel engines.

2.3 Utilisation of South Africa's rare minerals

PGMs, in particular, offer an opportunity to develop a globally relevant industry by capturing the local value added from a resource that is now exported as a raw material. A cornerstone of the government's hydrogen strategy is a 'platinum valley', an industrial cluster to combine various applications into an integrated hydrogen ecosystem [13]. This is one of the four catalytic projects identified in the strategy document to start the country's hydrogen economy.

South Africa possesses 80% of the world's PGMs. This material is a critical resource used in the production of hydrogen through electrolysis and generation of electricity from hydrogen using fuel cells [14,15]. South Africa is one of the competitive industrial economies; however, it can differentiate itself by using proprietary Fisher-Tropsch technology to target the export of sustainable aviation fuel and manufacture electrolysers and fuel cells using PGMs available locally.

In terms of existing petrochemical infrastructure, Sasol and PetroSA can utilise their existing expertise in adapting their production, storage, and transport for green hydrogen. Sasol has experience in producing brown hydrogen from coal. Although brown hydrogen is not environmentally friendly, this can be combined with carbon capture storage to reduce carbon emissions by around 90% [16]. This would allow South Africa to capture a first-mover advantage while developing infrastructure for green hydrogen production. PetroSA's large gas-to-liquids refinery near Mossel Bay utilises natural gas, however, their gas resources are becoming scarce and they are well positioned to be repurposed to produce hydrogen. The facility's close proximity to the Coega Special Economic Zone (SEZ) and deep-water Port of Ngqhurha makes it an attractive potential hub for the production, storage, and export possibilities of green hydrogen [17].

3. Economic opportunities for Green Hydrogen

The demand for green hydrogen is accelerating in the European Union, Japan, and South Korea, all of whom are positioning themselves as major importers of green hydrogen [25]. This creates a significant opportunity for South Africa with its high levels of renewable energy potential to become the main exporter of green hydrogen. The export of the molecules, however, has to meet varied requirements of its trading partners.

According to Air Products South Africa, the price of grey hydrogen in South Africa was approximately R300 per kg in February 2021. This is far from the Japanese target price for imported blue/green hydrogen set at R52.20 per kg. However, this has been labelled as achievable for South African hydrogen producers. Furthermore, a joint European Union and South African investigation into power fuels and green hydrogen found that a long-term price of R26.50 per kg for exported South African green hydrogen is possible [17].

Table 2: SA hydrogen prices

Hydrogen Prices	Price (ZAR per kg)
Current price of industrial hydrogen	R300
Japanese target price for green hydrogen	R52.2
Long-term price of South African green hydrogen	R26.5

Source: Prepared by TWIMS using data from Air Products South Africa (Pty) Ltd (2021); M. Creamer (2020); Roos and Wright [17]

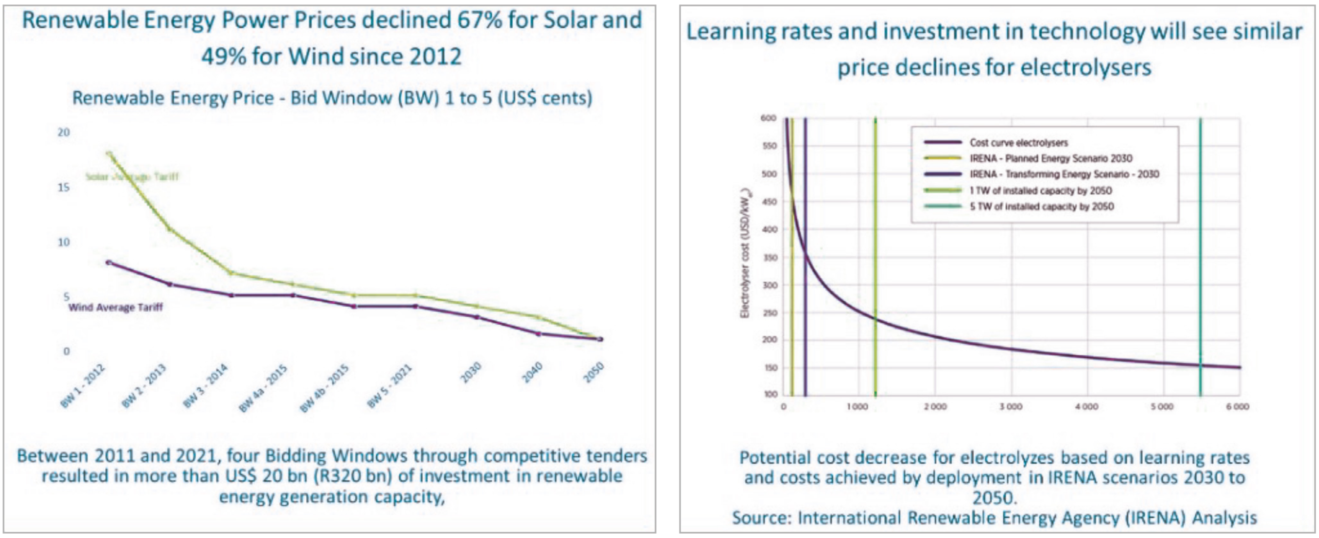

Figure 3: Envisioned price reduction trend [2]

Green hydrogen may be economically viable by 2020–2025. However, the combination of cost reductions in electricity and electrolysers, together with increased efficiency and operating lifetime, has the potential to deliver 80% reduction in hydrogen cost over time. Scale-based targeting projects will also contribute to equipment cost reductions by aggregating demand [2]. In the long run, the levelised cost of hydrogen will improve over time and allow South Africa to be one of the most economical options in the future (see Figure 4 below).

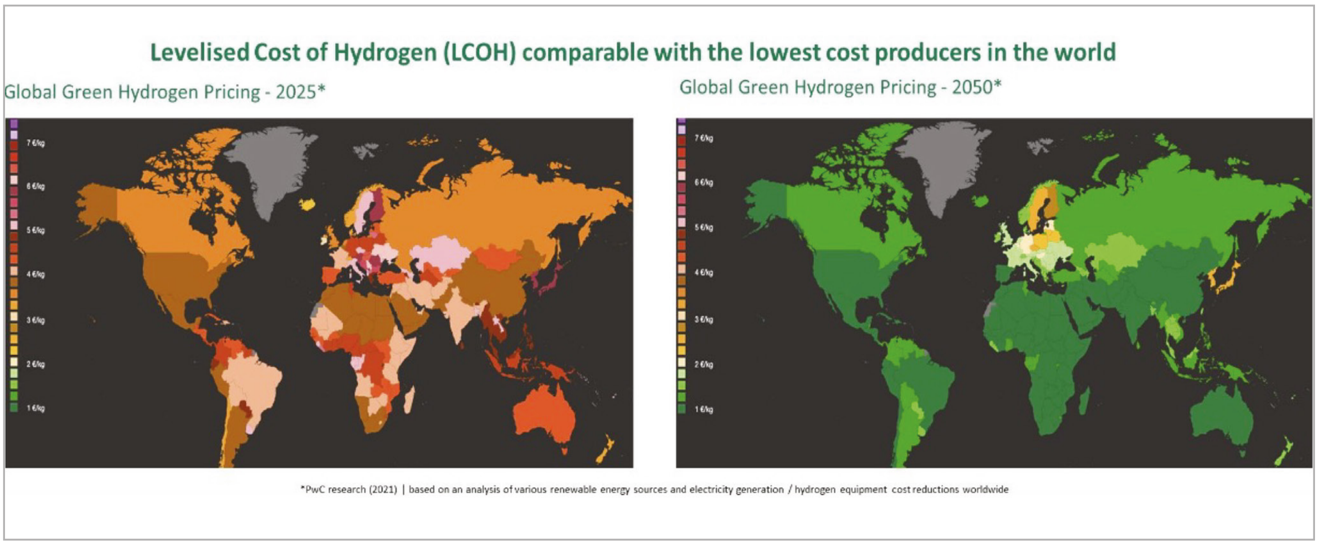

Figure 4: Levelised cost of hydrogen comparable with the lowest cost producers in the world [2]

In summary, green hydrogen presents several economic opportunities for South Africa:

1. **Energy security and economic growth:** Moving rapidly towards a green hydrogen economy will help South Africa secure its domestic energy supply and drive economic growth by exporting green hydrogen power fuels and technology to European and Asian markets. Moderate estimates indicate that the country has the potential to be an important player in the green hydrogen economy and could secure 10% of the global export market share [2, 13, 18].
2. **Job creation:** A recent report by PwC South Africa highlighted the immense potential of the green hydrogen economy to create long-term jobs and open the market for substantial investment [2, 13, 18].
3. **Utilisation of PGMs:** South Africa is endowed with vast reserves of PGMs, which are critical for proton exchange membrane electrolysers needed to produce green hydrogen and hydrogen fuel cells in electric vehicles [2, 13–15, 18–20]. This presents an opportunity for South Africa to develop a globally relevant industry, capturing local value added from a resource that is now exported as a raw material [21].
4. **Renewable energy resources:** South Africa is also well placed to pursue green hydrogen technology due to its abundant renewable energy resources for both onshore and offshore power generation. It is possible to generate significantly more electricity from wind and solar PV energy than the country needs, even when considering spatial exclusion zones [2, 13, 18–20].
5. **Chairship of the Africa Green Hydrogen Alliance (AGHA)**: South Africa has been awarded the AGHA chairship and is committed to advancing the continent's green hydrogen agenda [22]. This position will allow South Africa to support opportunities for peer learning and technology transfer [23].

These opportunities, if used effectively, could help South Africa secure its domestic energy supply, while also driving economic growth through the export of green hydrogen power fuels and technology applications to European and Asian markets.

4. Policy landscape

Hydrogen as an energy source can influence a wide range of economic sectors, ranging from energy, residential, transportation, and industry. Consequently, introducing green hydrogen in energy mixes includes evaluating and integrating various sectors' policies and strategies. In South Africa, while the Hydrogen Society Roadmap and Green Hydrogen Commercialisation Strategy are the main policy documents focusing on green hydrogen, some policy, strategy, and master plan frameworks have been analysed to deepen the policy context in which green hydrogen is to be integrated. To highlight the most relevant documents for this task, a policy priority list has been compiled:

1. The National Climate Change Response White Paper
2. National Development Plan
3. National Determined Contribution
4. The Industrial Policy Action Plans
5. Green Hydrogen Commercialisation Strategy
6. Hydrogen Roadmap
7. Integrated Resource Plan
8. Hydrogen Society Roadmap
9. Electricity Regulation Amendment Bill.

These documents are considered a priority because they are broad, interdependent in scope, and related to hydrogen topics. Furthermore, other policy documents are useful for achieving/updating sectorial targets needed to formulate hydrogen strategies (e.g., the Green Transport Strategy and Steel Industry Master Plan).

4.1 Financing the Green Economy

The JET Investment Plan (JET IP) outlines the financing gap necessary to enable early adoption of the green economy. According to the JET IP, R319 billion will be needed in total for strategic green hydrogen projects. South Africa received $8.5 billion in financial support from the COP26 JET Partnership, and R10 billion is allotted to accelerate the green hydrogen economy. For the period 2023–2027, a total funding deficit of R285 billion will be needed from a variety of finance mechanisms to accelerate South Africa's JET in the hard-to-abate sectors. This finance is necessary for economic diversification as well as developing infrastructure, skills, social support, and inclusion.

Although South Africa has shown great strides in demonstrating policy certainty which has been the main driver for attracting funding, there are still numerous hurdles that must be overcome such as the release of the Integrated Resource Plan and its impact on sector coupling to assure investors that hydrogen is incorporated in the IRP.

4.2 Regulations - water

South Africa is in the process of assessing its readiness for the green hydrogen economy. This includes reviewing existing technical regulations, codes, and standards for production, transport, trade, and application in the hydrogen and PtX industry at an international level and in South Africa [24]. However, South Africa currently does not have a regulatory framework that specifically concerns hydrogen.

4.3 Grid access - market reform

The electricity market in South Africa is regulated by the Energy Authority of South Africa (NERSA) through the Electricity Regulations Act (ERA) (No. 4 of 2006). The country's electricity sector is currently moving from a market structure based on a monopoly—Eskom as the main producer and one-source buyer of electricity—to a multi-market model in which multiple private and public institutions play a role in producing and purchasing electricity. Recently, significant legislative and regulatory changes have been introduced to support the transition of the electrical supply industry, including (among others):

1. Exempting private distributed power plants from needing market licences by NERSA, enabling them to enter the electricity market more easily. The current regulations (amended in October 2021) exempt the need for NERSA to obtain market permits for construction projects up to 100MW in capacity. Following the announcement by the President of the Action Plan for South Africa's load-shedding crisis in July 2022, Update 43 of the draft regulation was published for comment, which exempts projects with "indefinite capacity" from licenses.
2. Legal provisions for Eskom's restructuring and establishing an independent Transmission System Operators and a future and balanced market, thus facilitating the transition from the single buy-only model and developing a trade power market.
3. Regulatory amendments to allow municipalities to buy or procure power from new generation capacity.
4. Enable the supply and/or sale of electricity to several unrelated customers by a direct connection or a wheel.

5. Recommendations

The potential benefits of green hydrogen for South Africa are substantial and far-reaching, encompassing economic, environmental, and energy security advantages.

First and foremost, South Africa is endowed with abundant renewable resources, particularly wind and solar power, which can be harnessed to produce green hydrogen efficiently and cost-effectively. This presents an opportunity to reduce the nation's reliance on fossil fuels, decrease carbon emissions, and mitigate climate change. By embracing green hydrogen, South Africa can align its energy sector with global sustainability goals, attracting environmentally conscious investors, and demonstrating its commitment to a cleaner, greener future.

From an economic perspective, developing a green hydrogen industry can stimulate job creation and economic growth. Building and operating green hydrogen production facilities, as well as the entire supply chain, will require a skilled workforce and investment in R&D. South Africa can become a hub for green hydrogen production and export, capitalising on its potential to supply not only domestic demand but also international markets seeking cleaner energy solutions. This export potential could bolster the country's balance of payments and diversify its economic base.

Additionally, green hydrogen can enhance energy security for South Africa. By reducing dependence on imported fossil fuels, the country can safeguard itself from price volatility and geopolitical risks associated with energy imports. Green hydrogen offers a stable and domestically producible energy source that can complement the existing energy mix and contribute to a more resilient energy system.

It is essential to develop effective policies that leverage the potential benefits of South Africa's green hydrogen to maximise its advantages. The following are some key policy recommendations:

1. **Set clear renewable energy targets:** Establish ambitious renewable energy targets to incentivise growth of green hydrogen production. Clear and quantifiable objectives will guide investment and development efforts.
2. **Financial incentives:** Introduce financial incentives such as tax breaks, subsidies, and grants to support the initial investment required for green hydrogen infrastructure. These incentives can attract private sector involvement and stimulate job creation.
3. **Invest in R&D:** Allocate resources for R&D to advance green hydrogen technologies. Encourage partnerships between academic institutions, research centres, and industry to accelerate innovation and reduce production costs.

4. **Infrastructure development:** Develop a robust infrastructure for green hydrogen production, storage, and distribution. This includes building electrolyser facilities, pipelines, and transportation systems to ensure a seamless supply chain.
5. **Regulatory framework:** Establish clear regulatory frameworks and standards for green hydrogen production, safety, and environmental impact. These regulations should promote best practices and ensure the safe handling and transportation of green hydrogen.
6. **International collaboration:** Foster collaboration with other countries to leverage their expertise, technology, and market access. Engage in international partnerships for knowledge sharing, trade, and investment in the green hydrogen sector.
7. **Skills development:** Invest in education and training programmes to build a skilled workforce capable of operating and maintaining green hydrogen facilities. This will create employment opportunities and enhance the nation's expertise in this emerging field.
8. **Public awareness and education:** Launch public awareness campaigns to inform citizens about the benefits of green hydrogen and its role in reducing carbon emissions. Public support is crucial for long-term success.
9. **Incentivise green hydrogen export:** Encourage the export of green hydrogen by creating policies that make it competitive in the international market. Negotiate agreements with potential importers to secure future market access.
10. **Environmental impact assessment:** Require comprehensive environmental impact assessments for green hydrogen projects to ensure sustainable practices and minimise any adverse effects on local ecosystems.

By implementing these policy recommendations, South Africa can harness the full potential of green hydrogen, leading to a cleaner, more sustainable energy sector, economic growth, and reduced carbon emissions. These policies should be developed and implemented collaboratively, involving government agencies, industry stakeholders, and the broader public to ensure a successful transition to a green hydrogen economy.

In conclusion, green hydrogen represents a transformative opportunity for South Africa. It can facilitate a transition towards a sustainable, low-carbon economy, driving economic development, reducing GHG emissions, and enhancing energy security. However, realising these benefits will require concerted efforts from the government, private sector, and the international community to invest in infrastructure and R&D. If South Africa seizes this opportunity, it can position itself as a leader in the global green hydrogen revolution while reaping the rewards of a cleaner, more prosperous future.

6. Annex A

6.1 General green hydrogen supply chain

The main elements of the green hydrogen value chain include:

1. **Renewable power sources:** These encompass renewable electricity sources such as solar, wind, and other forms of sustainable energy.
2. **Electricity infrastructure:** This covers the electricity grid, transmission, and distribution systems, substations, inverters, battery storage, and associated equipment, which are applicable to projects receiving renewable electricity directly or from the grid.
3. **Electrolysis and plant components:** This involves all the necessary equipment for the electrolysis process, along with devices for hydrogen and oxygen separation. It also includes equipment required for producing hydrogen at the specified flow rate, including desalination and reverse osmosis treatment infrastructure.
4. **Compression and storage:** When hydrogen is the end product, it needs to be compressed and stored. Achieving this, especially at high pressures (e.g., 300 or 700 bar), requires specialised equipment capable of handling pressurised hydrogen molecules.
5. **Value-added products:** Various pathways exist for value-added products, with green ammonia and methanol being prominent examples traded globally. Sustainable aviation fuel offers a means to reduce carbon emissions in air travel. Liquid hydrogen and liquid organic hydrogen carriers (LOHCs) are emerging but still evolving technologies.
6. **Electricity generation from fuel cell battery systems:** Green hydrogen can serve as a vector for long-duration energy storage, supporting balancing requirements across different time scales (daily, monthly, cross-seasonal). In this case, hydrogen is used in fuel cell batteries to convert back to electricity, with only water as the by-product.
7. **Logistics and supply chain:** The choice of logistics options depends on factors such as distance and the costs associated with converting to ammonia, liquid hydrogen, or LOHC, as well as the reconversion back to green hydrogen if necessary, particularly for ammonia.

Depending on the electricity source and the intended application, various pathways exist within the value chain, spanning from green electricity generation to the electricity grid, from green hydrogen production to compression and storage, from processed products (e.g., green ammonia, green methanol, liquid hydrogen, LOHC) to logistics, and potentially back to electricity generation. The overall cost of green hydrogen for end-users is determined by the combined cost of these components throughout the value chain.

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