GREEN HYDROGEN COMMERCIALISATION STRATEGY FOR SOUTH AFRICA

FINAL REPORT

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Glossary of Terms

Fuel Cell: A fuel cell is an electrochemical cell that converts the chemical energy of a fuel (often hydrogen) and an oxidizing agent (often oxygen) into electricity through a pair of chemical reactions.

Electrolyser: A system or device that uses the process of electrolysis which uses electricity to split water molecules into hydrogen and oxygen, producing hydrogen gas as a sustainable source of clean energy.

Liquid organic hydrogen carriers (LOHC): Organic compounds that can absorb and release hydrogen through chemical reactions. LOHCs act as storage media for hydrogen and are a transport medium.

Decarbonisation: The process of reducing the amount of carbon (mainly carbon dioxide (CO2)) sent into the atmosphere.

Green energy: Energy that is generated from natural resources, including sunlight, wind, water, and biomass. It often comes from renewable energy sources.

Green Hydrogen (GH_2): Hydrogen that is produced through the electrolysis of water which requires an electricity input that is generated from renewable sources, where the full life-cycle greenhouse gas emissions of the production of renewable hydrogen are negligible.

Balance of plant (BOP): Refers to all the supporting components and auxiliary systems of a power plant needed to deliver the energy, besides the generating unit itself. BOP may include transformers, inverters, switching and control equipment, protection equipment, power conditioners, and supporting structures.

Just Energy Transition (JET): Refers to the body of ideas and policy approaches encapsulating the energy transition and the need for justice in this transition. Here, the energy transition refers to the progressive global substitution of fossil-based carbon-intensive energy production with lower carbon energy production, including renewables, in order to mitigate carbon emissions. The JET focuses on identifying vulnerable groups during periods of transition and formulating policy tools to support these vulnerable groups such that they are not left worse off after the transition. The policy tools typically include temporary income support, reskilling/retraining into new and sustainable value chains, economic diversification of fossil-intensive regions and increased social support.

Membrane electrode assembly (MEA): Refers to an assembled stack of proton-exchange membranes (PEM) or alkali anion exchange membrane (AAEM), catalysts and flat plate electrodes used in fuel cells and electrolysers.

Proton-exchange membrane (PEM): Also known as a polymer-electrolyte membrane, this refers to a semipermeable membrane that is designed to conduct protons while acting as an electronic insulator and reactant barrier to oxygen and hydrogen gas.

Catalyst coated membrane: CCMs consist of catalysts, typically platinum and iridium, that are applied to membranes to maximise hydrogen production.

1. Introduction and Background

Achieving global Net Zero by 2050 has been estimated at a cost of $130 trillion by IRENA, making the energy transition possibly the single biggest global growth opportunity. South Africa, as a globally-integrated country has committed to domestic decarbonisation. While international decarbonisation is being driven by direct climate changes and policy impacts, there exist opportunities for countries to engage with new and sustainable value chains in order to domestically decarbonise and create new export products, as incumbent fossil-based value chains see long term declines in economic activity. Opportunities for technology innovation and commercial returns now abound but the timing and stages of development of sustainable value chains are an area that require more clarity.

Global energy models are shifting from the historic reliance on extraction and processing of fossil fuels, to future models that prioritise carbon mitigation across the value chain. The conversion and storage of natural energy resources such as solar, wind and water are a key component of the sustainability transition. The need for transportable and tradable green energy molecules is a critical part of satisfying future global energy demand as well as decarbonising hard-to-abate industries, and is driving the growth of a new global energy market for Green Hydrogen (GH_2). GH_2 or renewable hydrogen can be defined in a number of ways, but largely refers to hydrogen produced through the electrolysis of water which requires an electricity input that is generated from renewable sources, where the full life-cycle greenhouse gas emissions of the production of renewable hydrogen are negligible (EC, 2020).

Scientific modelling shows that the world will exceed the 1.5-degree warming scenario targeted under the Paris agreement. These predictions place growing pressure on accelerated supply and demand side interventions, including curtailment of fossil fuel investment as well as accelerated supply side development of GH_2.

Given this context, South Africa is currently a highly carbon intensive economy through its coal-based electricity generation and petrochemical production. Despite this carbon intensity, South Africa does possess advantages in the development of sustainable value chains. South Africa contains abundant solar and wind resources, combined with access to key metals and minerals. These resources, combined with access to key production technologies and the skills and resources that surround, provide the country with an opportunity for domestic decarbonisation, combined with opportunities for the export of new global commodities that are anticipated to see increasing demand over time.

In the context of GH_2 this specifically provides significant growth opportunities through the following pathways:

1. **The production and domestic use of GH_2 to decarbonise South Africa's economy, with a specific focus on hard-to-decarbonise value chains.** GH_2 holds potential for decarbonising domestic value chains and contributing to South Africa's net-zero journey. There are opportunities to decarbonise liquid fuels and chemicals, as well as iron and steel production, for example. Here GH_2 holds potential to decarbonise industrial processes and substitute away from fossil fuels. The decarbonisation of value chains will involve the adoption of new and sustainable technological methods, increasing investment in the economy and increasing demand for a new type of workforce. In a global Net Zero environment, "dirty" economies will increasingly be penalised through trade barriers and reduced financing for carbon-intensive industrial processes.

2. **The production and export of GH_2 and beneficiated products into future global green energy trading markets.** GH_2 is likely to play a significant role in the decarbonisation of key value chains in transition to a net-zero world. This is particularly the case for hard-to-abate value chains such as chemicals and iron and steel, for example. Early entry into the global market can establish SA's share in the global market as a future energy market global trader, securing foreign direct investment, earning foreign income and creating economic growth and development.

3. **South Africa already has key capabilities and advantages in GH_2:** South Africa has good renewables conditions (solar PV, wind), combined with access to PGMs and other green minerals, and access to key technologies such as the proprietary Fischer-Tropsch process and the skills and resources around these technologies. These capabilities are combined with innovations in the hydrogen sector, a robust financial system, globally recognised renewable energy programme and inclusion of GH_2 as a key element of the Government's energy transition plans.

4. **Supporting the Just Energy Transition:** South Africa has prioritised the Just Transition through a number of national and sub-national initiatives. The JT aims to ensure that vulnerable groups are not excluded in policymaking during periods of transition, leaving them worse off. Elevating the needs of vulnerable groups aims to ensure that they are not significantly impacted during periods of transition and are left better off after the transition. The energy transition towards a more sustainable format has been the subject of much focus, given the geographical concentration of the coal value chain and the high reliance on coal for electricity generation, petrochemical production and iron and steel production. Importantly, there is overlap between the development of GH_2 value chains and the JT, where incorporating JT tools in policymaking can achieve the development of new value chains while including impacted vulnerable groups. In developing this new industry for South Africa, a proactive focus to maximise development impact (incl. skills and economic development and social inclusion), ensure gender equality, BBBEE and community participation and to maximise job creation and alternative options for potential job losses will support the just energy transition.

5. **The development of industrial capabilities in the entire value chain, including in the manufacturing and supply of equipment used in the GH_2 value chains**. In developing GH_2, South Africa has an industrial development opportunity in supporting the growth of the entire GH_2 value chain. This includes the manufacture of key inputs for production and use, such as electrolysers and fuel cells, as well as the infrastructure required for the transportation of GH_2 such as pipelines and equipment that integrates various linked processes. On the input side, there are already a number of firms that have set up manufacturing bases for the production of catalysts, electrolysers, fuel cells and the integral components required for green hydrogen production and the harnessing of this energy. There is also the potential to localise the production of green ammonia and balance of plant equipment. Along with the local development of the value chain, there are opportunities to pivot the existing workforce away from fossil-intensive production towards roles in the GH_2 value chain. Here, there may exist synergies with the Just Transition processes, with a particular focus on vulnerable and impacted groups such as technical and vocational workers, coal miners, and communities, for example. The GH_2 downstream holds a lot of potential for development and the downstream is currently limited. Industrialisation and localisation efforts can be targeted throughout the value chain in order to scale production of inputs, green hydrogen production and the downstream value chains. Together with demand stimulation the development of a local production base can drive longer term GH_2 price reduction allowing penetration in various sectors. This will also facilitate

economic development via the multiplier effect and support the growth of South Africa's economy.

These opportunities present a significant overarching commercial opportunity for South Africa to develop a new green energy economic sector to drive growth and development, employment, improve energy security and to transition to a lower carbon economy and society. However, it also presents a series of complex challenges and decisions for stakeholders to ensure that this important lever to transition the economy to a lower carbon intensity is also aligned to the National Development Plan (NDP) and the need for inclusive participation in this new sector.

Alignment between the various policies and processes that govern the Just Transition, national climate ambitions, and value chain-specific support measures is paramount. The Government, for example, has mandated the Presidential Climate Commission (PCC) to oversee a Just Transition of South Africa's economy to lower carbon state across South African value chains, in line with our Nationally Determined Contribution (NDC) under the Paris Agreement climate change goal of 1.5-degree C warming scenario. This national commitment towards decarbonising the economy is in line with global standards and has important bearing on the scale and timing of domestic production of affordable GH_2.

A comprehensive strategy will outline the commercial opportunity and development approach for a viable GH_2 industrial sector, able to service both export as well as stimulate domestic demand and the right behaviour to meet sectoral decarbonization targets. Establishing such a new long-term industrial capability will however require staged, pragmatic and ambitious policy and government support aligned to support private sector driven investment in infrastructure, at a time where South Africa faces challenges related to low economic growth, electricity supply challenges and a constrained fiscal space with competing priorities. This is further complicated by the fact that that the global boom in GH_2 interest and investment is fairly recent and the global green hydrogen market is at its beginning stages. As countries embark on policies to develop domestic capabilities and posit themselves in global markets, the technology surrounding green hydrogen production, use, transport, and storage is still maturing and competitiveness and cost-parity with incumbent fossil-based routes has yet to materialise.

Securing international support and financing through bi-lateral and commercial arrangements where developed nations need to secure long-term security of GH_2 supply, and South Africa's need to drive economic recovery through green economic infrastructure that will also address the triple challenges will be key to the country securing an early mover market position.

This Green Hydrogen Commercialisation Strategy (GHCS) builds on the strong foundation of the work undertaken by the Department of Science and Innovation (DSI) with respect to its HySA programme and the recent development and publication of the Hydrogen Society Road Map (HSRM).

A GH_2 commercialisation strategy must align to national objectives whilst being responsive to competitive market drivers and success factors. The report outlines significant opportunities and benefits that can be derived for South Africa and suggests options and focused actions. It is important to note that recommendations are made based on relative ranking of multi-criteria and qualitative analysis as the detailed technical and financial quantitative modelling typically required for investment decisions has not been developed at this stage.

South Africa's GH_2 Vision must incorporate key strategic design principles to ensure a long term sustainable and vibrant sector design.

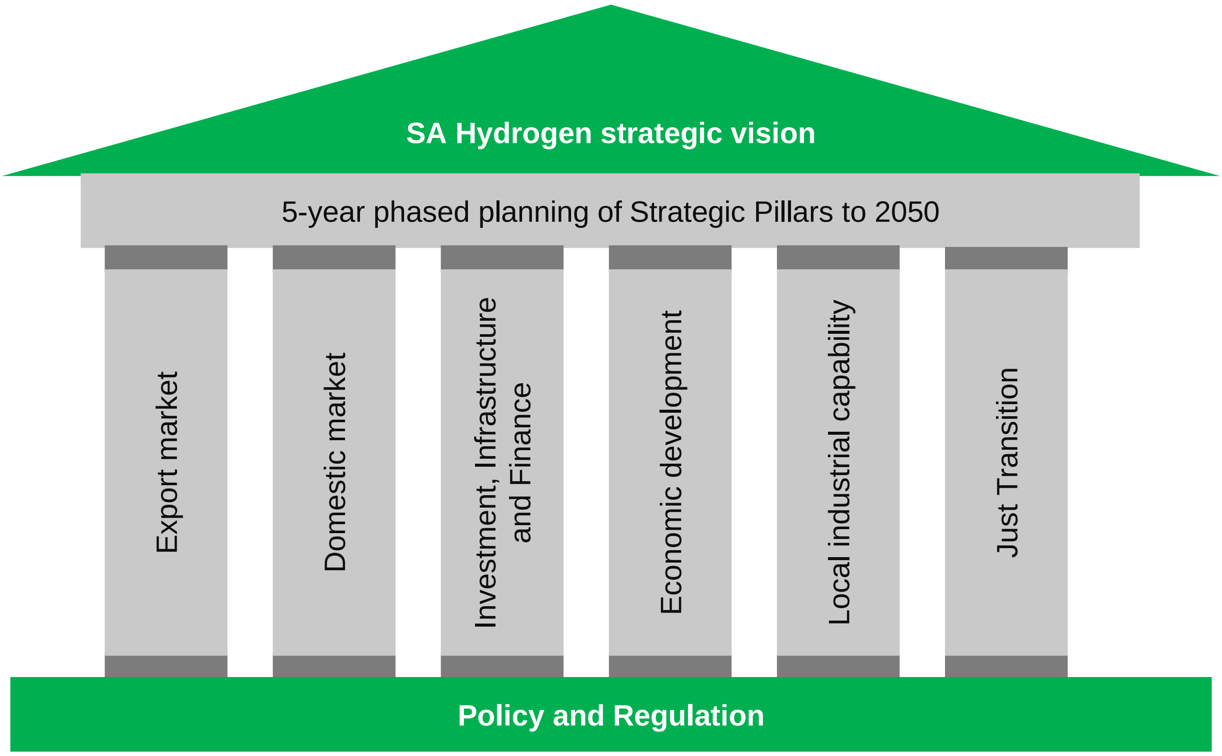


Figure 1: SA Hydrogen Strategic Vision - Developing a globally competitive, inclusive and low carbon economy by harnessing South Africa's entrepreneurial spirit, industrial strength and natural endowments.

The following strategic objectives should be considered in pursuit of South Africa's GH_2 Strategic vision outlined above:

1. **Export Markets: secure long-term global market share and competitive trade position:**
    - Strategically position South Africa as a preferred and reliable provider to key markets, specifically EU/UK, Japan and South Korea leveraging trade relationships and government support.
    - Secure global market and offtake MoUs with national procurement programmes such as H2 Global.
    - Expedite an export pilot project to ensure SA is seen as a serious global player and achieves early market entry.
    - Progress international strategy to comprehensively understand global demand by country and the extent to which South Africa can increase market share.

2. **Domestic Markets:**
    - Introduce supportive policies and a regulatory framework for GH_2 value chain development that reduces the cost differential between GH_2 and incumbent technologies to increase domestic GH_2 demand.
    - Support research and development with a focus on near-term opportunities in hydrogen mobility applications, particularly in Heavy Duty Fuel Cell Vehicles and as substitute for diesel fuel in rail transport.

- Demonstrate feasibility of GH_2 applications in hard-to-abate sectors such as non-ferrous metals, green steel, sustainable aviation fuel, fertiliser and cement in order to foster short term pilot projects and long-term commercialisation.

3. **Investment, Infrastructure & Finance: Foreign Direct Investment and low-cost green finance:**
    - Posit South Africa as a GH_2 investment destination by signalling to international markets. This can be positioned through:
        - Comprehensive hydrogen incentive packages such as, tax incentives, grant schemes and reduced import surcharges on technology options.
        - Establishing a regulatory and market framework around new[1] GH_2 manufacturing, production, use, transport and storage to drive investment in South Africa's GH2 economy.
        - Bilateral engagements and agreements between South Africa and key international consumers
    - Define a key set of catalytic infrastructure projects that will frame the national GH_2 strategy and enable private sector champions to roll out their strategies whilst meeting Government's longer-term objectives for inclusive economic growth. Such projects should be declared as Strategic Integrated Projects (SIPs) by the Department of Public Works & Infrastructure (DPWI).
    - Assess the current infrastructure requirements in terms of transmission grid, renewable energy, transport infrastructure (pipelines, ports, roads, rail) and the investments required in order to support the development of the value chain and ensure that private projects are able to access key infrastructure.
    - Define the government role, financial investment and support for pilot projects in order to expedite and enable private sector investment.

4. **Economic and socio-economic development:**
    - Contribute towards reaching South Africa's emission reduction goals as per the Peak, Plateau, Decline Emissions Trajectory Range reflected in the NCCRP and NDP. This should include the contribution GH_2 production can make to future NDC targets South Africa will need to consider in 2025 and beyond.
    - Focus on decarbonising hard-to-abate industrial sectors in SA economy, by aligned sectoral carbon budgets with the role that GH_2 can contribute to mitigation and financial support required for transition without prejudice.
    - Ensure integration of renewable energy through a robust GH_2 sector and regulatory framework that has a positive influence on energy security and domestic energy prices.
    - Incorporate non-financial criteria in procurement processes that support socio-economic development, skills transfer, local supply and enterprise development, and opportunities for local ownership
    - Develop training and skills development programmes to support job creation within the GH_2 sector.

5. **Local industrial capability and participation**
    - Support initiatives and intellectual property for local GH_2 production and inputs such as electrolysers, catalysts, fuel cells and the integral components that

[1] Here reference is made to the establishment of a regulatory framework beyond which hydrogen is currently regulated.

comprise these. These components include membrane electrode assembly (MEA), and catalyst coated membranes (CCM) for example.

- Support test cases for the commercialisation of hydrogen production and beneficiated products such as ammonia and methanol
- Support projects that aim to develop the domestic downstream market through green fuels and chemicals production, green steel, and heavy-duty transport, for example.
- Implement projects to develop skills and achieve localised industrialisation for key parts of the GH_2 value chain. Invest and implement research and development programmes.
- Understand the potential for industrialization of the renewable energy manufacturing supply chain through an aggressive GH_2 strategy. This should involve alignment of the Masterplans in process in the renewable energy, steel and automotive sectors as well as relevant Phakisa processes (e.g. oceans).
- Create partnerships and joint ventures to secure investment, technology partnerships, and long term demand off-take agreements.
- Work closely with the Department of Science and Innovation and Department of Higher Education and Training to drive the identified skills action plan.

6. Consider the need and role of a Just Transition:

- Analyse and plan for a Just Transition, ensuring appropriate public and social dialogue and understanding.
- Quantify the commercial and economic impact and sustainability of industrial sectors as they invest in decarbonising their businesses through the energy transition.
- Ensure appropriate training and skills development programmes to limit job losses and support employment as industry sectors decarbonise.
- Engage in a social dialogue between workers and their unions, employers, government and communities in order to ensure that GH_2 development contributes to climate change mitigation as well as adaptation.

2. Green Hydrogen in the context of South Africa's Electricity Crisis

South Africa is embedded in a severe electricity supply crisis currently, with electricity generation production unable to meet consumption demand. In 2022, there were over 200 days where load shedding was a feature, with expectations of a similar or worse outcome in 2023. The difficulty around estimating where future breakdowns in infrastructure and the proportion of unplanned maintenance creates further uncertainty around the extent to which generation infrastructure will deteriorate in the short to medium term. It is undeniable that significant investments into low carbon electricity supply are urgently required in order to meet national electricity demand and ensure sustainable economic growth and industrialisation.

This does present a challenge when considering investments into dedicated renewable energy for green hydrogen production with respect to the ongoing electricity crisis. Embarking on a wide scale green hydrogen strategy will require significant investments into renewable electricity generation in order to run the electrolysers required for green hydrogen production. Here, the principle of additionality is well established within the engineering and economics disciplines, and in this context requires that new electrolysers producing renewable green hydrogen have dedicated renewable electricity generation infrastructure that does not redirect investments intended for electricity security within a country. In other words, hydrogen production should be supporting decarbonisation and complementing electrification efforts, while avoiding pressure on power generation. This principle is especially important in the South African case given the current electricity supply challenges. Devoted renewable energy infrastructure for electricity generation will have to occur alongside investments into renewable energy for green hydrogen production. **Priority will have to be placed on renewable energy generation for electricity generation rather than for GH_2 projects, however GH_2 projects should not be deprioritised as GH_2 projects can also support electrification.**

There is potential for the development of RE for GH_2 production to be complementary to the general electricity supply situation in the country. This Commercialisation Strategy recognises that GH_2 projects should not compete with RE projects that will supply electricity into the South African grid to address the electricity crisis. It is expected that RE generation capacity will have been significantly increased to address the electricity crisis before large-scale RE is required for the GH_2' projects as many of the GH_2 projects plan to commence operation from 2025 onwards. GH_2 projects have the potential to supply excess electricity into the South African grid and measures to enable the GH_2 projects to support the electricity challenges are proposed below.

Given that green hydrogen acts as an energy carrier, it certainly can however play a potential role in electricity generation and the intermittency challenges with solar and wind generation, among other benefits. This feature of green hydrogen is highly unlikely to solve South Africa's sizeable electricity generation deficit alone, based on the current development within the country, technological evolution and commercial demonstration.

South Africa has the ability to leverage its current natural and industrial endowments through four important linkages which can assist with the shortage of electricity generation supply. Hydrogen can largely support the electricity crisis through four important links between green hydrogen and other energy sources i.e. renewable electricity and petrochemicals.

Renewable Energy and intermittency

The use of pure green hydrogen (or beneficiated products such as green ammonia) as an electricity fuel source does not feature prominently in commercial electricity generation currently. Despite this, there are a number of commercial and demonstration projects that seek to prove the commercial case.

Based on experience on green hydrogen production in Europe, a hydrogen plant operates as a combined hydrogen-and-power plant, and can produce both green hydrogen and usable excess power. As renewable energy profiles fluctuate on both a daily and seasonal basis, it is never the most efficient system configuration to build the electrolysis system large enough to use all the electricity produced. Roughly speaking, the ratio of renewable energy installed capacity to electrolysis is 2:1, and even with battery energy storage system (BESS), some curtailment is typically required with 10-15% of total energy produced being curtailed in the latter option (with storage).

Intermittency with solar and wind production mean that no electricity is produced from these technologies when the resource is not available due to weather conditions. Here, hydrogen can also assist as excess electricity can be used to produce hydrogen which can then be harnessed when electricity is required by producing electricity from the hydrogen. Hydrogen serves as a bridge between physical and chemical energy. Electricity can be stored as chemical energy in hydrogen by using an electrolyser. The chemical energy in hydrogen can in turn be converted back to electricity using a fuel cell device. Projects are already being developed in South Africa, where large scale hydrogen storage will be able to support grid stability.

These benefits from hydrogen mean that hydrogen projects are able to support the South African energy sector in three potential ways through this technical feature.

- Supply of Curtailed Energy: If projects are grid-tied or one-way-islanded, then they can supply excess electricity into the national energy system in order to reduce the demand on electricity from other sources. Any intermittency concerns can be addressed by limiting the proportion of renewable energy input and by managing intermittency through national energy storage initiatives such as the Eskom BESS projects that are already underway.

- Supply of Dispatchable Energy: In most large-scale green hydrogen systems there is a storage system. This is especially true in the case in fully islanded systems, one-way-islanded systems or where grid supply reliability is a challenge. In addition, many developers are looking at on-site re-electrification solutions from hydrogen and its derivatives that can act as auxiliary power backup or directly as peaking/dispatchable energy plants. Examples of these would be the Siemens energy green hydrogen gas engine plant in Dubai and the Mitsubishi ammonia gas turbines currently under development. With these solutions already being included as part of hydrogen projects, an opportunity exists for Government to leverage these technologies to provide dispatchable energy to the grid.

  Hydrogen and beneficiated products have also attracted global attention in the mobile telecommunications industry for backup power using fuel cells (IEA, 2019). Here, the use of fuel cell backup systems substitutes for diesel consumption, particularly in remote areas with limited grid access. Vodacom, for example, already has installed over 200 fuel cell backup systems across the country supplied by Chem Energy, the latter which is based at the Dube TradePort Special Economic Zone (Engineering News, 2023). These systems use a blend of methanol and water to produce hydrogen that is used in the fuel cell systems.

- Electricity supply to proximal/vulnerable groups: Green hydrogen projects can also increase electricity access for remote communities or groups currently facing electricity challenges. Ensuring that large scale green hydrogen projects also supply electricity to nearby communities, using mini grid solutions for example, can increase supply to these groups. Such mini grid infrastructure can also be integrated to be fed by other sources of alternative energy projects.

The above solutions provide some benefits for both green hydrogen project development and electricity supply, and provide some examples of how both renewable energy production and green hydrogen production can be scaled by simultaneously addressing the need to produce green hydrogen and attend to the electricity crisis.

Petrochemicals

Green hydrogen has an important role to play in the decarbonisation of the petrochemicals value chain. Hydrogen is currently used significantly in the production of key chemical products such as methanol and ammonia as well as normal fossil fuels to convert longer chain molecules in crude oil to usable fuel/petrochemical components. This currently occurs through the use of grey hydrogen produced from natural gas. Green hydrogen that is produced from renewables can substitute for this and together with sourcing of sustainable carbon can decarbonise the production of methanol and ammonia, which are key inputs into the fertilizer and explosive value chains. Green hydrogen also allows for the decarbonisation of liquid fuels through the production of sustainable aviation fuels and marine bunkering fuel. Sasol is currently conducting a feasibility assessment for production of sustainable aviation fuel in Secunda for export into Germany. The decarbonisation of liquid fuels also manifests through the use of hydrogen as a fuel for passenger transport and heavy-duty applications. The use of fuel cell electric vehicles, particularly over long distances, where electric vehicles face challenges, and uses in mining applications show promise.

There are a number of energy applications where green hydrogen can aid in alleviating the country's energy challenges. It is important for these technologies to be demonstrated commercially through pilot and demonstration projects. Once demonstrated, these projects can be scaled up and supported.

<u>Facilitating transmission infrastructure and enabling RE projects to connect to the grid</u>

South Africa's power grid is under pressure and constrained. A number of RE developers have received communication from Eskom stating that new generation capacity cannot be accommodated due to the capacity constraints currently in the Northern, Eastern and Western Cape.

Eskom has a very detailed transmission development plan (TDP), Figure 2. The TDP is a practical and executable plan that is updated periodically. The major constraint is the lack of funding in executing the TDP. This can negatively impact not only the GH_2 projects but other IPP projects either as part of REIPPP or for private consumption in the commercial and industrial market sector. Such projects can become stranded assets if grid connection remains an issue.

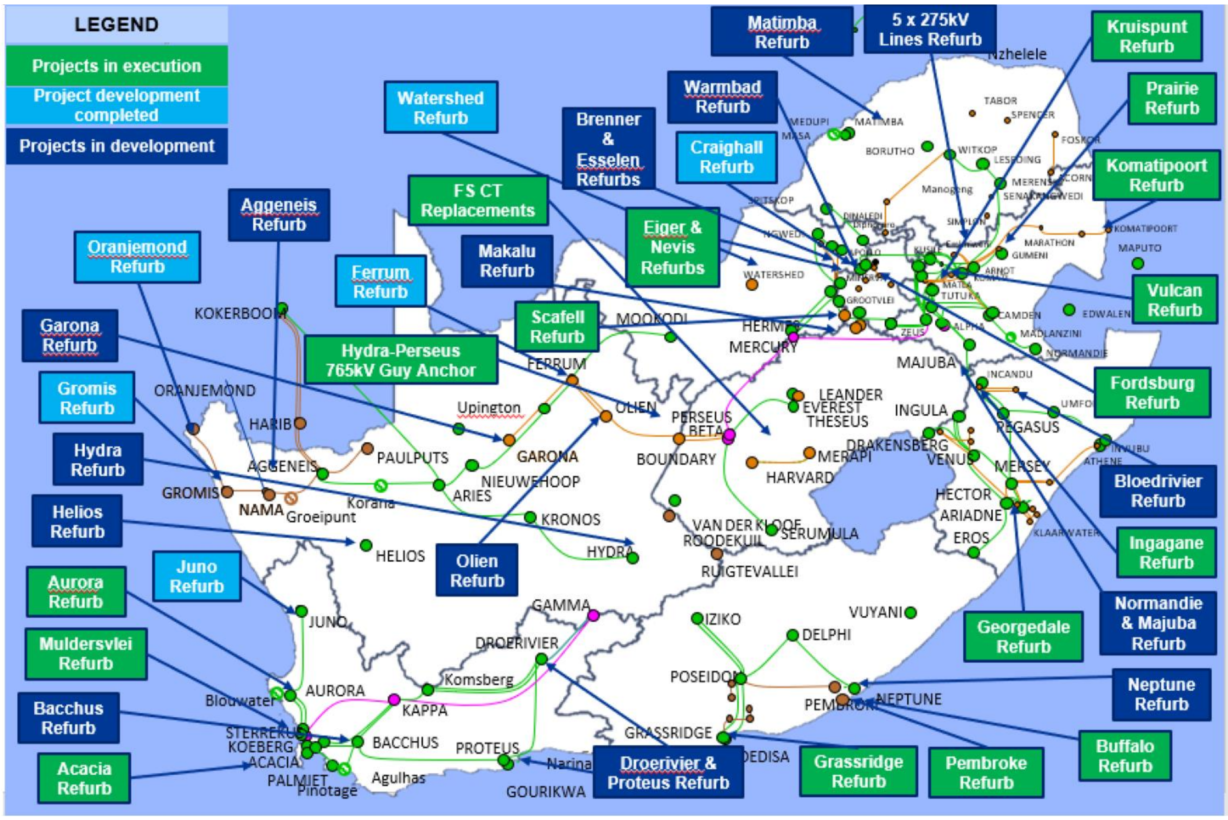


Figure 2: Eskom TDP 2023-2032, Source Eskom

There are approximately 20 GH_2 projects at various stages of development. These projects are planned to commence operation from 2025 to 2027 onwards. It is estimated that approximately 3 to 5 GW of RE will be needed for these projects. GH_2 projects that will need connection to the Eskom grid will need to ensure that required infrastructure is in place, including substation and transmission line infrastructure. Current GH_2 projects being developed have undertaken grid assessment studies to identify the areas where grid infrastructure strengthening is required. When this infrastructure is built for GH_2 projects, other RE projects have the potential to make use of this common infrastructure to supply electricity into the grid thereby enabling additional electricity to be connected. It has been estimated that by upgrading infrastructure in specific areas in the grid about 15 GW of developed RE projects can connect to the grid in addition to the GH_2 projects utilising the grid. A number of GH_2 projects are considering funding of the grid infrastructure as part of the overall project funding, increasing affordability and accelerating grid development. GH_2 projects could serve as an enabler to grid strengthening allowing for more RE projects to be connected for electrification.

The development of the TDP and IRP, however, do not currently accommodate the need for RE for GH_2. Preliminary discussions with Eskom have highlighted the need for closer collaboration to ensure the RE needs for GH_2 are incorporated into the TDP.

3. Market driven commercialisation

GH_2 represents a significant market opportunity for South Africa to decarbonise agriculture and heavy industry and enable global decarbonisation through exports, allowing other countries to decarbonise. South Africa can be positioned as a leader in the energy transition and could become a critical player in the new global GH_2 economy. Accordingly, GH_2 production and development will be driven by two distinct markets: export demand driven by the international trade of GH_2 and derivative between countries and regions; and domestic demand, driven by fuel switching and new vectors for the use of GH_2 for mobility, industrial processes, agriculture and power.

3.1. Export market potential

From a trade perspective, countries with strong renewable resources and efficient infrastructure will tend towards being net exporters of GH_2. Large, energy-intensive economies with lower quality natural resources, space limitations and limited alternate energy sources, will tend towards being net-importers of GH_2. The EU and Japan are predicted to be the largest global import nodes of GH_2 currently, which will have important bearing on an optimal South African demand mix using export demand to support domestic demand through economies of scale.

Countries have begun to position themselves in the global value chain as potential exporters and importers of GH_2 and have begun to set policy priorities for GH_2 development. Net-Zero commitments will also stimulate imports where higher carbon pricing systems, such as the EU emissions trading system (ETS), provide a significant green premium to incentivise imports. The uneven global endowment of renewable energy resources combined with space constraints in certain countries spurs trading of GH_2 between countries and trading blocks.

Ambitious nations have already made clear their intentions of global supply, so South Africa's entry into the market will face competition from other supplying countries. Countries have already begun to form trade relationships around green hydrogen and support packages for development. These arrangements can secure export demand and enhance investment into countries aiming to supply into global markets. The projected net-import demand scenario indicates that approximately 10% of total global demand will be traded between countries. The key countries that have indicated demand for imported GH_2 are indicated below:

- European Union: The 2030 forecast based on the REPowerEU (18 May 2022) plan indicates GH_2 demand projections of 10 million tonnes per annum (Mtpa) by 2030. The port of Rotterdam has set a target of importing 20 Mtpa of hydrogen for European markets by 2050.

- Japan: In 2022, Japan imported 2 million tonnes (Mt) of grey hydrogen and the revised Hydrogen Strategy (May 2023) aims for imports of hydrogen (grey, blue and green) of 3 Mtpa by 2030 and 14 Mtpa by 2040. Japan is expected to procure 0.3 Mt of GH_2 in 2030, with the share of GH_2 as a percentage of all hydrogen increasing to 2050.

- South Korea: Imported GH_2 demand is expected to be 0.3 Mt per annum from 2030 and 1.5 Mt per annum from 2050. Based on the South Korea Hydrogen Roadmap, the country's hydrogen demand today is 130 000 tpa. By 2040, the annual need will be some 5 Mtpa, with 20% from GH_2.

- United Kingdom: Based on the expansion of hydrogen production pathways analysis (July 2022), hydrogen may be imported to the UK, particularly from global regions with high resource availability of renewable electricity or natural gas. The UK hydrogen strategy focuses on domestic production using offshore wind resources. However, since the UK is a significant net energy importer, it could import as much as 0.7 Mt by 2050 depending on the development of domestic hydrogen production from offshore wind.

Summing up expected demand[2] from the primary import markets it is expected that the **import market for hydrogen will be between 14 and 27 Mt per annum by 2050**.

Many studies have been undertaken recently assessing the potential export market for hydrogen[3], indicating a 2% share of the global market for hydrogen. These studies indicate a significant variation in the quantum of exports relative to the total market for imports globally. A 1% market share for South Africa of the total global GH_2 market would equate to 4.2 Mtpa of GH_2. South Africa will have to secure a long-term global market share and competitive trade position against competition from other exporters. **Export potential is estimated at about 2 Mtpa by 2050 with upside to be as high as 6 mtpa in longer term.**

3.2. Domestic market potential

Domestic demand uptake will largely be driven by relative price parity to incumbent routes, and scale with incumbent fossil fuels plus any carbon related taxes. The strategic co-location of GH_2 production that can be located with applications such as mining, where the cost of distribution infrastructure can be avoided, will likely be the earliest to achieve price parity. Longer term demand will grow with market maturity and will rely on reducing production costs, expanding infrastructure, developing new applications, and using carbon markets and other incentives to sustain price parity. Domestic demand can also be leveraged using South Africa's existing technology endowments such as the Fischer Tropsch process for sustainable aviation fuel production, and the direct reduced iron process for the production of green steel.

GH_2 has a strong role in driving domestic decarbonisation. Hydrogen is currently used in the mining, processing, and chemical industries in South Africa. Green hydrogen can also decarbonise the agricultural industry by being in input in the manufacture of green fertilisers. Most of South Africa's energy (95%) is fossil fuel based (primarily coal) and represents a significant opportunity for decarbonisation. Domestic demand drivers include:

- decarbonisation based on the export country or company commitments;
- current consumption of grey hydrogen to be switched to GH_2;
- cost competitiveness of GH_2 enabled through incentives and taxes versus its fossil alternatives;
- the availability and access to GH_2;
- early production of green products for export to countries with decarbonisation priorities and
- the maturity and acceptance of the application technology and access to support ecosystems.

Domestic demand will accelerate as price parity gets closer to fossil fuels. Co-located production projects (e.g. Mining sector) will have accelerated commercial value due to lower infrastructure and supply chain dependencies and hence lower cost. Domestic

[2] It must be noted that these estimates reflect the current import demand based on countries that have assessed their domestic hydrogen needs and where they wish to be positioned. Given that numerous countries are in the process of developing their approach to engagement with international hydrogen value chains, this import demand will likely evolve in quantum and distribution across countries. Related to this, increased supply competition may manifest based on new supplier entry into the global market.
[3]Notably the IHS Markit Super High Road; NBI BUSA BCG; Engie – South Africa Hydrogen Roadmap.

potential is estimated at about **2 - 3 mtpa by 2050 with upside as high as 6mtpa.** Sasol currently produces about 2mtpa of grey hydrogen for self-consumption in the petrochemical process.

4. Hydrogen Demand Assessment

Unlike fossil fuel energy models, the scale of GH_2 production is technically limitless assuming free and abundant renewable energy feedstock and sufficient scale of installed equipment. The cost of the capital-intensive conversion process however creates a commercial limitation based on affordability and price competition to the end user application.

Demand sources are naturally segmented in export potential and domestic potential for the purposes of the analysis.

From an export market perspective, large, energy-intensive economies with lower quality natural resources, space limitations and limited alternate energy sources, will tend towards being net-importers of GH_2, while countries with strong renewable resources and efficient infrastructure will tend towards being net exporters of GH_2. The EU and Japan are predicted to be the largest global import nodes of GH_2 based on the current assessment, which will have important bearing on an optimal South African demand mix using export demand to support domestic demand through economies of scale.

Domestic demand uptake will largely be driven by relative price parity to incumbent routes, and scale with incumbent fossil fuels plus any carbon related taxes. The strategic co-location of GH_2 production that can be located with applications such as mining, where the cost of distribution infrastructure can be avoided, will be the earliest to achieve price parity. Longer term demand will grow with market maturity and will rely on reducing production costs, expanding infrastructure, developing new applications, and using carbon markets and other incentives to sustain price parity. Domestic demand can also be leveraged using South Africa's existing technology endowments such as the Fischer Tropsch process for sustainable aviation fuel production, and the direct reduced iron process for the production of green steel.

4.1 Export demand drivers

There has been a global surge in interest in the development of GH_2 since the pivotal IEA green hydrogen report in 2019 (IEA, 2019). Countries have begun to position themselves in the global value chain as potential exporters and importers of GH_2, and have begun to set policy priorities for GH_2 development in their industry. Accelerated national Net-Zero commitments will also stimulate imports where higher carbon pricing systems such as the EU emissions trading system (ETS) provide a significant green premium to incentivise imports. The Net-Zero commitments are borne out of the need to decarbonise due to policies (e.g. carbon taxes) and mandates (e.g. blending of GH_2 into natural gas pipeline systems) that require decarbonisation to be applied to supply chains and production processes to enable relative competitiveness. The uneven endowment of renewable energy resources combined with space constraints in certain countries, among other factors, spurs trading of GH_2 between countries and trading blocks.

Ambitious nations such as Australia and Chile have already made clear their intentions of global supply so South Africa's entry into the market will face competition from other supplying countries as well as competition from domestic production within countries that intend to import. Further, countries have already begun to form trade relationships around green hydrogen and support packages for development. Australia has already shipped super-cooled liquid hydrogen to Japan in a test case, with Japan (Australian Government, n.d.; Stringer, 2023). Japan has further committed $1.6 Billion of state financing to Australia's Coal-to-Hydrogen Plan. These arrangements can secure export demand and enhance investment into countries aiming to supply into global markets.

The projected net-import demand scenario indicates that approximately 10% of total global demand will be traded between countries and is shown below.

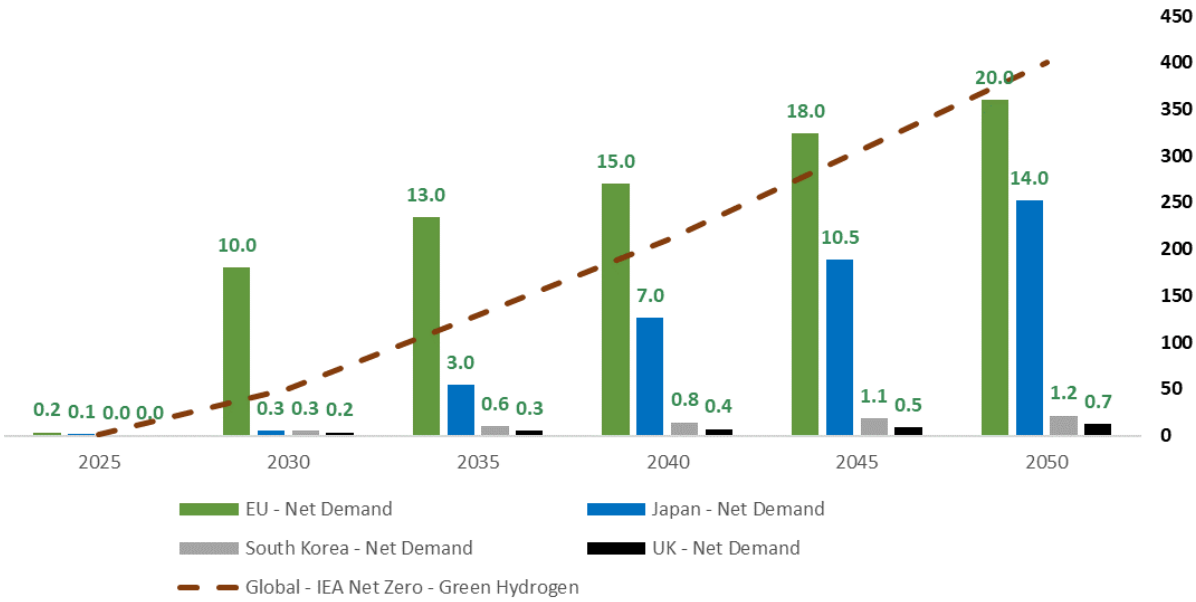


Figure 3: Average Net Imports by Country/Regions vs Total Global Demand (Mt GH_2)

In order to establish the potential size of South Africa's GH_2 exports, the International Energy Agency's (IEA) Net Zero GH_2 Scenario to 2050, referred to in Figure 3 has been used to compare market shares relative to total net import demand for different scenarios (intermediate year points have been extrapolated to show a demand build-up):

3.3. South Africa export demand potential

Many studies have been undertaken recently assessing the potential export market for hydrogen, notably the IHS Markit Super High Road; an NBI BUSA BCG, October 2021; Engie – South Africa Hydrogen Roadmap, which indicated a 2% share of the global market for hydrogen and was evaluated against the IEA "World Energy Outlook, 2022 (WEO)" scenario; and Sasol's analysis, which provided a "Moderate" Scenario and "Ambitious" Scenario. These studies indicate a significant variation in the quantum of exports relative to the total market for imports globally. An assessment of the import market for GH_2 (27 Mt per annum) based on the various studies is provided in Figure 4. The WEO, October 2022, estimated a total 530 Mtpa of hydrogen is required in 2050, of which about 112.5 Mtpa will come from blue hydrogen and the balance of about 418 Mtpa from GH_2. A 1% market share for South Africa of the total global GH_2 market would equate to 4.2 Mtpa of GH_2 in this scenario.

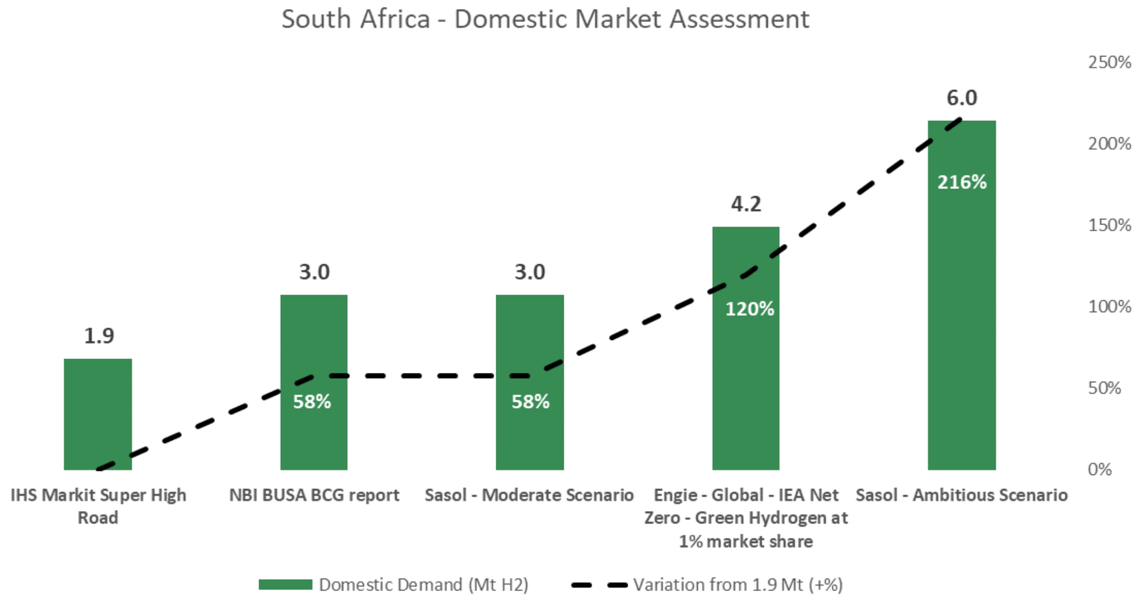


Figure 4: South Africa - Export Market Assessment Based on Share of Global Import Market to 2050

Analysis of global net exporters has been completed using the 1.9 mtpa scenario or about 7% of the global import market as a SA base[4] . At higher South Africa export scenarios, increased market shares are required, which in turn require a more competitive offering to other exporting countries and who are potentially better positioned to South Africa.

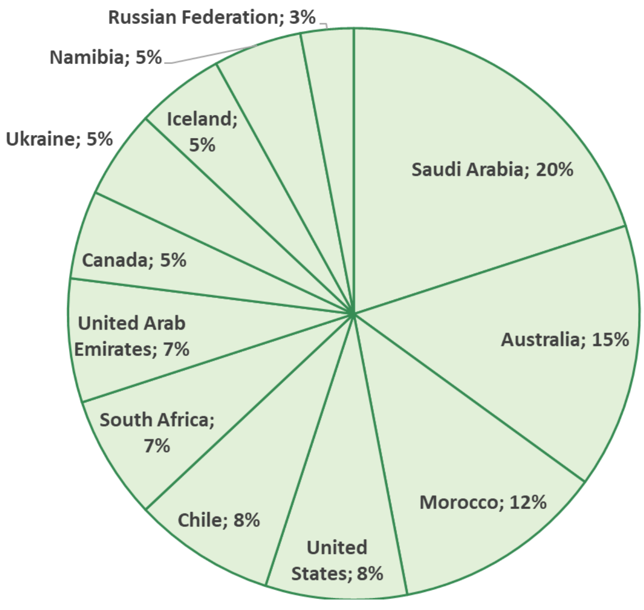


Figure 5. Assessment of Market Share Potential (%)

[4] The relative market shares of exporting countries are determined using the global hydrogen model developed by PwC and the International Energy Council. These shares are calculated using public domain parameters such as renewable resource, land space, proximity to markets, investments required in infrastructure and stated policies and programmes to determine relative competitiveness in the global export market

If technology and learning rates advance significantly to bring GH_2 costs down to 2050, making GH_2 lowest cost relative to grey and blue hydrogen, or fossil alternatives like oil or gas, this production could be entirely constituted of GH_2.

Based on the estimates, South Africa has the potential for close to 7% market share. South Africa will likely compete directly with Morocco, Russia, Chile and the UAE, and at more than 15% with Saudi Arabia and Australia.

Southern Africa, mainly Namibia and South Africa, could tap into a 10–22 Mt of hydrogen equivalent export market (Green Hydrogen Organisation, 2023).

The United States of America Inflation Reduction Act package could enable the US to become a significant global player in the GH_2 export market mainly to Japan and South Korea as the Act included both an investment tax credit as well as a production tax credit for hydrogen (the credits' impacts fade steadily after 2023, until they expire in 2032). The IRA could also stimulate demand for inputs like PGMs required for electrolysers and fuel cells, which could benefit South Africa.

To increase global market share, South Africa will therefore require significant interventions by government, public sector institutions, and the private sector as a unified effort to drive value chain efficiency and lower cost.

4.2 Developing competitive South Africa exports

Absent any state and private sector supportive measures, South Africa faces a disadvantage in comparison to the Middle East and Australia to compete for in key GH_2 markets such as Japan and South Korea. This is largely due to closer geographical proximity allowing for lower transport costs, early mover advantage, and the already strong established relationships in the energy value chain between these countries, where Australia and the Middle East currently supply into the energy ecosystem in Japan and South Korea.

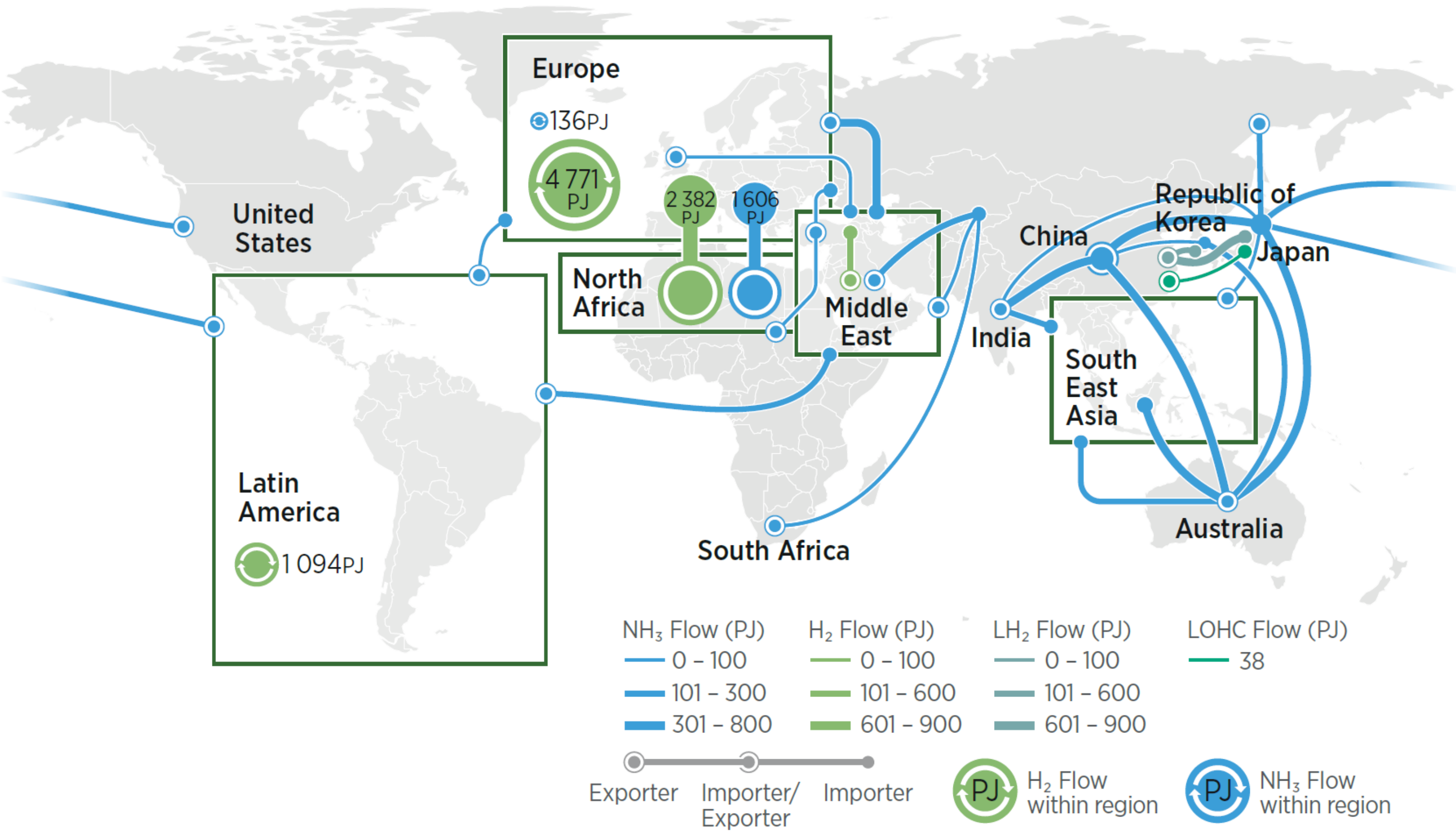


Figure 6. Global Hydrogen Trade Flows

Source: IRENA (2022), Global hydrogen trade to meet the 1.5°C climate goal: Part I – Trade outlook for 2050 and way forward, International Renewable Energy Agency, Abu Dhabi. Note: Optimistic capital expenditure assumptions for 2050: Photovoltaic (PV): USD 225-455/ kW; onshore wind: USD 700-1 070/kW; offshore wind: USD 1 275-1 745/kW; electrolyser: USD 130/kW. Weighted average cost of capital: Per 2020 values without technology risks across regions. Green hydrogen technical potential is based on assessing land availability for solar PV and wind. Demand is in line with a 1.5°C scenario from the World Energy Transitions Outlook 2022 (IRENA, 2022a). LOHC = liquid organic hydrogen carrier.

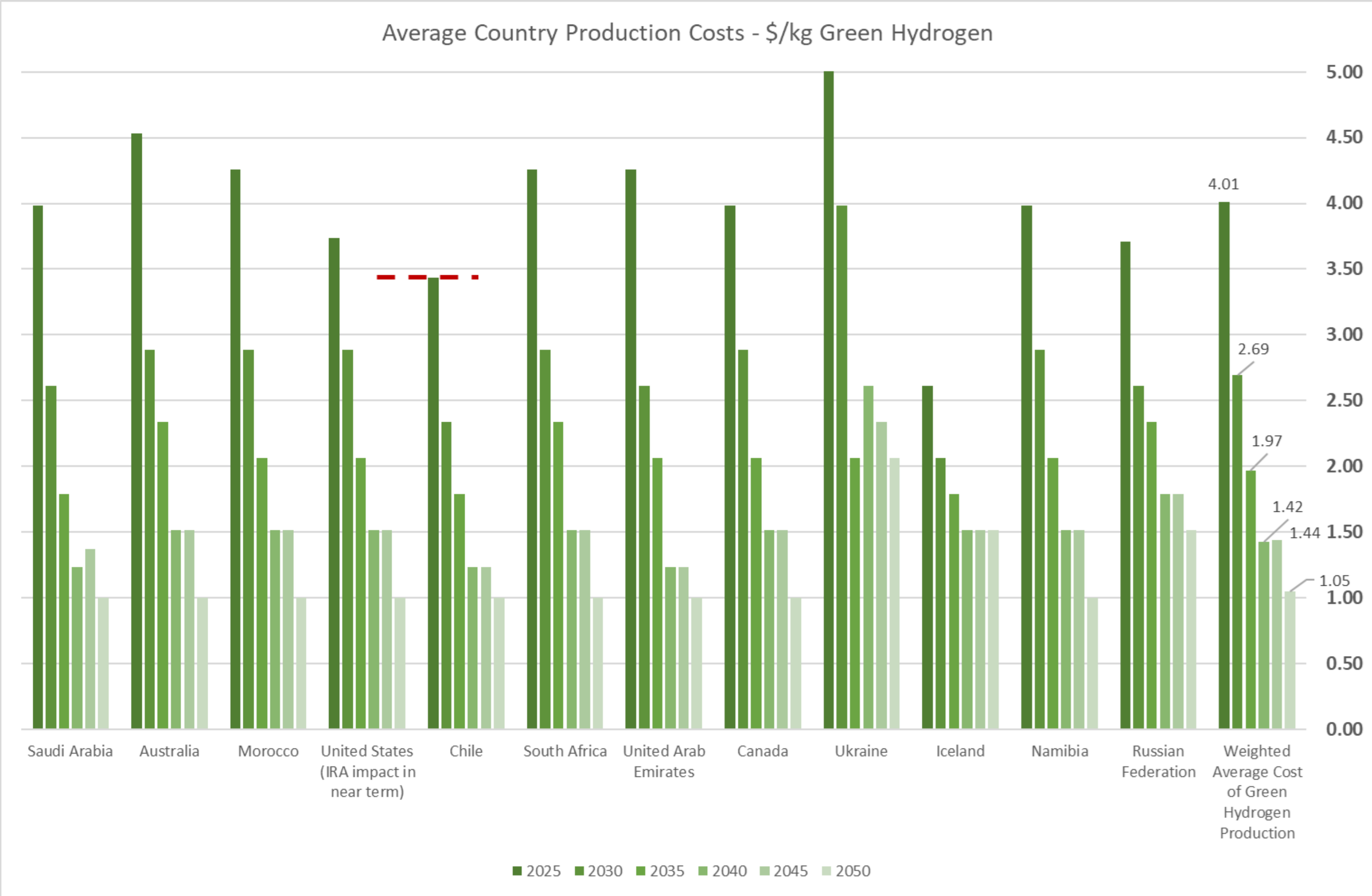


Figure 7: 2025-2050 – Average Forecast GH Prices of Exporting Countries (US$/kg H2)

Figure 7 indicates the current forecast of South Africa's production price evolution relative to other comparator countries. These forecasts predict a price evolution from approximately $4/kg in 2025, to $3/kg in 2030, to $2.5/kg in 2035, to $1.5/kg in 2040, to $1/kg in 2050.

Despite these challenges associated with South Africa's geographical placement and the proportion of transport costs in the final GH_2 price, importing countries may seek to diversify supplies of energy, and South Africa could target GH_2 sales to East Asian markets. Blue hydrogen will compete with GH_2 in the Japanese market, as Japan has already commenced the importing blue ammonia. Encouragingly, many global GH_2 value chain participants are active in South Africa and are investigating participation in the GH_2 value chain in South Africa.

South Africa's primary market will most likely be the EU and the United Kingdom. There are significant initiatives already undertaken by the EU to enable and facilitate GH_2 imports, including with South Africa. The European Union, notably Germany, have already introduced policy and have indicated a willingness to pay a premium price through the implementation of long-term (10 year) supply agreements to stimulate GH_2, ammonia and Power-to-X market development in specific jurisdictions. KfW, the German Development Bank, on behalf of the German government launched a €23 million (R3.4 billion) grant financing initiative in November 2022 with the IDC seeking to catalyse the development of a GH_2 economy in South Africa.

It must be noted, however, that South Africa will face significant competition for this European Union market from Morocco, for example, which has already announced initiatives for GH_2 with the European Union, as well as Iceland. Namibia, due to its historical ties to Germany also has an opportunity to collaborate with South Africa.

Focusing on the supportive policies and creating a regulatory framework that encourages cost competitiveness will allow South Africa to play to win in the global GH_2 landscape.

4.3 Focal export sub-markets – shipping fuel and sustainable aviation fuels

Given the potential for South Africa to export GH_2 into global markets, two cases are illustrated for specific application within the GH_2 value chain – marine bunkering and sustainable aviation fuel.

Oil products currently dominate the shipping sector, and the current use of hydrogen-based fuels in shipping is very limited. Ships do not use ammonia as fuel today, but oil and gas products (containing the equivalent of ~3.5 Mt hydrogen) is used to fuel ships, and if the volume of international shipping triples by 2050 under current trends, this demand from shipping will increase to the equivalent of ~10.5 Mt of hydrogen per year by 2050. To meet the emission targets of the International Maritime Organization (IMO), about 25% of shipping will be fuelled to 15 Mtpa as green ammonia, or 13 Mtpa as green methanol, utilising 2.6 Mt of GH by 2050. There are currently pilot initiatives exploring the commercial case for green ammonia and green methanol, and technology and cost will ultimately decide whether ammonia or methanol prevails as a maritime fuel. Sasol and ITOCHU have signed a MOU in September 2022 to jointly study and develop the market and supply chain for green ammonia, focussing on its use as bunkering fuel. In 2022, Itochu consumed about 72 Million litres of the A,B and C Heavy Fuel Oil (ITOCHU, 2022).

South Africa's access to both the Indian and Atlantic oceans could enable the country to secure an 8-10% market share of the global ammonia or methanol fuels market for shipping, equivalent to 0.8 to 1.0 Mt per year of GH (about 4 Mt of green ammonia or 3.2 Mtpa green methanol) by 2050 as shown in Figure 8.

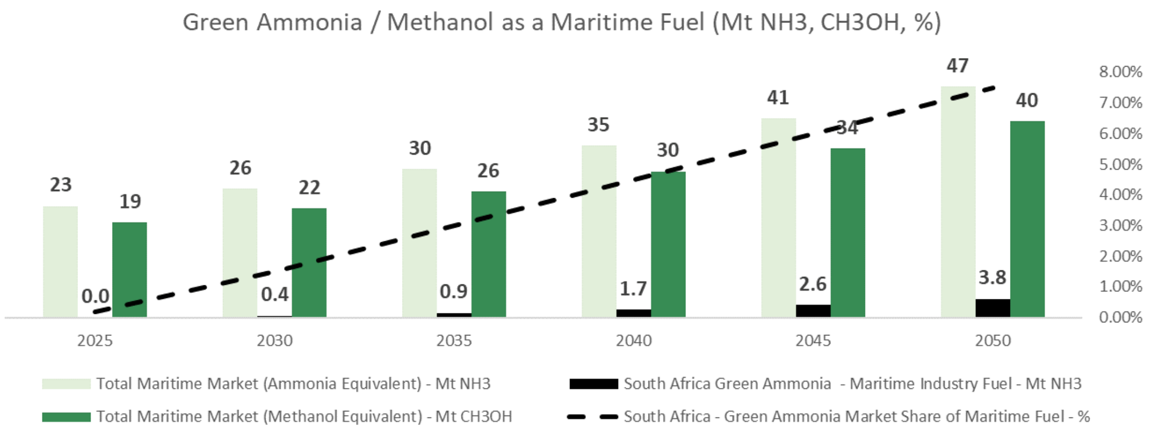


Figure 8: Green Ammonia and Methanol as a Maritime Fuel, Global and South Africa Market Share

Aviation lags other decarbonisation efforts in the transportation sector and Sustainable Aviation Fuel (SAF) is deemed as the only viable large-scale solution for the aviation sector.

As a result, governments are considering blending mandates to introduce SAF into the jet fuel market. In 2017, International Air Travel Association (IATA) members unanimously agreed a resolution on the deployment of SAF, including for constructive government policies, and committed to only use fuels which conserve ecological balance and avoid depletion of natural resources. The attractiveness of the SAF opportunity is underpinned by decreasing renewable energy costs and green hydrogen production costs, with green hydrogen expected to decline below \$2/kg H_2 by 2030, from the current \$4,00-5,50/kg H_2 cost range.

The global SAF market, as percentage of the global aviation fuel market, is estimated to be about 10% by 2030 (\$30bn of the \$314bn market) and is forecast to reach 47% by 2050 (\$180bn of \$387bn), ranking it the largest by market share in the aviation fuel sector and offering an attractive market in a relatively short period of time.

Sasol's Fisher Tropsch process is positioned to produce a range of sustainable liquids and chemicals, and the Fisher Tropsch based Power-to-Liquid route to SAF is deemed to be very competitive in the long term.

4.4 Domestic demand drivers

Green hydrogen can certainly play a role in driving domestic decarbonisation within the country. The primary source of current domestic demand for hydrogen are the current uses of hydrogen in the mining, processing, chemical industries in South Africa. Based on the latest available data from Statistics South Africa, the total value of sold "Hydrogen, nitrogen, oxygen, carbon dioxide and rare gases; inorganic oxygen compounds of non-metals" was valued in 2017 at R5.5 billion (2014: R4.3 billion). At present, it is difficult to obtain data on the volume and value of hydrogen traded in the South African economy and as a result, it is recommended that in future Statistics South Africa create a separate reporting code for hydrogen and oxygen, which is a by-product of electrolysis.

South Africa is a significant energy consuming economy at approximately 5-6 exajoules of energy, ranking South Africa 20th in terms of energy consumption and on par with countries like Italy, Australia, Spain and Thailand. Most of this energy (95%) is fossil fuel based (primarily coal) and represents a significant opportunity for decarbonisation and domestic GH_2 demand growth.

Domestic demand drivers include decarbonisation based on country or company commitments and enforced through final product requirements; current consumption of grey hydrogen to be switched to GH_2; cost competitiveness of GH_2 enabled through incentives and taxes versus its fossil alternatives; the availability and access to GH_2; and the maturity and acceptance of the application technology and access to support ecosystems.

GH_2 production lifetime costs can be estimated as follows; cost of electricity (60-70% at current renewable energy prices) and cost of electrolyser and balance of plant equipment (30% to 40%). Based on current cost estimates, the production cost of GH_2 is not cost competitive with other hydrocarbon-based fuels that it must displace over time. When considering fuel switching to GH_2, the effect of carbon taxes on fossil fuel energy serves to increase the price of these fossil fuels over time and thus accelerate market price parity. Although the combination of declining cost of GH_2 production coupled with increasing carbon taxes is predicted to achieve GH_2 price parity from 2025 to 2027, this doesn't account for the overall higher cost of energy to end-users or capital costs of transitioning energy assets. A more realistic or market view of achieving local price parity may therefore be closer to 2030.

Noting the above considerations and adopting the more aggressive demand view the key drivers of future South African demand – 2023 to 2050 are illustrated in Figure 9.

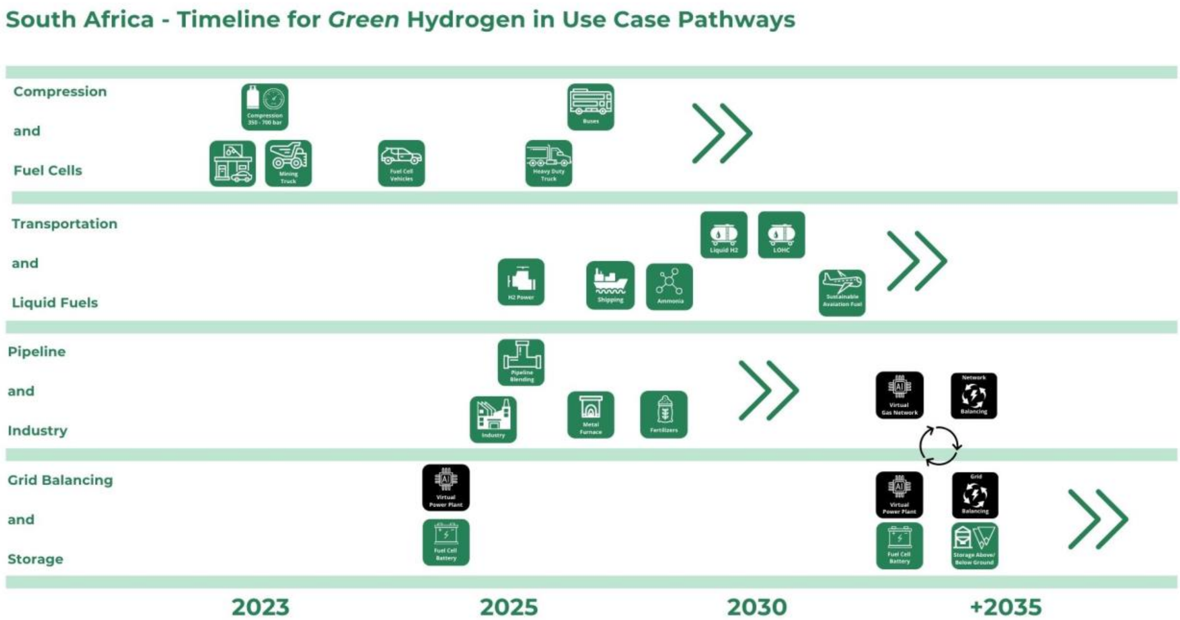


Figure 9. Indicative GH commercialisation roadmap and timeline

- 2023-2025: Road transport, primarily Fuel Cell Vehicles (FCVs), of which a significant component will be Heavy Duty Vehicles (HDVs). Many projects are underway globally, including in South Africa with a hydrogen powered truck at Anglo Platinum's Mogalakwena PGMs mine, the Hydrogen Valley which is an 835km industrial and commercial corridor focused on mobility, and Sasol and Toyota South Africa Motor's partnership to commence exploration of the development of a GH_2 mobility ecosystem. Mobility represents a significant opportunity for South Africa, but this will be sequenced based on economic viability, which will be dictated by volume and carbon emissions. Mining represents the best early adopter of hydrogen for mobility, followed by heavy duty logistics (trucks and buses) and later, when hydrogen refuelling stations are more widely available, fuel cell vehicles for mass transportation. Anglo American launched the world's first zero-emission hydrogen-powered mine haul truck capable of carrying a 290-tonne payload on 6 May 2022. Anglo American also intends on a full roll out of this initiative by 2028 which will allow the displacement of diesel at the mines. Anglo American is also exploring switching smaller heavy-duty vehicles to hydrogen and fuel-cell technology (Anglo American, 2022).

The ambitions on GH_2 mobility will be calibrated with the planned shift to New Energy Vehicles (NEVS) and the time frames will be aligned with the rollout plans for battery electric vehicles that will be complementary to both BEVs and FCEVs.

- 2023-2025: Refining and processing, which consumes significant amounts of hydrogen for the production of petroleum products and chemicals. Many refining and process plants that currently consume or produce grey or blue hydrogen have active projects to switch to GH_2. Sasol has signed a long-term contract for the supply of 69 MW of renewable energy to its Sasolburg site in the Free State – the first of several agreements Sasol intends finalising in the coming months as it secures the renewable energy supply required to produce green hydrogen.

- 2025-2030: Chemical and Industry, notably the non-ferrous metals, green steel, and cement sectors, which will need to decarbonize to remain globally competitive. The world's first green steel pilot for fossil-free steel commenced operations in August 2021 as part of the HYBRIT project in Lulea, Sweden.

- 2028-2030: Green ammonia and methanol, which will replace current production from grey and blue hydrogen and add new production from new use cases. Ammonia is widely traded globally, and there are many pilot projects underway globally to evaluate ammonia as means to export hydrogen or as a direct fuel in many use cases, notably marine fuels (Omnia, 2023). Green ammonia can also be used to manufacture green fertiliser locally and replace the very expensive imported grey fertiliser products. Omnia Holdings have announced the commencement of a feasibility study to investigate the production of green ammonia for fertiliser production.

- +2030: Power Storage and Balancing, which will see GH_2 being used for long duration storage based on daily, monthly, and cross-seasonal balancing requirements. The round-trip efficiency of Power-to-Power is a limiting factor for uptake, however, with greater renewable energy penetration into the global energy system, the need for hydrogen as a means to store curtailed/surplus renewable energy will increase, which will create a market for GH_2 from this sector.

4.5 South Africa – developing a vibrant and sustainable domestic market

Demand estimates for the South African market assessed the size of the South African market for GH_2. These studies indicate significant variation in the quantum of domestic demand as shown in Figure 10.

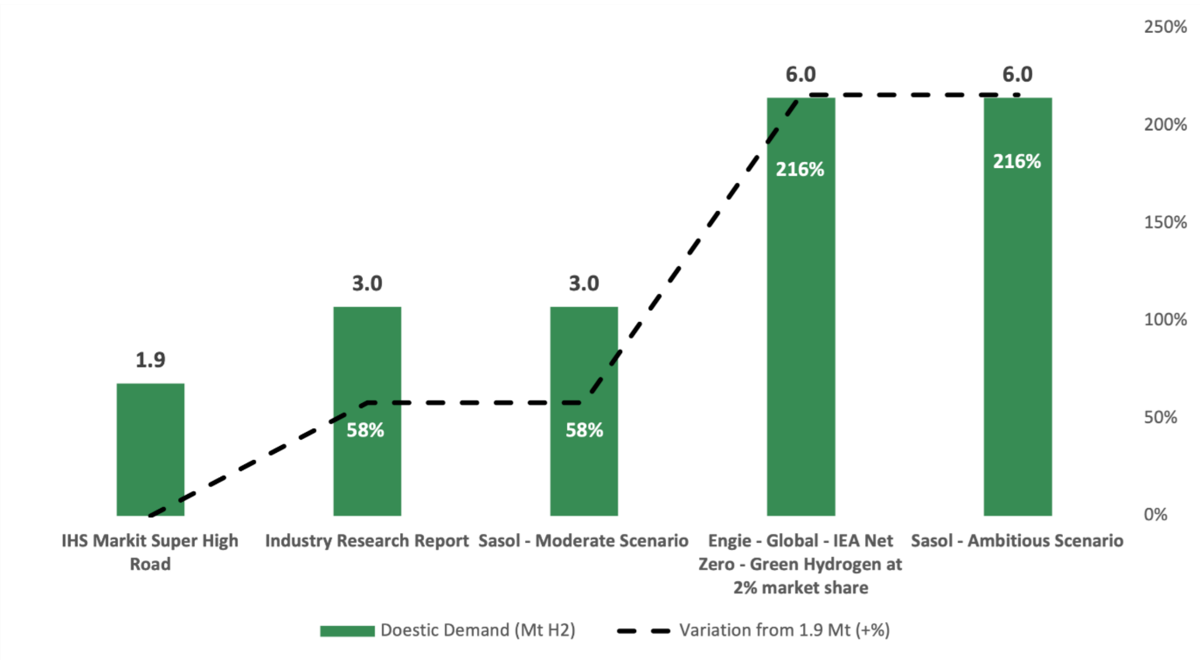


Figure 10. South Africa - Domestic Market Assessment

The initiatives that South Africa needs to undertake to spur demand for GH_2 in the local economy and enable the domestic market to scale up consumption to the higher tonnages are indicated in Figure 9 and will require specific coordination and interventions between the public and private sector.

From a demand perspective, to achieve ambitious domestic demand in the >3mtpa range, will require supportive policies and incentives, as organic domestic demand growth absent support for this range is highly unlikely. Further detailed studies will be needed to consider the overall economic cost-benefit impact and value for money proposition of deeper government support and interventions to achieve more aggressive market demand.

A key input into GH_2 production is renewable electricity. The recent high levels of load shedding at incidence levels of Level 6 and above may impede the roll-out of domestic renewable electricity for GH_2, as this renewable electricity may be sold directly into the grid to support the significant shortfall in generation. Solving the general electricity supply situation in the country will be key to enabling renewable energy availability for GH_2 production as discussed in Section 2.

GH_2 represents a significant opportunity for South Africa to enable global decarbonisation through exports, allowing other countries to decarbonise, and domestic carbon reduction of its energy economy which consumes 5-6 exajoules of energy (ranked 20th globally). In adopting this approach, South Africa will be seen as a key leader in the energy transition and could become a critical player in the new global energy economy providing an example for other emerging economies.

Accordingly, GH_2 production will be driven by two distinct markets: export demand driven by the international trade of GH_2 between countries and regions; and domestic demand, driven by fuel switching and new vectors for the use of GH_2 for mobility, industrial processes and power. Focusing on the hydrogen-supportive policies, creating a regulatory framework that encourages cost competitiveness and ensuring national coordination on hydrogen infrastructure and hub development will allow South Africa to play to win in the global GH_2 landscape and spur the uptake of GH_2 in the domestic economy.

5. Industrialisation opportunities

Both the above export market potential and domestic market potential presents many new industrialisation opportunities for South Africa. A range of local and export use cases that can anchor demand for GH_2 in South Africa are shown in **Figure 11**.

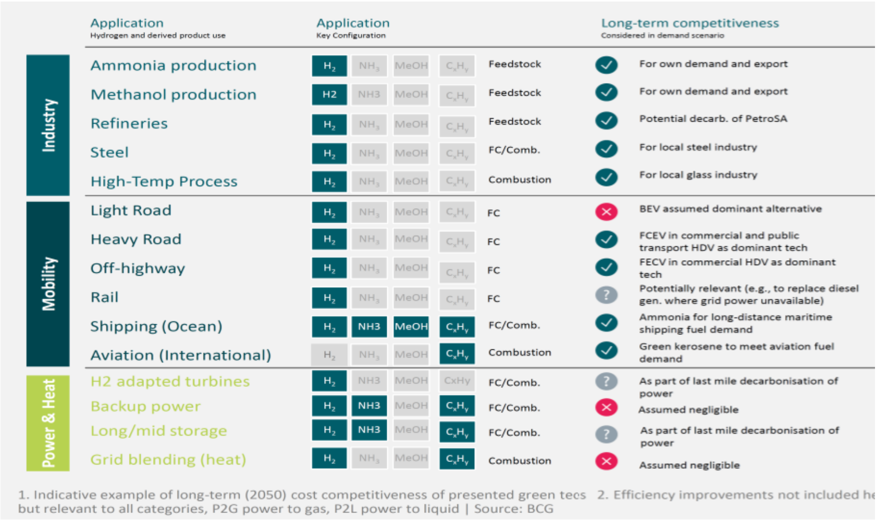


Figure 11: GH2 use cases for South Africa (source NBI, BUSA, BCG, 2021)

5.1. Ammonia production

Ammonia is widely traded globally, and there are many pilot projects underway globally to evaluate ammonia as means to export hydrogen or as a direct fuel in many use cases, notably marine fuels. Green ammonia can also be used to manufacture green fertiliser locally and substitute imported grey fertiliser products. Projects are being developed in South Africa to produce green ammonia for the export and local market.

5.2. Green steel production

The steel industry contributes 7% of global emissions or 2,6 Gt of CO_2. Steel is an important circular material that should be decarbonised. The H2 direct reduced iron (DRI) is an important steel making input to decarbonise steel making. Arcellor Mittal South African (AMSA) Saldanha Bay plant asset has the potential for the production of green steel as it has an existing Midrex facility and installed electric arc furnace. AMSA is investigating the opportunity of producing green DRI at its Saldanha Works plant for local consumption and to export to EU and other countries.

5.3. Aviation fuel exports

Sustainable Aviation Fuel (SAF) is deemed as the only viable large-scale solution for the aviation sector. In 2017, the International Air Travel Association (IATA) members unanimously agreed to a resolution on the deployment of SAF and committed to only use sustainable fuels.. The attractiveness of the SAF opportunity is underpinned by decreasing renewable energy costs and green hydrogen production costs, with green hydrogen expected to decline below \$2/kg H_2 by 2030, from the current \$4,00 - 6,00/kg H_2 cost range. The global SAF market is estimated to be about 10% by 2030 (\$30bn of the \$314bn global aviation fuel market) and is forecast to reach 47% by 2050 (\$180bn of the \$387bn global aviation fuel market). These estimates make SAF an attractive market in a relatively short period of time.

5.4. E-methanol for local consumption

Hydrogen and beneficiated products have also attracted global attention in the mobile telecommunications industry for backup power using fuel cells (IEA, 2019). Here, the use of fuel cell backup systems substitutes for diesel consumption, particularly in remote areas with limited grid access. Vodacom, for example, already has installed over 200 fuel cell backup systems across the country supplied by Chem Energy, the latter which is based at the Dube TradePort Special Economic Zone (Engineering News, 2023). These systems use a blend of methanol and water to produce hydrogen that is used in the fuel cell systems. An opportunity exists to roll out the fuel cell back-up power systems to all the mobile networks and consecutively ramp up e-methanol production using GH_2.

5.5. Electrification support and ramping RE for scale

The investments into renewable energy and storage to support electrification and GH_2 production, presents a sustained and predictable demand for inputs that can be locally produced. This includes solar and wind energy generation and storage. Linkages with the renewable energy industry can be leveraged to provide scale of demand and enable local manufacturing of renewable energy components for example solar panels, solar cells, wind towers, wind nacelles, steel and aluminium structures and balance of plant components.

Detailed analysis on local content is obtained from the South African Renewable Energy Masterplan (SAREM). Key findings on the economies of scale required to attract investment and ensure sustainable development of localisation are outlined below:

- Wind: A local market of 400 MW/year/OEM for a minimum of 5 years is required for the local manufacture of blades. Further, a local market of 1,000 MW/year is required for local nacelle assembly, and manufacturing of generators and converters.
- Solar PV: A sustained demand of at least 1,000 MW/year is required for local module assembly.
- Components: Production of components locally is an enabler for the growth of local raw material supply chains (e.g. glass, steel, concrete, copper, and aluminium).
- Similarly, deployment of PV and wind locally will expand existing local manufacturing supply chains and services for Balance of Plant.

South Africa has sufficient GH_2 production demand potential to justify the above localisation breakpoint estimates.

- Meeting SA's 2030 potential GH_2 demand requires an additional 17GW PV (3.4GW/year) and 8GW wind (1.6GW/year) deployment.
- The above needs to be considered and included in the SAREM, the Integrated Energy Plan (IEP), the Integrated Resource Plan (IRP), and the Gas Utilisation Master Plan (GUMP).
- Huge transmission and distribution grid expansion will need to happen rapidly for both electricity security and GH_2 ambitions by 2030.
- This also needs to be considered and included in Eskom's Transmission development plan (TDP).

5.6. Water security

Sourcing of water is essential to the electrolysis process to produce GH_2. The water source must also be sustainable for the hydrogen to qualify as sustainable or green. Extreme climate and rainfall fluctuations make South Africa a highly water-stressed country. The use of potable water for hydrogen generation is neither feasible nor sustainable. For the production of coastal GH_2, the feedwater will likely be desalinated seawater. Export hydrogen in particular will be produced at or near the port of shipment.

The desalination cost component of water has been calculated to vary between 0.005-0.020 $/kg of hydrogen produced.[5] For a targeted hydrogen production cost of $1/kg by 2050, the water cost equates to between 0.5% to 2% of the 2050 target price, showing that water is a relatively small cost component in the overall cost of production of GH_2. This important factor can be used to oversize the desalination part of GH_2 projects and make the excess desalinated water available to surrounding communities. It is recommended (Roos, 2020) that desalination plants supplying the electrolysis plants for bulk hydrogen production be oversized to at least 300% the capacity required for the electrolysis plant alone. The extra capital costs as shown above will not significantly influence the GH_2 price.

For the production of hydrogen for inland domestic use, the feedwater can be treated water from heavily contaminated sources not treatable by municipal wastewater treatment plants i.e. mine water, acid mine drainage and industrial waste-water specifically in the Vaal region. Municipal waste-water should only be used when these other sources are fully exhausted, as industry may need this water source in the future (Roos, 2020).

GH_2 production can therefore contribute to water resilience rather than detract from it. Excess potable water can be made available to surrounding communities, increasing resilience and access to potable water.

The volume of water required for GH_2 production is insignificant compared to the volume of water consumed in the country. Assuming that 12kg of water is required to produce 1kg of green hydrogen (Roos, 2022) and based on water demand projections for South Africa up to 2035[6] (2018, Institute for Security Studies), the water required to produce the quantities of GH_2 as targeted in this GHCS is less than **0.5%** of the projected water demand for South Africa.

5 T. Roos, "Renewable Hydrogen Generation and Transport Costs," CSIR Energy Centre Report, 2020, (Roos 2020)

6 2018, Institute for Security Studies - A delicate balance Water scarcity in South Africa, Zachary Donnenfeld, Courtney Crookes and Steve Hedden

5.7. Fertiliser production

South Africa is a net importer of fertilisers. As a fertilizer precursor, ammonia is a well-known chemical, with mature and well-established synthesis processes (Haber-Bosch). Green ammonia can be used to manufacture green fertiliser locally and replace the expensive imported grey fertiliser products. Local ammonia consumers are dependent on ammonia imports which are presently constrained by challenges with rail logistics. Omnia Group and WKN WindCurrent S.A (PTY) LTD (WKN), a fully owned subsidiary of German based PNE AG, have signed a Memorandum of Understanding (MoU) to evaluate the onsite production of green hydrogen and ammonia at Omnia's Sasolburg plant. This will assist Omnia in achieving their decarbonisation targets by replacing CO_2 intensive, conventionally produced ammonia with green ammonia.

5.8. Mine haul vehicles and heavy-duty vehicles

GH_2 has been recognized as an alternative fuel for the mobility sector in the EU and other countries. In South Africa, hydrogen powered vehicles or fuel cell electric vehicles (FCEV), in particular buses and heavy-duty vehicles, might play a significant role in climate change mitigation within the transport sector and the development of the GH_2 economy. Fuel Cell Electric Vehicles (FCEVs) shows promise particularly over long distances, where electric vehicles face challenges, and uses in mining applications show promise. Many projects are underway globally, in South Africa the following mobility projects are currently at various stages of development:

- Hydrogen powered truck at Anglo Platinum's Mogalakwena PGMs mine Anglo American launched the world's first zero-emission hydrogen-powered mine haul truck capable of carrying a 290-tonne payload on 6 May 2022. Anglo American also intends on a full roll out of this initiative by 2028 which will allow the displacement of diesel at the mines. Anglo American are also exploring switching smaller heavy-duty vehicles to hydrogen and fuel-cell technology (Anglo American, 2022).

- Hydrogen Valley – This is an 835km industrial and commercial corridor focused on mobility. Three catalytic green hydrogen hubs have been identified in the Valley: In Johannesburg hub (JHB hub with spokes extending to Rustenburg and Pretoria); Durban hub, compassing both Durban and Richards Bay, and a third hub encompassing Mogalakwena and Limpopo. Nine promising pilot projects have been identified to kickstart the Hydrogen Valley in the mobility (mining trucks, buses), industrial (ammonia/chemicals) and buildings (fuel cell power) sectors.

- Sasol and Toyota South Africa Motor's (TSAM) partnership to commence exploration of the development of a GH_2 mobility ecosystem. Sasol and TSAM will jointly pursue the development of a proof-of-concept demonstration for a green hydrogen mobility ecosystem. The parties intend to develop a mobility corridor and expand the demonstration to a pilot project using one of South Africa's main freight corridors, such as the N3 route between Durban and Johannesburg, for hydrogen powered heavy-duty long-haul trucks.

- West Coast mobility – opportunities also exists for hydrogen mobility corridors in the west coast with projects being developed in this area.

Mobility represents a significant opportunity for South Africa, but this will be sequenced based on economic viability, which will be dictated by volume of vehicles and carbon emissions. Mining represents the best early adopter of hydrogen for mobility, followed by heavy duty logistics (trucks and buses) and later, when hydrogen refuelling stations are more widely available, fuel cell vehicles for mass transportation. The ambitions on GH_2 mobility will be calibrated with the planned shift to New Energy Vehicles (NEVS) and the time frames will be aligned with the rollout plans for battery electric vehicles that will be complementary to both BEVs and FCEVs.

5.9. Marine Bunkering Fuel

The current use of hydrogen-based fuels in shipping is limited with ships currently using oil and gas products. The equivalent demand of hydrogen for oil and gas products in shipping is about 3.5 Mt. If the volume of international shipping triples by 2050 under current trends, this demand from shipping will increase to the equivalent of about 10.5 Mt of hydrogen per year by 2050. This represents a key downstream opportunity for hydrogen to substitute for existing oil and gas fuels. There are currently pilot initiatives exploring the commercial case for green ammonia and green methanol. Technology and cost will ultimately decide whether ammonia or methanol prevail as a maritime fuel. Domestically, Sasol and ITOCHU have signed a MOU in September 2022 to jointly study and develop the market and supply chain for green ammonia, focussing on its use as bunkering fuel. South Africa's access to both the Indian and Atlantic oceans could enable the country to secure an 8-10% market share of the global ammonia or methanol fuels market for shipping. This equates to 0.8 to 1.0 Mt per year of GH_2 (about 4 Mt of green ammonia or 3.2 Mtpa green methanol) by 2050.

5.10. Equipment manufacturing

Localisation of certain elements of the value chain are possible for catalysts, electrolysers, fuel cells and energy storage components. South Africa has firms that currently manufacture or are establishing manufacturing facilities to produce these key components. In addition to the RE component manufacturing mentioned in section 5.5 certain GH_2 value chain components are expected to drive localisation as export and domestic industries grow. These include electricity grid and associated infrastructure, compression and storage equipment, beneficiated products, and logistics. This growth in localisation requires planning, commitment and investment enablement.

5.10.1. Value chain component - Electrolyser systems

High priority localisation opportunities identified in the short-term include:

- **PGM raw material mining and beneficiation:** SA is responsible for 72% of global PGM supply and considered the most important component in the hydrogen economy.
  - PGMs currently contribute approximately 8% of the cost of a PEM electrolyser.
  - Iridium demand is expected to increase substantially.

- **CCM electrolyser components:** Beneficiation of locally mined PGMs into higher value components. The CCM contributes approximately 7.5% of the PEM electrolyser system costs.
  - CCM requirements to meet anticipated global installed electrolysis will result in a substantial market for CCM revenues.

- **System integration and O&M:** A domestic GH_2 market will drive the need for local development. Skilled local talent is available and can be trained. Installation contributes 33% of installed system costs.

Medium priority localisation opportunities identified include:

- **Local electrolyser stack, systems and components:** The availability of PGM materials at competitive prices is a key enabler in developing local factories that are globally competitive businesses for the manufacture of such equipment and components.
    - Localisation of electrolyser stack or systems can be achieved
    - Localisation opportunities require agreements with international OEMs.
    - This is considered medium priority for now as it is a long-term consideration and dependent on the development of an off-take market, incentives, and policies to make localisation of facilities attractive for international OEMs.
- **Recycling:** Secondary PGM supplies because of recycling are expected to increase. Currently this route contributes approximately 25% to the platinum supplied.

5.10.2. Value chain component - Fuel cell systems

High priority for localisation identified in the short-term include:

- **PGM raw material mining and processing:**
    - PEM fuel cells potentially can create a demand for platinum that will become a substantial percentage of mined platinum.
- **PGM Beneficiation:** Further beneficiation of locally mined PGMs into higher value components. MEAs contribute approximately 7% of a PEM fuel cell system cost.
    - Substantial local manufacturing can support additional potential for localisation of up-stream supply chain components (e.g., membranes).

Medium priority opportunities identified include:

- **Local fuel cell stack, systems and components:** The availability of PGM materials at competitive prices is a key enabler in developing local factories that are globally competitive businesses for the manufacture of equipment and components.
    - Technologies that will benefit from competitive PGM prices include PEM and PAFC.
    - This is considered medium priority as it is a long-term consideration and is dependent on the development of an off-take market, incentives, regulations, and policies to make localisation of facilities attractive for international OEMs.
- **Recycling:** Secondary supply because of recycling is expected to increase and contributes approximately 25% to the platinum supplied with the number expected to increase.
- **Automotive manufacturing:** Several major automotive OEMs are already present in South Africa.
    - The automotive industry is transitioning from ICE to BEV and FCEV.
    - BEV is expected to dominate the global passenger vehicle market with FCEV being more applicable to the heavy-duty mobility industry.
    - Several new FCEV OEM start-ups are emerging. The industry is still new, and OEMs have not yet established manufacturing contracts.

5.10.3. Value chain component – Energy Storage

High priority for localisation identified in the short-term include:

- Investment in mining and mineral beneficiation of battery minerals across the continent to supplement SA's limited resource base.
- Processing of material into battery-grade minerals and chemicals as commodities.
- Particular focus on accelerating the vanadium redox flow battery (VRFB) value chain, including the manufacture of batteries.
- Developing the local Battery Energy Storage System (BESS) market (including financial instrument for commercial and industrial consumers) and supporting the growth of battery assemblers and ancillary operations

High priority for localisation identified in the medium-term include:

- The development of a mineral processing hub and ensure value addition on the continent, taking advantage of AfCFTA developments and SA's current industrial capabilities.
- Development of the precursor processing industry.
  Holistic development of a downstream ecosystem for the assembly of electric vehicles.
  Supporting local technological advancement (in addition to capacity) and industrial scale manufacturers for BESS applications, both for the local market and exports.

6. Value Chain, local supply chain and hydrogen hubs

This section sets out the GH_2 value chain and its key components in order to understand the linkages between the various stages. Section 4.1 sets out the value chain, while Section 4.2 examines what is required in order for projects to succeed on the basis of this value chain. Section 4.3. then turns to the concept of hydrogen hubs as the basis for igniting the industry the progress to date in South Africa.

6.1. Value Chain Definition

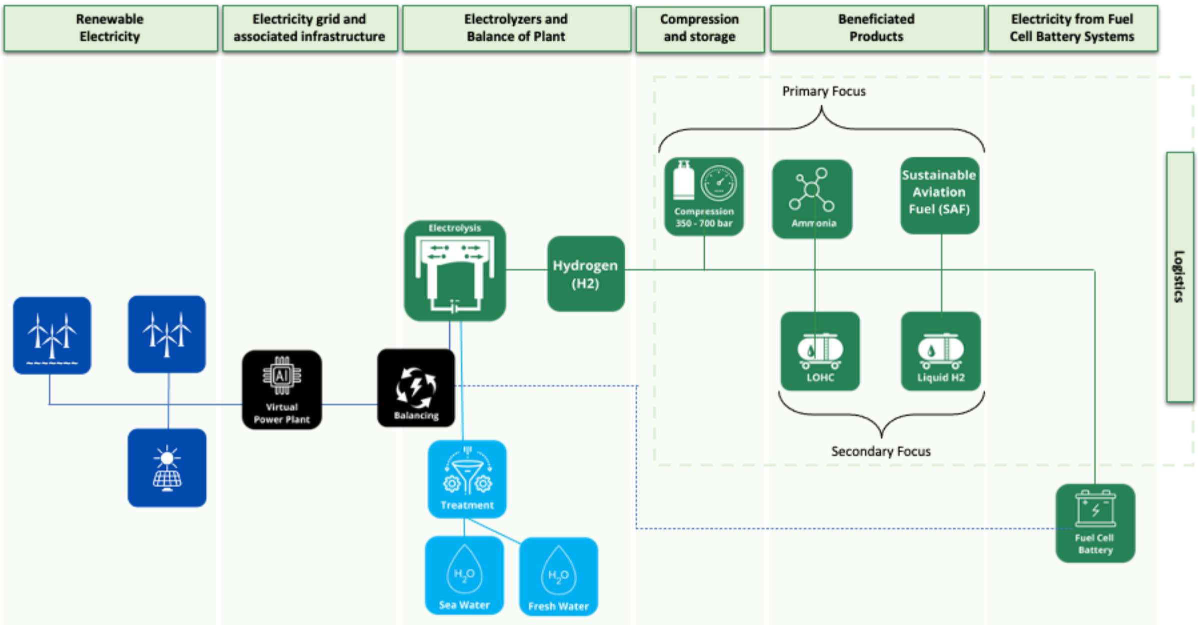


Figure 12: GH Value Chain

Understanding the GH_2 value chain provides insight into the economic linkages between the various stages of manufacturing and production. The value chain is depicted in Figure 12 above[7].

The key GH value chain components are:

- **Renewable electricity:** Renewable energy is a key input into GH_2 production. The electrolyser converts electricity and water into GH_2, and for the hydrogen to be considered green requires a low carbon input which comes from renewable energy. In South Africa, this principally refers to the use of solar and wind renewable electricity generation, but can also include other sources of renewable energy. These are inputs into GH_2 production and have their own related value chains for manufacturing and production.

- **Electricity grid and associated infrastructure:** The electricity grid is another vital component in the GH_2 value chain. The grid carries electricity from the renewable generation source to the GH production point. Given the geographical placement of competitive renewable energy sources in South Africa, renewable energy will have to be moved from the site of generation to the GH_2 production point. This infrastructure includes transmission and distribution infrastructure as well as substations, inverters, battery storage and other associated (ancillary service) equipment, which has application to projects with dedicated renewable electricity supply or electricity wheeled from the grid.

[7] Value chain dependencies including South Africa's resources and the key stakeholders required to harness South Africa's resources are represented in Appendix A.

- **Electrolysers and Balance of Plant:** Electrolysers are the heart of GH_2 production and use electrical energy to drive a chemical reaction, in a process called electrolysis, that splits water into its component parts of hydrogen and water, in the presence of a catalyst. The Proton Exchange Membrane (PEM) electrolyser is currently a common technology choice and typically uses a platinum catalyst. Classic and sturdy Alkaline electrolyser designs are known to behave very reliably, reaching lifetimes above 30 years. The electrolyser and balance of plant includes all the necessary equipment for the electrolysis process, as well as associated equipment to enable hydrogen and oxygen separation and the production of hydrogen to the required specification at the designed flow rate of the plant (including desalination/reverse osmosis treatment infrastructure).

- **Compression and storage:** Hydrogen gas is relatively light and occupies a large volume at standard temperature and pressure conditions. This makes it challenging to store and transport hydrogen its gaseous form efficiently. To deal with this technical reality, hydrogen is typically compressed or converted into another form before being transported and stored. These conversion processes have an impact on the costs of projects and additional infrastructure is required for conversion. Compression from a pressure of 30 bar, which is the typical exit pressure from the GH_2 production plant, to higher pressures of 300 or 700 bar for storage requires compression equipment and specialized storage equipment capable of handling pressurised hydrogen molecules.

- **Beneficiated products/transport mediums**: There are many pathways for beneficiated products, most notably green ammonia and methanol, which are traded globally. Sustainable aviation fuel offers an opportunity to decarbonise air travel. Transport mediums such as liquid hydrogen and liquid organic hydrogen carriers (LOHC) are at an early stage of development and will develop over time as costs and technologies improve. The downstream value chains are currently being investigated for decarbonisation of existing hydrogen routes (e.g. ammonia, methanol,) and the creation of new value chains (use of GH_2 in electricity generation, heat, and mobility)

- **Electricity from Fuel Cell Systems:** A fuel cell essentially reverses the electrochemical reaction that occurs in an electrolyser and allows electricity to be produced from GH_2. The fuel cell uses the GH_2 to drive a chemical reaction that produces electricity and water. Here GH_2 acts as an energy vector for long duration storage enables storage based on daily, monthly and cross-seasonal balancing requirements.

- **Logistics and supply chain**: GH_2 can be transported via road, rail, pipeline and shipping. The transport economics between the different options are sensitive to the distance. In cases where GH_2 is converted to another form for transport, such as in the case of ammonia, liquid hydrogen or LOHC, the cost of conversion to ammonia, liquid hydrogen or LOHC and reconversion back to GH_2, also impacts the costs of transport and the infrastructure required.

Based on the above elements of the value chain, the total cost to the end user of the GH_2 is approximated as the sum of the component costs along the value chain pathway, and will vary based on the form of GH_2 required in the end use and conversion processes required, along with the method of transport, among other factors.

It is important to note the scale of renewable energy and electrolyser build required in order to supply the domestic and international markets. On the basis of a scenario of 1.9 Mt GH_2 for export and 1.9 Mt GH_2 for domestic consumption to 2050, significant investments in estimated installed capacity for renewable energy and electrolysers are required. It is estimated that a combination of 56 GW of solar and 24 GW of wind will be required as an electricity input, combined with an aggregate electrolyser capacity of 41 GW to meet the demand anticipated in this scenario (see Figure 13).

Here, GH_2 represents a significant opportunity for South Africa to enable global decarbonisation through exports, allowing other countries to decarbonise, and domestic carbon reduction of its energy economy. In adopting this approach, South Africa will be seen as a key leader in the energy transition and could become a critical player in the new global energy economy providing an example for other emerging economies.

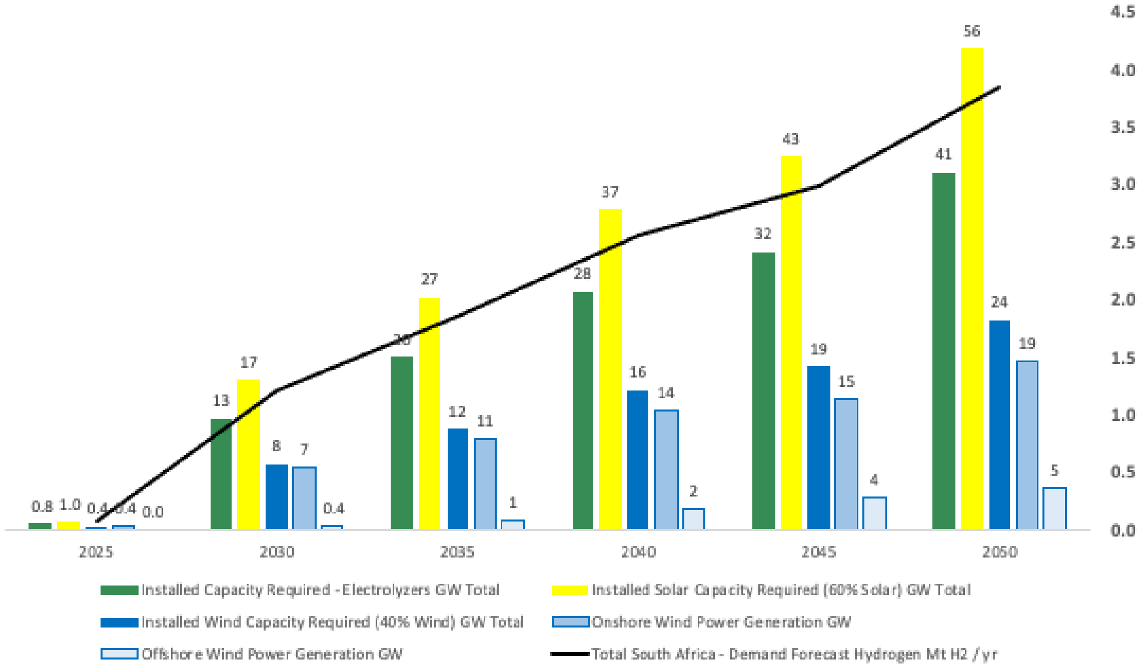


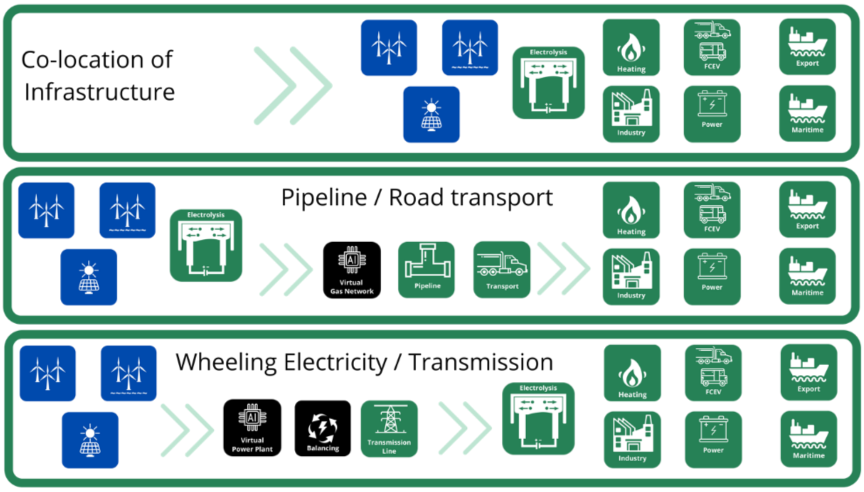
Figure 13: Total Installed Capacities in 5 Year Increments (GW) to Meet Demand

The key difference between the export and domestic market price for GH_2 will be the need for the costs for ammonia conversion. For the export price, the costs of conversion for ammonia and transportation needs to be included, currently estimated at \$0.5/kg GH_2.

6.2. Project location considerations

In the South African context, three supply archetypes for large scale projects will need to be considered:

- Co-locate renewable energy with demand, limited transportation and distribution infrastructure is required by users.
- Centralise renewable energy and the electrolyser to optimise natural resources and use pipeline or road transport to move the hydrogen molecules to areas of demand.
- Decentralise renewable energy to transport electrons and co-locate the electrolyser with areas of demand or production hubs.



There are many emerging examples of isolated in-house projects globally. The most notable projects are those of Amazon Inc. the retailer and cloud services company, which is the largest private procurer of renewable energy globally and has plans to be a significant participant in the GH_2 value chain, notably for logistics and data centres and other use cases within its group of companies. Ultimately, it is these in-house projects that will result in the most GH_2 usage over time as they will be driven by the need for GH_2 solutions to solve in-house demand challenges and use carbon incentives for fuel switching to fund these projects from internal resources.

Figure 14: Global GH Projects

6.3. Identification of GH_2 Hubs and Supply chain analysis

Th concept of a hydrogen hub has become a popular policy and planning tool in order to ignite the GH_2 industry. A hub in this context refers to a cluster of local hydrogen production, storage, and demand. With production, storage and demand located in close proximity, this reduces the need for transport of electricity or GH_2 over long distances which increases the cost of GH_2 to the consumer. Hubs also help to limit the cost of infrastructure and support economies of scale in producing and delivering hydrogen to consumers, and facilitating cross-sector opportunities for innovation and collaboration (WSP, 2022).

When considering the value chain GH_2 supply chains can be designed on 2 models as follows:

1. Co-locating renewable energy and GH_2 production equipment (such as electrolysers) and transporting the product or GH_2 molecules by road or pipeline if economies of scale can be achieved; or

2. Locating GH_2 production (electrolysis process) near the demand node and transporting electricity via wheeling on the national grid or dedicated grids if economies of scale can be achieved.

Before identifying the hubs, it is important to note that provincial government efforts have played a strong role in highlighting and identifying opportunities for development in the GH value chain. Here, it is vital that national level plans and strategies align with provincial plans in order to identify synergies and avoid duplication. The Northern Cape, Western Cape and Gauteng regions have all embarked on ambitious plans to develop GH2 within their provinces.

The Northern Cape Economic Development Agency was instrumental in the development of the Northern Cape Green Hydrogen Strategy that was announced at COP 26 and has been the pathway to driving the Boegoebaai green hydrogen development programme that has been gazetted in the South African context as a Strategic Integrated Programme (SIP). The programme has been able to undertake the pre-feasibility study for the first 5-Gigawatt Electrolyser output with Sasol and this will be concluded in June 2023. The programme has also transitioned with the development of a Master Plan that will enable multiple industry players to locate within the envisaged proposed Boegoeberg se Baai SEZ that is 30000 ha in size to ensure the minimum 40-Gigawatt ambition is attained by 2050. The latter masterplan will be concluded and issued in November 2023.The RFQ announcement for the Port and Rail is envisaged in May 2023 with the view of transitioning work that will enable exports of green hydrogen and derivatives in line with the minimal determined contributions. The World Bank is currently engaged in a study on Zero-Carbon bunker fuels at Saldanha and Boegoebaai. The objective of this assignment is to assess the pre-feasibility of the production, storage, supply and or export of zero-carbon bunker fuels at two port locations across South Africa.

In November 2022, the Northern Cape and Western Cape also signed a Heads of Agreement (HOA) to develop a green hydrogen (GH2) hub and corridor. The agreement will consolidate efforts towards a Western SADC Green Hydrogen Corridor. The Western Cape Government has allocated about R500 million for energy projects, including a R60 million allocation for Wesgro and Freeport Saldanha.

In Gauteng, the Vaal SEZs strategic objectives encompass a broad range of initiatives, which include a strategic plan for the development of a Hydrogen Valley hub in the Vaal Special Economic Zones (SEZs) site located in Rietspruit in the Emfuleni Local Municipality. A key priority is the identification of catalytic projects. The first of these projects is Project Phoenix, a Hydrogen Fuel Cell Manufacturing Facility that will be developed by Mitochondria Energy Systems.

Based on analysis and industry engagement, the following hubs have been identified as preferred locations for GH_2 development for exports and domestic consumption, shown by Figure 15.

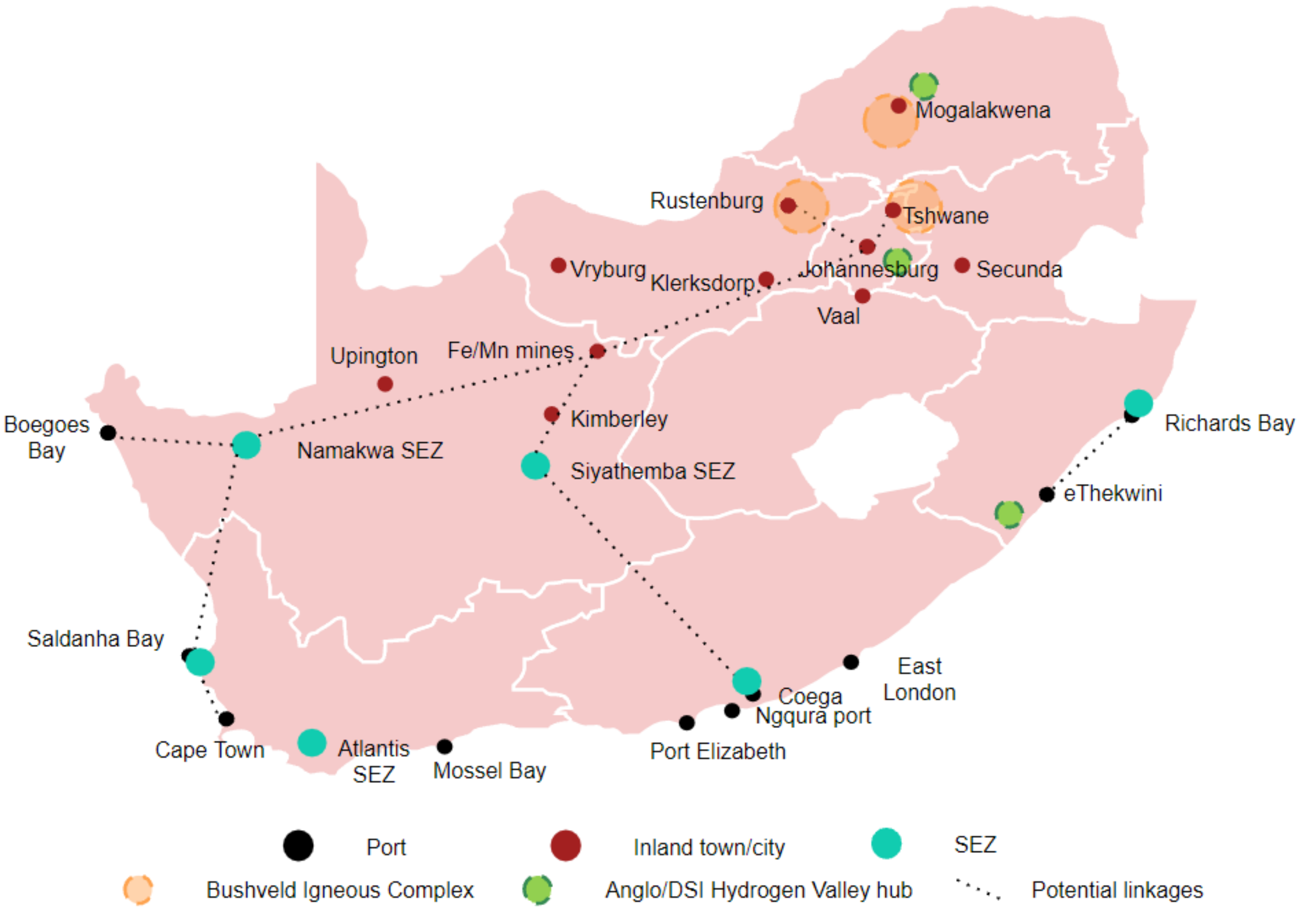


Figure 15. Geographic location of potential GH Hubs

Inland Hubs include the following regions

- The Vaal/Johannesburg Hub (extension to Rustenburg, Tshwane, and Mogalakwena; incorporating the whole Bushveld Igneous complex).
- Limpopo/Mogalakwena Hub.

Coastal Hubs include the following regions

- eThekwini/Richards bay hub.
- Port of Ngqura/Coega SEZ.
- Atlantis SEZ (greentech focus) Hub.
- Port of Saldanha bay and Saldanha bay SEZ.
- Boegoebaai port/Namakwa SEZ.

Hubs have been assessed for the West Coast of the country, Eastern Cape, the East Coast, and the Vaal Triangle. These are explored in more detail below[8].

A potential hydrogen hub on the West coast can link to the Northern Cape which has good solar resources for solar electricity generation and can be an optimal export opportunity to EU and potential American markets. Here there are two port options - Saldanha bay and Boegoebaai. These destinations have very different dynamics, however. Saldanha Bay is a well-established port with an IDZ, local demand potential and logistics infrastructure.

[8] A detailed illustration of the assessment criteria used to evaluate the hubs, their market focus, advantages and other factors is found in Appendix B.

Boegoebaai is currently not significantly developed and will be a green-field port development. The pre-feasibility study for the Boegoebaai development is nearing completion and will provide greater insight into the commercial viability of a hub located there.

A hydrogen hub in the Eastern Cape can link to Eastern Cape, which possesses good wind resources for wind electricity generation. This hub has clear advantages around the existing Coega port. The port facilities of Ngqura, by Coega, is a well-established port and IDZ and will give access to trading routes both East and West of South Africa.

On the East Coast, the Port of Durban (eThekwini) is a well-established trading port, but the port and surrounds are currently highly congested. The Port Authority's strategic planning is focused on container traffic with the aim to relocate the energy cluster at Island View to Richards Bay. Richards Bay also has a well-established trading port, as well as industrial activity to potentially diversify the local use of hydrogen. Richards bay's offshore wind resource is amongst the best in South Africa.

Inland, the Vaal triangle is an attractive location due to the concentrated industrial manufacturing activity that has developed over time. Key proximal economic activities include Sasol's Sasolburg plant, ArcelorMittal's (AMSA) steelworks, and Safripol's polymer processing. The Vaal would specifically focus on domestic uptake of hydrogen.

Although all locations have above average renewable energy resources, Boegoebaai, Saldanha, and the Vaal have the best relative solar resources, while Coega and Richards Bay have the best relative wind resources. Boegoebaai, the Vaal, and Coega have the closest proximity to a REDZ which could incentivise the financing and construction of solar and wind farms. The closest REDZ to Durban and Richards Bay is over 600 km away, indicating a lack of renewable energy financing schemes to leverage off of.

Durban is not seen as an optimal location due to port congestion and constrained land. Richard's bay has an added attraction of already being proposed for large scale marine bunkering and has a bigger industrial footprint closer to its port. Foskor's fertiliser processing and Rio Tinto's titanium mining operations could expand the scope of local adoption of hydrogen.

The above locations have a connected logistics network which will make access to resources (human capital, components, equipment) simpler and cheaper.

The Vaal is strongly domestic oriented and can fulfil the domestic deployment of hydrogen due to its industrial footprint, well established infrastructure, and its inland location. The Vaal triangle could also serve the purpose of anchoring hydrogen in the PGM industry; the existing pipeline infrastructure could be used to transport hydrogen across the North West, Gauteng, Limpopo, and Mpumalanga where most PGM activity occurs.

Coega's market outlook is both export and domestic, however its focus should be on export. It is a viable location for export due to its immediate port access and central location along South Africa's coastline. Coega is home to a sizeable industrial footprint, including FMCG and pharmaceutical companies, and provides an option for local deployment of hydrogen as part of domestic demand growth.

Saldanha bay has strong existing port and industrial infrastructure; local demand through opportunities like Saldanha Steel, Namaqua Sands and other industries further provide attractive domestic demand. Saldanha bay also has well established logistics and an IDZ. This will give Saldanha an opportunity to move quicker at lower cost and lower risk as an export hub for green ammonia.

The Boegoebaai green hydrogen hub in the Northern Cape can be a strategic project to open Southern Africa's full green energy potential. The location places it relatively close in proximity to rich mining and agriculture sectors compared to other existing ports. The Boegoebaai Port will provide an enabling platform for the province to achieve the key frontiers proposed in the 2021 Sustainable Infrastructure Development Symposium South Africa (SIDSSA). Supporting the efforts by the Northern Cape Economic Development Agency in the development of the Boegoebaai programme needs to be given top priority.

It is important to create focus and prioritisation in the initial design and planning. This has also been identified by international OEM's as well as in the literature review as global best practice. It is therefore proposed that the identified locations be promoted for longer term development as the GH sector develops in South Africa.

7. Tracking key South African projects to date

There has been a surge of interest in GH_2 projects in the country given the need to test commercial cases across the value chain. In December 2022, Minister of Public Works and Infrastructure, Ms Patricia De Lille, gazetted the nine projects that have received Strategic Integrated Projects, which are indicated below.

These projects[9] target different portions of the value chain, along with targeted and early-win downstream applications such as mobility (heavy duty), beneficiated GH_2 products (e.g. ammonia, sustainable aviation fuel), and GH_2 production.

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[9] A more comprehensive list of South African projects is indicated in Appendix C along with geographical descriptions of projects and investment requirements to increase production.

Table 1. Strategic Integrated Projects (SIP) gazetted in December 2022

* Minor, medium, major rating of Project Scale based on size of hydrogen/ammonia capacity, investment, electricity generation, or equipment used

#	Location	Project	Status	Description	Stakeholders
1	Mpumalanga, Secunda	Sasol HySHiFT	Cooperation agreement announced	Sasol intends on developing a sustainable aviation fuel production demonstration facility, based on GH, at its Secunda operations, in Mpumalanga to be bid in the first round of the H2Global auction programme.	Sasol, Enertrag, Navitas, Linde
2	Northern Cape, Prieska	Prieska Energy Cluster	Feasibility study and scoping (2025 commission date)	The project targets the production of green hydrogen and ammonia from 2025. This entails the development of Green Ammonia Production facility in Prieska, Northern Cape. The Project will inject R6.3 billion in capital investments in the first phase, with an additional R48 billion in investments during the expansion phase. The first phase of the Project, which will be located 10km outside Prieska in the Northern Cape, South Africa, will result in the production of 70,000 tons/annum of green ammonia with a GH content of approximately 12,350 tons.	Mahlako a Phahla investments, Central Energy Corporation (Cenec) and IDC.
3	Northern Cape, Boegoebaai	Boegoebaai GH Port	Feasibility study (memorandum of agreement signed)	Port, Rail and Infrastructure Project driven by the Northern Cape Provincial Government. The port has a capital value of approximately R13 billion and is underpinned by the export of mining commodities. 60,000 hectares of well irradiated land adjacent to the site would	Northern Cape Economic Development, Trade and Promotion Agency, Sasol

#	Location	Project	Status	Description	Stakeholders
				support a 30 GW solar and wind farm (6 times SA's current installed renewable energy capacity) and support 5 GWs of electrolysers	
4	Northern Cape	Ubuntu GH Project	GH beneficiation feasibility study/Unknown	20MW GH production project in the Northern Cape	Ubuntu Green Energy
5	Saldanha Bay Industrial Development Zone (SBIDZ), Western Cape	Atlanthia Green Hydrogen	Pre-feasibility conducted	Atlanthia will produce green hydrogen and ammonia GH2 and GNH3. Solar, wind and battery storage will supply electricity to the hydrogen electrolysis (20MW), desalination, air separation and green ammonia forming processes, via the production of GH2 and green nitrogen. Their pre-feasibility study completed in 2021 indicated economic viability for export and favourable local conditions for the adoption of GH2/GNH3 in South Africa's hard-to-abate clean fuels and chemicals sectors.	Atlanthia (Pty) Ltd
6	Upington, Northern Cape	Upilanga Solar and Green Hydrogen Park	Bankable Feasibility Study	Upilanga Green Hydrogen Valley is a green Power-to-X (P2X) project. Phase 1 of the project consists of a 400MW Integrated CSP+PV Power Plant (ICPH) with 12 hours of Thermal Energy Storage (TES) and a 500MW Electrolyser area for the production of Green Hydrogen and possibly derivatives (Green Ammonia, Green Methanol) Part of	Emvelo Energia, Upilanga Green H2 and DBSA.

#	Location	Project	Status	Description	Stakeholders
				the phase 1 roll out incorporates a 10-20MW Green H2 pilot demonstration.	
7	Free State	Sasolburg Green Hydrogen Programme	Sasol has signed a long-term contract for the supply of 69 MW of renewable energy	The Msenge project is one of several similar projects on which Sasol is focusing to complement its overall renewable energy programme procurement process. Msenge will come online in early 2024, subject to final regulatory and financial approvals.	Sasol, IDC
8	Eastern Cape	Hive energy Green Ammonia	The first phase of the plant is expected to be concluded in 2025	Hive Hydrogen has announced an investment of over $6 billion in green ammonia in South Africa. Hive has established a $4.6bn Green Ammonia Plant in the Eastern Cape. Targeted markets include agricultural, chemical, mining and maritime shipping.	Hive Energy/Built Africa
9	Limpopo, KZN and Gauteng corridors	Hydrogen Valley Feasibility Investigation - Johannesburg Hub	Various stages of feasibility	The Hydrogen Valley Programme consist of nine projects that assess the feasibility of developing corridors between the hubs of KZN, Gauteng and Limpopo. Various production and applications are being tested for their feasibility including feedstock switching, ethylene production, heavy duty vehicles, mining trucks, and buses	DSI, Anglo American, Engie, SANEDI, Bambili Energy

7.1. Requirements for Hydrogen Project Success

There are two types of projects that are under development globally, large scale GH_2 projects for multiple GH_2 customers, and isolated or co-located GH_2 production for specific use case/s.

There are many examples of large-scale projects globally, notably the project by ACWA in NEOM, Saudi Arabia, which will produce 650 t per day of GH_2 for export, reducing carbon emissions by 3 Mt CO_2 per year. Shell has commenced construction of a 200MW electrolyser that will produce up to 60 000 kilograms of GH_2 per day powered by the offshore wind farm Hollandse Kust (noord), which is partly owned by Shell. GH_2 produced will supply the Shell Energy and Chemicals Park Rotterdam, by way of the HyTransPort pipeline.

To get to GH_2 production levels advocated by various forecasts to displace 15-20% of global primary energy by 2050, will require more than two million projects globally consisting of large scale and mostly smaller isolated/co-located GH_2 projects. The NEOM project, another large GH_2 global project, will displace just 15 000 barrels of oil per day, or 0.015% of daily global oil consumption. Over 400 GH_2 projects have been announced (Figure 14), noting the sustainable aviation fuel project from Sasol and the mining truck/hydrogen valley project from Anglo American.

Irrespective of the size or type of project, all GH_2 projects face the following key requirements to enable project success:

1. Significant quantities of renewable electricity are required at the lowest price. The primary enabler of a GH_2 economy is access to large allocations of cheap renewable energy. South Africa's endowment of renewable energy resources (solar and wind) gives an advantage in potentially producing cheap renewable energy. Here, electricity infrastructure is also required to support the movement of electrons. Currently the best locations for cheap solar power are in the Northern Cape where the national grid is constrained in terms of potential to export electricity to the Gauteng (central load centre). The placement of electrolysers at the coast with the water source is limited by the national grid if the electricity is supplied from a significant distance.

2. Renewable electricity is required for the most hours. Based on current renewable energy prices and electrolyser costs and efficiencies, GH_2 projects are economic at 14 hours per day (at current renewable energy and electrolyser costs) or 5 000 hours per year. This means that solar power alone may not be sufficient to provide adequate returns or a competitive GH_2 price and needs to be supplemented with wind, grid and/or other renewable energy options. The Northern Cape has South Africa's highest peak sun hours at 2 600 to 3 000 hours per year, and when combined with wind will exceed 5 000 hours in certain locations.

3. Electrolyser and Balance of Plant at the lowest price. This includes access to water. Ideally, seawater with a desalination option will be used such that freshwater resources are not constrained. Excess potable water can be made available to surrounding communities thereby also increasing access to potable water.

4. Maximum electrolyser efficiency vs price. There exist options for the deployment of electrolysers and the technology choices will impact capital expenditure and efficiency amongst other factors. Currently alkaline electrolysis has a lower efficiency but is

cheaper than a PEM electrolyser, the latter which has a higher efficiency and is more expensive. Innovation in electrolyser equipment will see significant changes in years to come. Efficiency can be improved through scale, operations optimisation, and investing in Research, Design and Development (RD&D).

5. The hydrogen price to enable project returns. The standard IRRs for project finance related projects e.g., 8% yield for a European project and 18-20% yield for a project based in South Africa.

6. Off-take agreements to ensure viability of projects. Here foreign programmes are likely to be denominated in Euros or US Dollar which allow for the obtaining of cheap debt.

7. A favourable debt-equity split, typical >60% - 70% debt with balance as equity will be very dependent on market off-take risk.

8. Favourable terms for debt, with typical periods of >7 years for debt payback commencing at the start of commercial operations.

9. Long term off-take agreements – typical projects require a 20-year term to enable cash flow certainty and bankability. This will be a challenge in light of national procurement programmes such as Germany H2Global only offering contracts to 10 years which will require project sponsors taking merchant risk at the tail.

To demonstrate the two project types outlined above i.e., a consumer driven project and an isolated/co-located project, two projects are considered in detail in Appendix 3 and various cross-sensitives to demonstrate the most important elements to enable project success are included.

7.2. Showcasing projects

Green Ammonia Production for Export

Hive Energy and Built Africa are developing a \$4.6bn Green Ammonia Plant. The plant will have a dedicated power supply at the Coega Special Economic Zone, alongside the Port of Ngqura. The plant will produce approximately 780,000 tons per year of green ammonia for the export market. This project is working together with Cerebos in a mutually beneficial way, which entails Cerebos provide the project with desalinated, demineralized water while the project will supply green energy to Cerebos.

Green Steel Production

ArcelorMittal South Africa (AMSA) is investigating the viability of restarting the Saldhana Bay operations to produce green steel with green hydrogen. AMSA plans to be the first African green flat steel producer using green hydrogen by producing direct reduced iron (DRI) via the Midrex facility at its Saldanha Works.

Fuel Cell Manufacturing

Mitochondria Energy is planning to build a hydrogen fuel cell manufacturing facility in the Vaal Special Economic Zone (SEZ) in partnership with the IDC, DTIC and DBSA. Mitochondria's plans involve developing manufacturing capacity to build units totaling 250 MW a year, with plans to eventually ramp up to 1 000 MW a year, dependent on demand at the time.

Sustainable Aviation Fuel

Sasol as part of a consortium known as HyShiFT, is developing a sustainable aviation fuel (SAF) project in Secunda. Other partners in the consortium include German-based renewable energy company Enertrag and chemicals company Linde. The project entails using green hydrogen and sustainable carbon to produce SAF for the export market.

8. Infrastructure considerations

This section covers the importance of the appropriate key infrastructure required in order for the GH_2 value chain to be developed. These key infrastructure elements are integral to the development of the value chain to both service the domestic and export markets, and ideally would be in place to support the development of the value chain.

8.1. Transmission Grid Infrastructure

South Africa currently faces challenges around the availability of transmission infrastructure to transport electrons from the areas of high renewables availability to areas of demand. These constraints require investment into transmission infrastructure in order to increase capacity for the transport of electricity. The importance of investments into transmission infrastructure has been widely acknowledged by stakeholders and the imperative for this transmission infrastructure to serve the demand for electricity.

In the light of green hydrogen development, South Africa faces two challenges. Firstly, the investments into transmission infrastructure will have to be used to alleviate electricity supply shortages. Given the severity and importance of dealing with the electricity crisis, transmission infrastructure will have to be built to firstly prioritise the demand for electricity. In this planning and investment, the demand for electricity to meet green hydrogen demand should also be considered. This includes the use of green hydrogen as an energy storage vector.

Based on infrastructure needs, the transmission grid will require investment of about R132 billion over the next five years (2023-2027) and a total of R374 billion over the next 12 years (2023-2035) (Presidency, 2022).

Currently Eskom is the custodian of the national transmission infrastructure and publishes transmission development plans in order to understand the transmission investments required in order to service the transforming electricity system. These plans are intended to be living documents and are updated as the context changes. In the latest Transmission Development Plan (2023-2032), the increase in green hydrogen interest in the Northern Cape is acknowledged, however the increased demand for electricity for green hydrogen production is not featured as an input into transmission investment plans.

In the latest Transmission Development Plan (2023-2032), Eskom estimates 45 GW of renewable energy demand as the total demand for renewable energy for electricity by 2032, based off of the IRP (2019) demand, combined with the demand for electricity estimates in Eskom's 2035 Corporate Strategy (Eskom, 2022). While Eskom does note decarbonisation efforts and the use of alternate fuels such as hydrogen as a source of transmission grid transformation, the demand forecast does not mention the demand for electricity for green hydrogen production specifically. Based off of Figure 13, the demand for electricity for green hydrogen from renewable sources are estimated to range between 25GW and 39GW between 2030 and 2035, covering roughly the same period as Eskom's investment plans. This 25-39GW would represent additional renewables capacity required for green hydrogen production. This demand will have to be factored into transmissions plans and demand forecasts, to the extent that planned projects utilise the transmission infrastructure to transport electrons.

It is vital that the transmission infrastructure investment needs be reassessed to align the transmission infrastructure upgrades with increased accommodation of electricity demand for green hydrogen.

8.2. Ports Infrastructure

Ports are a fundamental component of the green hydrogen value chain. Port infrastructure is required to support GH_2 projects with the infrastructure to move GH_2 and its products such as ammonia, LOHC and other GH_2 transport vectors onto maritime transport for the export market. Further, ports can ignite the development of hydrogen hubs by acting as international centres for hydrogen production, application, import and transport (WSP, 2022).

As outlined in Section 6.3, a number of hubs and ports have been identified to connect production, conversion, transport and export infrastructure. While a number of ports have attracted interest, three ports stand out in terms of current development and project attraction. The ports of Boegoebaai, Saldanha and Coega have been identified as key ports for development in the South African context, for the export and transport of GH_2 to international markets. Each of these ports possess their own unique advantages, such as the availability of existing infrastructure, proximity to different markets, and proximity to renewables resources, among other factors.

The key developments at each of the ports is briefly indicated below.

In Saldanha Bay, Sasol has already signed an MoU with Freeport Saldanha Industrial Development Zone to facilitate a green hydrogen hub. Additionally, Sasol has signed a joint development agreement with Arcelor Mittal (AMSA) to develop carbon capture technology to produce sustainable fuels and chemicals. This includes plans to reignite AMSA's Saldanha Works to produce and export green steel through incorporating green hydrogen and other processes.

The port of Coega has also attracted attention for its strategic placement and infrastructure. Hive Energy is currently developing a green ammonia project in the port focusing on supplying green ammonia for the clean fuel and maritime industry across the Far East and Europe. The planned infrastructure includes a solar plant, desalination plants, hydrogen and ammonia production plants, a waste-to-energy plant, ammonia storage, and a liquid bulk terminal site.

The port of Boegoebaai is also currently being investigated by Sasol, for green hydrogen derivative exports, together with the Northern Cape Economic Development Agency. Boegoebaai has the advantages of large spaces of land and close proximity to good renewables resources in the Northern Cape.

Transnet is the custodian of South Africa's major ports and has already begun assessing port infrastructure. In late 2022, Transnet issued a Request for Qualification (RfQ) for the appointment of a developer to design, fund and construct a deep-water port and the necessary infrastructure in Boegoebaai (Transnet, 2022a). This is a greenfield investment and will require the completely new construction of infrastructure, and intends to support Northern Cape's GH_2 strategy and enable the transport of GH_2. Around the same time, Transnet also released a request for information (RfI) to procure 50-80MW of renewable energy at its eight ports across the country (Transnet, 2022b).

As more interest and investments accrue into these and other ports in South Africa, **it is vital that port infrastructure is assessed with respect to the readiness for green hydrogen integration and projects.** Importantly, **no single port should be viewed as a silver bullet export option** and the commercial cases for various exported GH_2 products, markets and value chain focuses should be tested and established across the ports of interest.

8.3. Transport infrastructure including integration with pipelines

Pipelines are an important transport infrastructure that can be leveraged to transport green hydrogen from production to consumption sites, particularly for domestic and regional access. In general, when considering the transport of hydrogen, transport costs are sensitive to the quantity of hydrogen transported, the distance, the transport means, the form[10] of hydrogen transported, and the availability of infrastructure. Hydrogen can be transported as a gas, compressed hydrogen, liquefied hydrogen and chemical hydrogen carriers (ammonia, liquid organic hydrogen carriers (LOHC), methanol).

The final cost of GH_2 is influenced by the costs of production and the costs of transport. Given this, the investment decision into transport infrastructure has to compare the costs of producing GH_2 in areas of good renewables potential and transporting the GH_2 to the consumer, versus producing GH_2 in close proximity to consumer demand, perhaps at lower renewable potential. GH_2 can be transported via ship, pipeline, trains and trucks. Once the GH_2 is transported, it then may undergo another conversion step[11] to process or extract GH_2 in order to meet the purity and pressure requirements of the consumer.

South Africa's natural gas pipeline system is composed of two networks: the Mozambique to Secunda Pipeline (MSP), Figure 16, and the Transnet Gas Pipeline Network (TGPN), Figure 17

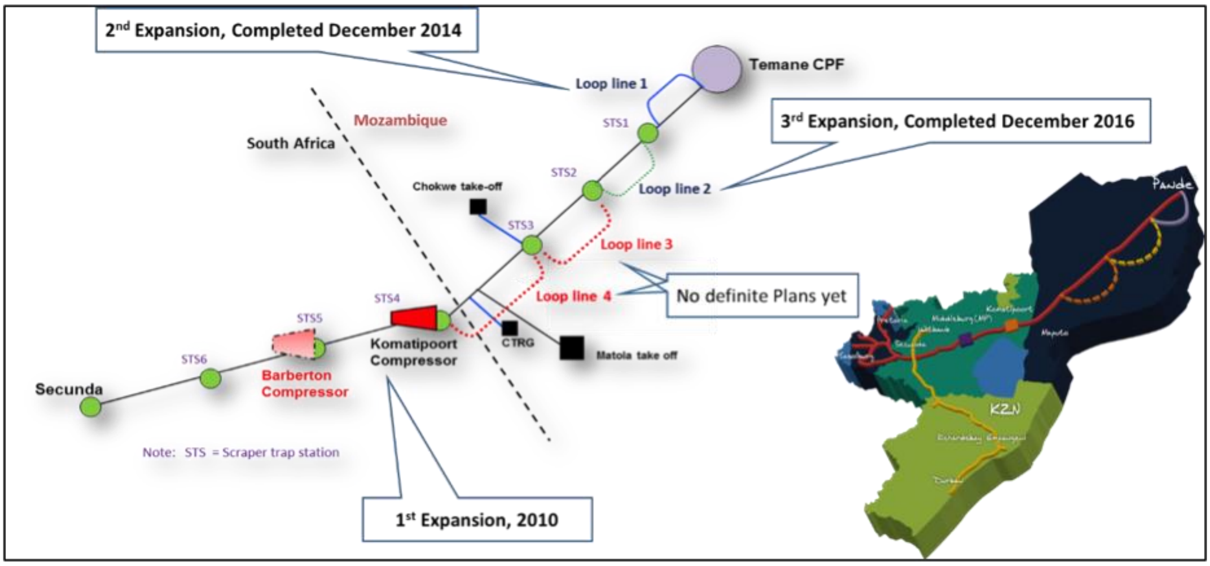


Figure 16: ROMPCO pipeline route

The MSP is an 865 km long gas transmission pipeline from the Central Processing Facility at the Temane gas field near Vilanculos in Mozambique to Secunda in South Africa and was commissioned in 2004. The first expansion project on the MSP to increase throughput capacity to South Africa was the compressor station at Komatiepoort. The project was initiated in 2008 and the compressor station was commissioned in December 2010. In 2012, the second expansion on the MSP to increase throughput capacity to Mozambique was approved. This is

[10] The form refers to whether the hydrogen undergoes compression or liquefaction processes, or is converted into another chemical for the purposes of transport. Conversion processes occur in compression or liquefaction plants, or in chemical reactors for LOHC hydrogenation, and ammonia and methanol synthesis.

[11] This conversion requires equipment such as compressors, pumps, evaporators, dehydrogenation reactors (for LOHC) or ammonia cracking plants. Purification systems may also be required.

a 26” diameter 127 km long gas transmission pipeline running parallel to the original MSP from the CPF to the first Scraper Trap Station (STS), STS1. Loop Line 1 was commissioned in December 2014. The third expansion on the MSP is also a 26” diameter 127 km long gas transmission pipeline running parallel to the original MSP but from the first to the second STS, i.e., STS1 to STS2. The pipeline was commissioned in December 2016.

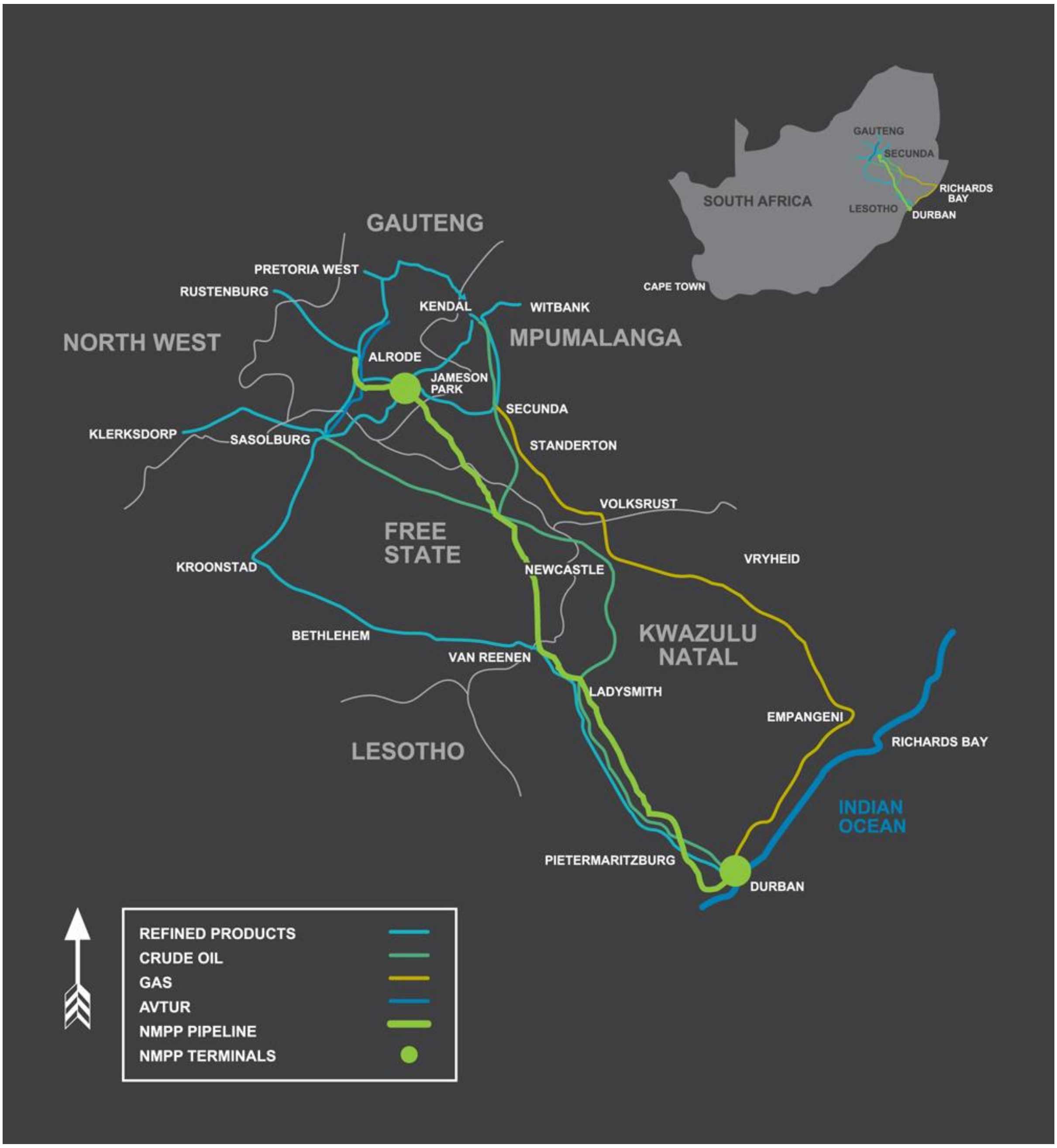


Figure 17: Transnet gas pipeline route (orange line in above image)

The TGPN (a converted line previously used for liquids) runs from Secunda to Durban via Empangeni. It has take-off points at Newcastle and Richards Bay as well as along the route between Empangeni and Durban. The pipeline transports 450 million cubic metres of gases.

Given the high capital costs of new pipeline construction, the blending of hydrogen with natural gas in existing pipelines has attracted a lot of attention as a low cost GH_2 integration pathway (US DoE, n.d.). The blending of up to 15-20% of hydrogen within natural gas is regarded as a modest modification to existing infrastructure. If the hydrogen in the existing pipeline network

(MSP and extension and TGPN) is above 15-20%, this will require new pipelines to be laid. Rather than a repurposing of existing pipelines, this will require repurposing of the pipeline network on the pipeline route.

As part of the development of the EU Hydrogen Strategy, the European Commission investigated[12] the cost competitiveness of different transport modes for GH_2. Based on this analysis, for distances up to 2 600km, GH_2 pipeline and compressed hydrogen shipping are the cheapest options to transport hydrogen (EC, 2021). For distances above 2 600km, liquefied hydrogen or ammonia are the cheapest options as shown in Figure 18.

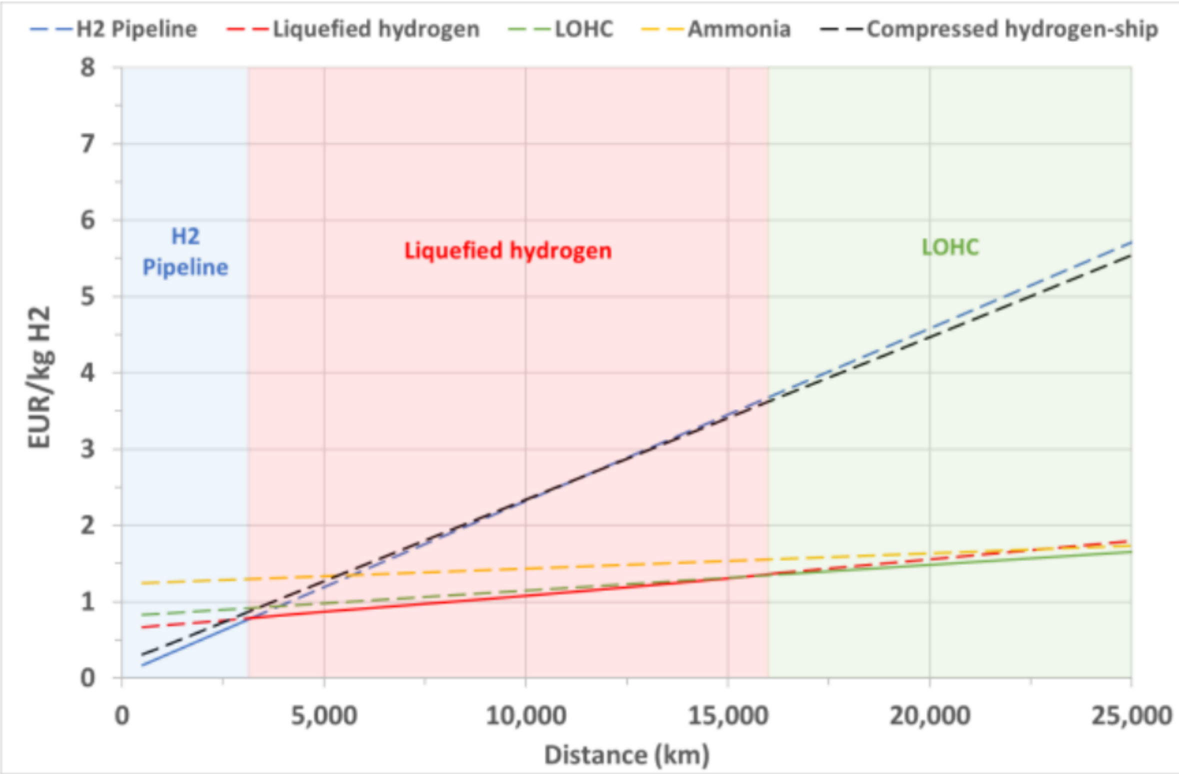


Figure 18. Hydrogen delivery costs for a simple point to point transport route

The above study however makes a number of assumptions around the production costs of hydrogen, the cost of electricity, and the availability of storage mediums, to name a few variables. These assumptions and cost estimates require testing in the South African context, in order to assess the transport modes technically available, and how the cost of transport varies across distance. **It is thus recommended that a pre-feasibility study be undertaken to determine the suitable transport modes and their cost variance for transporting GH_2, including the costs and viability of building new hydrogen pipelines in the country.** The latter will be informed by considering a few pipe route options, undertaking pipeline concept designs and associated cost estimates as part of such a pre-feasibility study.

SA has limited natural gas pipeline network infrastructure. However, the potential to exists to extend existing hydrogen pipelines (SBG Springs) and to optimise renewable energy infrastructure, grid infrastructure and pipeline infrastructure. Figure 19 provides an overview

[12] The study acknowledges the current technical uncertainty around the transport economics of GH_2. There are currently only a handful of working examples of functioning GH_2 transport mediums, limiting the data available. This is further complicated by the fact that the scale of these prototypes is typically small.

of the Phased Gas Pipeline Network (PGPN), which emanated from the Operation Phakisa Oceans Lab, with South Africa's Renewable Energy Development Zones (REDZs).

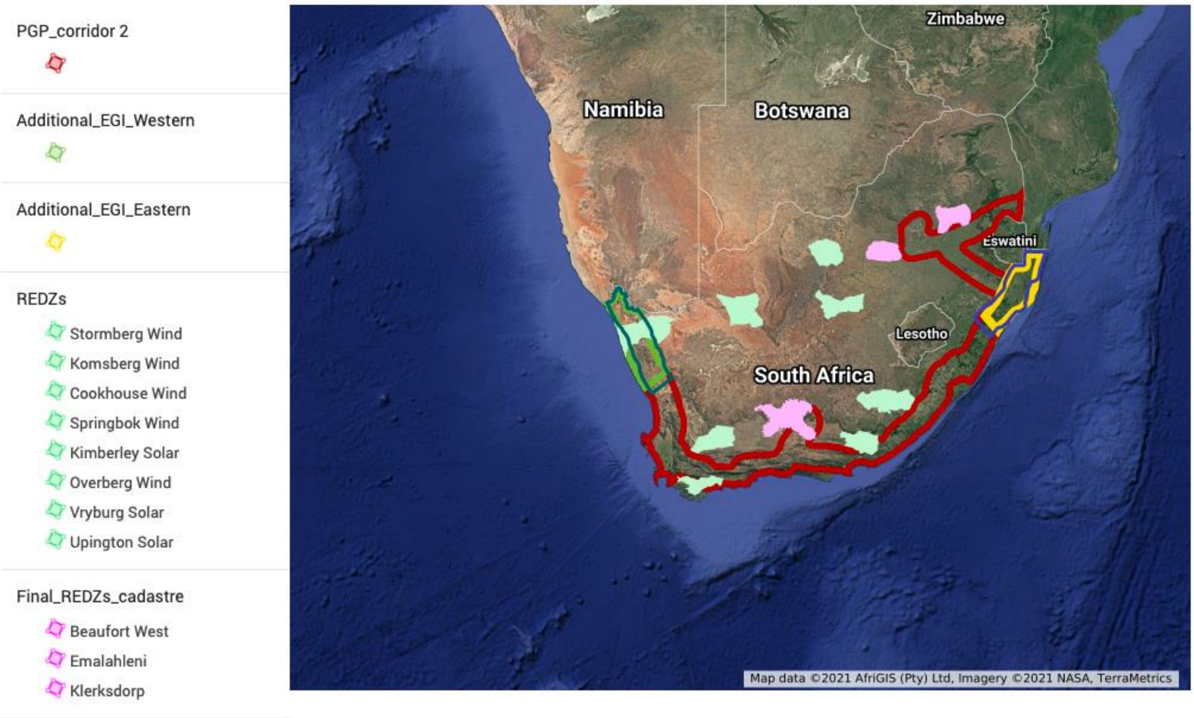


Figure 19. Phased Gas Pipeline Network overlayed Renewable Energy Development Zones

For the new pipeline system, **it is likely that these pipelines will require additional detailed study on the best option to ensure the pipelines can be used for both natural gas and hydrogen service, and the options for the best material for the pipeline construction will be done at the time of final investment decision based on relevant engineering studies.**

9. GH_2 localisation and manufacturing opportunities

The localisation of certain elements of the value chain hold potential in developing local competencies and capabilities surrounding the production of catalysts, electrolysers, and fuel cells, which describe the core components required for GH_2 production. South Africa already has a collection of firms in that currently manufacture or are setting up manufacturing facilities to produce these key components. Additionally, linkages with the renewable energy industry can be leveraged to provide scale of demand and enable local manufacturing of renewable energy components for example solar panels, solar cells, wind towers, wind nacelles, steel and aluminium structures and balance of plant components.

Moving forward, there are six configurations in which localisation can be established (see Table 2). Throughout this section different localisation opportunities are identified and require careful consideration to determine the topology mutually beneficial.

Table 2. Topologies for localisation (Source: SAREM)

Manufacturing topology	Description	Intellectual property
Local subsidiary of foreign company	Can be an OEM or supplier to OEM	OEM / supplier
Local manufacturer: under toll or license	Set up equipment to manufacture	OEM / supplier
Local assembly plant	OEM combines imported and locally made components	OEM / supplier
Local partner manufacturer	OEM / supplier to OEM provides manufacturing support (e.g., tooling, expertise)	OEM / supplier
Local manufacturing partnership	Installs local production line in partner company	OEM / supplier
Local manufacture	Supplier to OEM / balance of plant	Local

9.1. Breakdown of Value Chain definition for local content analysis

A high-level assessment of localisation potential for the GH_2 value chain is provided using a 3-level ranking system. Localisation opportunities in the supply chains are given priorities of high, medium, or low indicated by green, yellow, and blue background blocks respectively. The GH_2 value chain is provided in Figure 12 and analysed in detail in Chapter 6. The areas of the GH_2 value chain analysed in detail include GH_2 production via PEM electrolysis and fuel cells including mobility end-use applications. Certain GH_2 value chain components are expected to naturally see localisation as export and domestic industries grow. These include electricity grid and associated infrastructure, compression and storage equipment, beneficiated products, and logistics.

9.1.1. South Africa’s attractiveness in the global GH environment

The high-level attributes that make South Africa attractive for localisation includes:

- **Abundant local resources of PGMs.** Provides opportunity for SA to support PGM mining companies and local PGM beneficiation through policies and financial incentives to supply locally into local PGM beneficiation initiatives and attract international OEMs to establish local manufacturing facilities.
- **South Africa has an abundance of RE resources (wind and solar) to produce GH_2.** A sizable local market is anticipated by the international community, and this anticipated market is attractive for international OEMs to establish local manufacturing facilities and supply into the domestic GH_2 industry, with potential to export to other markets.
- **Large land availability served by a transmission grid that is the size of Europe.** Limitations on grid capacity in specific preferred resource locations where land is available, such as Northern Cape requires considerable grid expansion projects to optimally harness South Africa’s full solar renewable potential to produce cost competitive GH.
- **Established manufacturing, engineering, and technical expertise.** South Africa has an established manufacturing sector that provides confidence to OEMs to establish manufacturing and penetration into the region. This also supports local balance of plant (BoP) manufacturing, plant construction and operation and maintenance activities.

On their own each of these attributes do not necessarily provide sufficient motivation for localisation, but when considered collectively they contribute to the overall attractiveness for South Africa.

9.1.2. Value chain component - Renewable energy

This report does not include a detailed local content analysis on renewable energy sources, specifically wind and PV. Detailed analysis work is ongoing and obtained from the South African Renewable Energy Masterplan (SAREM). SAREM’s focus is on the localisation potential of the renewable energy manufacturing value chain under different scenarios of renewable energy ambition. RE is a key component in the GH_2 value chain and low cost RE and high capacity factors (CF) are two key enablers for successful GH projects.

Key findings on the economies of scale required to attract investment and ensure sustainable development of localisation are outlined below:

- Wind: A local market of 400 MW/year/OEM for a minimum of 5 years is required for the local manufacture of blades.
- Wind: A local market of 1,000 MW/year is required for local nacelle assembly, and manufacturing of generators and converters.
- For solar PV a sustained demand of at least 1,000 MW/year is required for local module assembly. However, this will come at a 25-30% premium to imported panels.
- Production of components locally is an enabler for the growth of local raw material supply chains (Glass, steel, concrete, copper, and aluminium). Further detailed analysis is required to consider demand linkages, supply capability and breakeven volumes.
- Similarly, deployment of PV and wind locally will expand existing local manufacturing supply chains and services for Balance of Plant which now makes up 65% of the capex of a project. Further detailed techno-economic analysis is required to quantify the broader benefits.

- The ability of local manufacturers to prove and guarantee component and system quality and performance price competitively compared to imported modules is crucial

Based on demand projections outlined in Section 4, South Africa has sufficient GH_2 production demand potential to justify the above localisation breakpoint estimates.

- Meeting SAs 2030 potential GH_2 demand requires an additional 17GW PV (3.4GW/year) and 8GW wind (1.6GW/year) deployment.
- The above needs to be considered and included in the SAREM, the Integrated Energy Plan (IEP), the Integrated Resource Plan (IRP), and the Gas Utilisation Master Plan (GUMP).
- Huge transmission and distribution grid expansion will need to happen rapidly for both electricity security and GH ambitions by 2030.
- This also needs to be considered and included in Eskom's Transmission development plan (TDP).

9.1.3. Value chain component - Hydrogen production through electrolysis

Three main electrolyser technologies are available for GH_2 production: Polymer Electrolyte Membrane Electrolysers (PEM) electrolysers, Alkaline Electrolysers and, Solid Oxide or High Temperature Electrolysers (SOEC or HTEL). These have similar supply chain components with distinct differences in the use of PGM catalysts present in PEM technology. Nickel and other non-PGM materials are used in Alkaline as well as SOECs. PEM electrolysers are emerging as the preferred technology for future GH_2 production from intermittent renewable energy. South Africa's unique benefit in the global supply of PGMs and the preference shown for PEM technology in the future GH economy, is a good indication that South Africa should attempt to leverage its PGM resources to promote localisation of PEM electrolysis technology equipment and components. The SOEC technology also shows promise of increased efficiencies and uses other metals also found in South Africa. Equipment and components include electrolyser stacks, electrolyser systems, electrolyser catalyst coated membranes and membrane electrode assemblies (MEAs), as well as electrolyser Balance of Plant components. The main cost drivers for selecting PEM electrolysis as the technology of choice for future GH_2 production are CAPEX and RE input costs.

Figure 20 shows the supply chain components of a PEM electrolyser and indicates the localisation priorities assigned. Table 8 in Appendix D provides an indication of the ranking of these supply chain components.

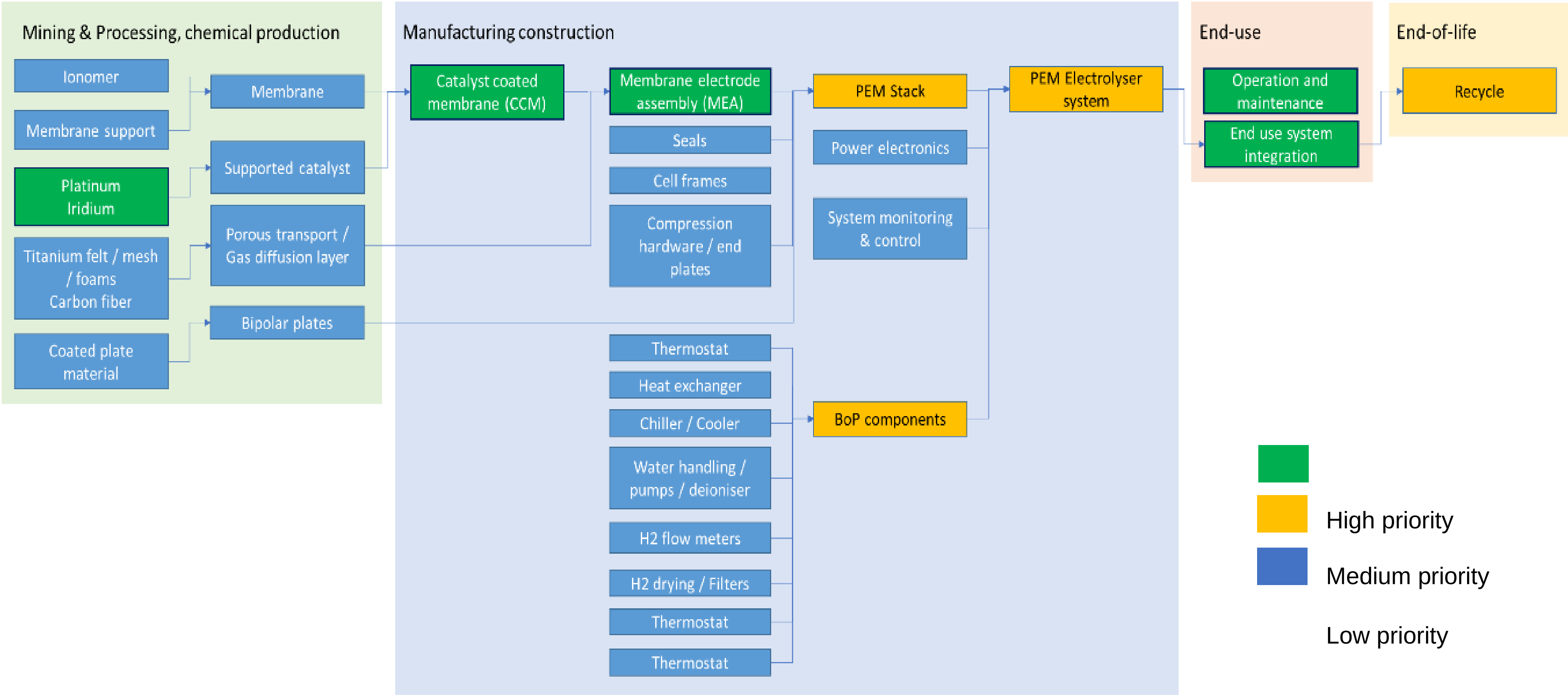


Figure 20. Localization potential for PEM electrolysis components

9.1.4. Value chain component - Energy from fuel cell systems

Several fuel cell technologies are available on the market. The main technologies include Low Temperature PEM Fuel cells (LT PEM FC), Alkaline fuel cells (AFC), high temperature PEM fuel cells (HT PEM FC), phosphoric acid fuel cells (PAFC), and solid oxide or high temperature fuel cells (SOFC or HTFC). LT PEM FC is the current market leader with the biggest global market share (approximately 68%, 2019) and lowest cost. Majority of fuel cell OEMs globally (listed in Table 13) supply LT PEM FC technology. The LT PEM FC segment's high market share is primarily due to its commercial readiness and extensive use in stationary, transportation, and portable applications.

SOFCs and PAFCs are emerging with potential of a significant market share (8% and 12% respectively, 2019). These are favoured for stationary applications and have high efficiencies when operated in combined heat and power mode, however SOFC costs are still high. LT PEM FCs operate at low temperatures (approximately 80°C), giving it the advantage of faster start-up, load following capabilities, and reduced component stresses. With the renewed focus globally on decarbonisation causing the shift towards the hydrogen economy, it is expected that the demand for PEM FCs will increase.

The different fuel cells have similar construction and supply chain components with distinct differences in materials used for manufacture. The important difference being the use of PGM catalysts which is found in PEM and PAFC technologies. Nickel and other materials including low loadings of PGM and non-PGM materials mined locally are used in AFC and SOFC. South Africa's unique benefit in the global supply of PGMs and the potential for PEM technology in the future GH economy, is a good sign that South Africa can rely on its PGM resources to promote localisation of LT PEM FC and PAFC technologies' stacks, systems, components, and equipment. SOFC can also provide opportunity for localisation as is seen with Mitochondria's project Phoenix.

Figure 21 shows the supply chain components for LT PEM FCs. LT PEM FCs are the dominant fuel cell technology used in mobility applications. LT PEM FCs are expected to generate substantial PGM demand 2030+ as GH use becomes mainstream. High and medium priority components are assessed in more detail in Table 10.

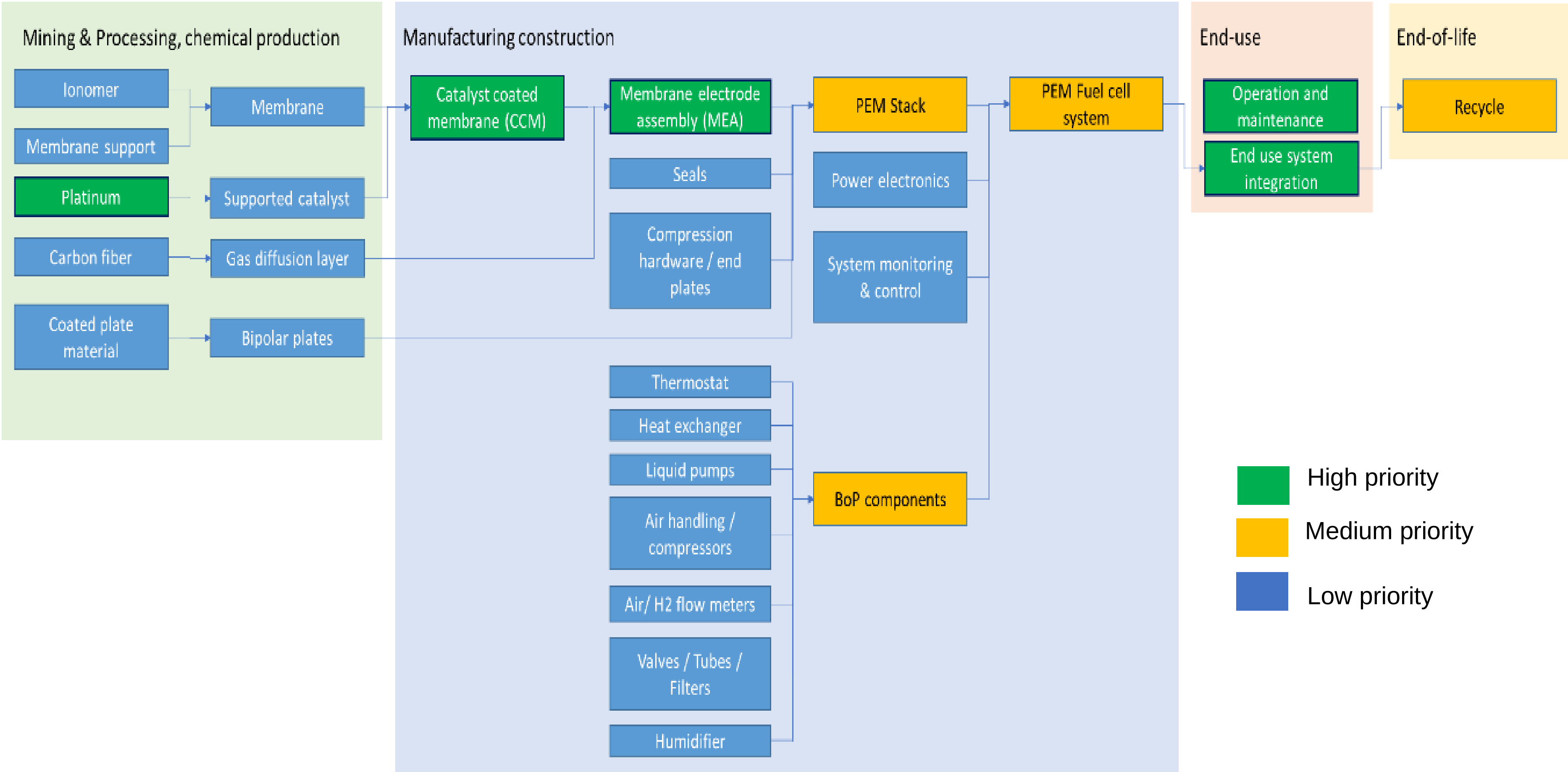


Figure 21. Localization opportunities for PEM fuel cells

9.2. Phased plan and enablers required to localise

South Africa and Zimbabwe possesses close to 90% of the world's platinum reserves and will inherently benefit from GH through the PGM catalyst used in PEM electrolysis and several fuel cell technologies.

9.2.1. South Africa's attractiveness in the global GH environment

- **Abundant local resources of PGMs.** Provides opportunity for SA to incentivise international OEMs to establish local manufacturing facilities of components, stacks, or systems.
    - From the projects identified in the Engie Impact Hydrogen Valley report, the total amount of platinum required to fulfil the equipment (PEM electrolysers & fuel cells) just in the H2 Valley, will increase the annual platinum production in South Africa by 1-2% in 2025.
        - The report gives 2030 GH_2 demand for the three hubs analysed between 94 – 183 kt GH/year that results in the 1-2% Pt demand. This is less than 0.1% of the most conservative global demand of 300mT by 2050.
        - The PGM sector could see significant gains from the hydrogen economy, as platinum and other PGMs are a key catalyst material for both fuel cell and (PEM) electrolyser manufacturing.
        - Policies and incentives, both for PGM mining companies and OEMs to localise, are required to leverage the local PGM resources. This demand for platinum could generate up to $100 million US in revenue to the sector by 2030 (Figure E.3).
    - Figure 45 shows the PGM demand that could result from the global GH_2 electrolysis and fuel cell deployment.
    - Iridium demand for PEM electrolysis alone by 2050 requires 1/3 of current global Iridium demand. SA supplies 85% of global iridium.
    - Pt usage in PEM fuel cells, will result in a gradual increased demand for platinum in the medium to long term.

- **PGM beneficiation.** Beneficiation of PGM materials into higher value components provide South Africa with an opportunity to compete in the global GH value chain with value added PGM beneficiated components for PEM electrolysis and fuels cells.
    - As with PGMs raw materials, PGM beneficiation through CCM and MEA component manufacturing provides a considerable opportunity to supply these components into the global market.
    - Local technology developers already manufacturing and supply low volumes into the global market.
    - Easy access to PGM resources must benefit current local component manufacturers.
    - Figure 44 shows the potential revenue from CCM and MEA supplies with optimistic assumptions of market penetration and global demand for PEM electrolysers (Figure 2.1) and PEM fuel cells.
- **South Africa has an abundance of RE resources (wind and solar) and land available to produce GH_2.** A sizable local market is anticipated by the international community, and this anticipated market is attractive for international OEMs to establish local manufacturing facilities.
- **Established manufacturing, engineering, and technical expertise.** SA has an established manufacturing industry and expertise along with a labour force that is

completely trainable. Leveraging PGM resources is possible to motivate OEMs to localise manufacturing of components, stacks and systems and establish penetration into the Southern African region as well as export of components, stacks, and systems.

Major cost drivers and enablers for GH_2 with potential to optimise cost:

- **Electricity price:** Electricity contributes the biggest cost component to the cost of GH_2.
- **Access to water:** This should preferably not be fresh water and thus desalination or mine wastewater is preferred.
- **Capacity factor (CF):** Wind and solar are both constrained in terms of CF. Combining wind and solar power, and adding batteries, will give the highest utilisation (running hours) of electrolysers. Consideration must be given to CSP/PV hybrids to benefit from the storage available from CSP and the low-cost energy from PV.
- **Plant size:** (through scale of economies and improved efficiency by improved utilization of BoP).
- **Capital cost:** South Africa can be cost competitive in electrolyser manufacture when leveraging availability of local resources (RAW materials), a local market, as well as lower labour costs compared to developed countries.
    - Efficiency can be improved through scale, operation optimisation, and investing in RD&D.
- **Infrastructure and storage:** South Africa are at a disadvantage when considering hydrogen infrastructure and storage. Other countries have extensive existing gas infrastructure which can be retrofitted for hydrogen. These gas infrastructures provide considerable storage potential at a low initial cost for storage and transport. Locating and sizing GH_2 production close to the hub (export, local use) is key.

9.2.2. Market and economic requirements for localisation

To make localisation attractive for international OEMs to establish local facilities, a wish list to establish local facilities has been identified. A detailed analysis is required to determine what makes sense for the country. The wish list identified through stakeholder engagement includes:

- South Africa needs to lead in the energy transition across Africa.
- Establish hydrogen hubs that focus on specific applications, e.g., hydrogen for maritime fuel, mining, solar to hydrogen, sustainable aviation fuel (SAF), etc
- Set the vision and targets for hydrogen penetration.
    - An explicit market for electrolyser target of 500MW/year to 1GW/year. A requirement of 2.5GW to 5GW by 2030.
    - Market demand must exist and be confirmed by project references.
        - To meet the most conservative model's 2050 demand (IHS = 1.9 Mt GH import and 1.9 Mt GH export) Figure 13 shows a 13 GW local electrolysis by 2030.
        - The 2025 local installed electrolysis according to Figure 13 is 0.8 GW.
        - In 2050 the total installed will have grown to 41GW.
- Local availability of main inputs and raw materials (e.g., steel, nickel), suppliers, distribution centres, and customers should be considered.
- Access to utilities and transportation (e.g., road, rail, air) with favourable costs.
- Design a heavy goods hydrogen refuelling plan to remove diesel
- Availability of current (and future) workforce with the required and/or upgradeable skills.
- Establish alternative fuels strategy: hydrogen, methanol, ammonia, SAF

- Facility and site should be able to physically accommodate future expansion and growth.
- Local advice and support to estimate project costs as precisely as possible.
- Suitability of location – climate, rainfall, extreme weather risks, etc.
- No significant deviations in the local codes and regulations compared to the home market.
- No significant objections or barriers from stakeholders to local manufacturing and site locations.
- In terms of funding support:
    - Incentives that bridge the gap on production costs given increased competition from India and China.
        - tax incentives ideally together with a local institution e.g., the IDC that provides guidance and assumes control over all applications and local bureaucracy processes.
    - Attractive loans
    - Grant funding for establishing manufacturing.
    - Grant funding for Feasibility and FEED studies.
    - Annual Contracts for Difference to incentivize GH_2 for industry.
    - Subsidy for GH_2 transport fuel to drive demand.
    - Expedited permitting
    - Tax abatements and credits

9.2.3. Existing local technology providers

Beneficiation into high-value components, largely done abroad, is an immediate opportunity for localisation. Support for existing local content must be a high priority. Existing local developments of components and assembly of PEM electrolyser and fuel cells include:

- **Hydrox Holdings** - Hydrox Holdings is a South Africa company that has developed IP for a membrane-less Alkaline electrolyser. They have in the past received funding from Shell to develop a scaled-up demonstration system.

- **HyPlat** - HyPlat is a University of Cape Town/HySA spinoff company that manufactures fuel cell MEAs. HyPlat currently supplies low numbers and sizes of PEM fuel cell MEAs into the international market and are currently in the process of acquiring funding to scale up production to 1m units per year.

- **Chem Energy SA** - The Chem Group's head office is based out of Taiwan. They have established a local fuel cell system assembly company (Chem Energy SA) and plant in the Dube Trade-port near Durban. Their focus is on remote systems (telecom backup) and based on a methanol reformer. It is thus fuelled with methanol which is supposed to be more readily available and easily transported than compressed hydrogen. This solution is not CO_2 emission free.

- **HYENA Energy** - A University of Cape Town spinoff company that manufactures remote fuel cell-based power packs fuelled by LPG. They have developed a catalyst and reformer to produce hydrogen from LPG and water which is more readily available than compressed hydrogen, especially for remote areas away from the major centres. There is 15% less CO_2 emissions when compared with diesel generators.

- **Isondo Precious Metals (IPM)** - IPM have obtained equipment to localise MEA manufacturing under license. They have received funding from DTIC and are in the process of construction of their manufacturing facilities (Date announced: 16 July 2021).

9.2.4. Priorities for localisation

Localisation initiatives should consider supporting local industries that are already providing key components into the GH_2 industry to expand, and develop an environment (market, policies, incentives, etc.) to attract international OEMs. Priorities are:

- Analyse the potential for support to expansion of one or more existing local technology providers.
  - Beneficiation of PGM materials by supporting and investing in a local manufacture of CCM/MEA components for the global PEM electrolyser and fuel cell markets could create a substantial export market revenue.
- Provide an environment to attract equipment, component, and system manufacturing for:
  - Electrolysers (Comprehensive list provided in **Table 12**)
  - Fuel cells (Comprehensive list provided in **Table 13**)
  - Fuel cell vehicles – Several major automotive OEMs are already present in South Africa. The automotive industry is transitioning from ICE to BEV and FCEV. Majority transitions will be to BEV which will have an unwanted effect on the local automotive manufacturing industry, with most OEMs likely to move manufacturing and assembly of BEV and FCEV back to their countries. This opportunity does not appear to be attractive for localisation and is considered a risk of automotive OEMs exiting the country as they transition to BEV.

9.2.5. Key linkages to other economic sectors

The table below highlights links between the GH_2 value chain and services and inputs provided by the economic sectors in South Africa.

GH value chain / Economic sectors	Water resources	Renewable energy	Electricity grid and associated	Electrolyser and BoP	Compression, storage and	GH and beneficiated	Electricity from Fuel cell & Battery
Agriculture	X	X					
Electricity	X	X	X	X		X	X
Construction	X	X	X	X	X	X	X
Personal services							
Resource extraction, Mining	X	X		X	X	X	X
Transportation & communication					X	X	
Manufacturing	X	X	X	X	X	X	X
Trade		X	X	X	X	X	X
Government	X	X	X	X	X	X	X
Finance	X	X	X	X	X	X	X

Economic sectors that will benefit across most of the GH_2 value chain components are:

- **Government and finance:** These are seen as a first requirement across the entire GH_2 value chain and important for both policies and regulations to fast-track GH_2 implementation and establishing government to government (G2G) relationships for export market and establishing infrastructure.
- **Electricity:** Electricity and capacity factor of renewable energy (RE) inputs are major cost drivers for the GH_2 value chain. Currently South Africa's grid is constrained in certain RE resource dominant corridors (e.g., Northern Cape). Availability of infrastructure (overhead power lines or pipelines) to link RE to GH_2 hubs and local demand centres is crucial infrastructure that takes several years to develop.
    - Requires integration with SAREM
    - Requires integration with Integrated Energy Plan (IEP) and IRP
    - Requires integration with TDP
- **Resource extraction, mining:** RAW material is identified as a high priority for localisation of both PEM electrolysers and PEM fuel cells equipment, components and/or systems.
- **Manufacturing:** PGM beneficiation, steel and other metals industry, machinery and equipment through local equipment and component manufacture for electrolyser and fuel cell stacks, integrated systems, and end use applications (FCEV).
- **Construction:** The construction sector will inherently benefit from the development of new hydrogen hubs, ports, electrical and gas infrastructure, renewable energy plants and is likely to be the sector to contribute most to terms employment.

10. Designing an enabling ecosystem

The success of a South African GH_2 industry lies in a holistic and investor friendly ecosystem with clear and focused government support. Strong collaboration models between public and private sector will be required with much stronger leveraging of private sector capacity, capability and finance than has typically been seen in the South African economy. Such an ecosystem should recognise the need for speed with clear and bold policies if South Africa is to be a competitive global player.

Key enablers that help create such an ecosystem have been outlined below under Skills, Regulation and Finance. In addition to these essential requirements of skills, supportive policy/regulations and access to preferential financing it is essential that mechanisms be set in place to facilitate the interaction between the state and the private sector to assist with engaging across multiple ministries and to coordinate interactions at government-government level, i.e., effectively a "One Stop" shop for engaging with government to secure the delivery of GH_2 projects (as opposed to coordinating strategy). This approach certainly has proved successful in the fast-tracking of green hydrogen projects and developments in other countries such as Namibia, for example, where regulatory and policy hurdles can be easily identified and navigated.

10.1. The role of Government and the private sector

Stronger partnerships will need to be built between Government, the private sector and civil society to create an enabling environment. Implementation should also drive international partnerships while protecting national interest.

Government's role is to creating a conducive investment environment to attract investment into this industry. This will entail:

- Position of GH_2 as a key early contributor to decarbonization and a just transition in the country programme of work being collated by the JET-IP Task Team ensuring a fair proportion of climate finance is sourced to enable development of this industry.
- Prioritize the execution of the green hydrogen commercialisation strategy and the development of a national GH_2 infrastructure plan
- Drive the required policy and regulatory changes required to sustain long term growth of the new hydrogen industry.
- Mobilise and coordinate the Government support required to support the development of this new industry for South Africa.
- Drive the implementation of infrastructure by partnering with the private sector. This will include port, rail, pipeline and electrical transmission and re-fuelling infrastructure.

The role of the private sector will include the initiation, development and execution of green hydrogen projects along the value chain for domestic consumption and export.

10.2. Ensuring skills development for a successful GH_2 economy

South Africa's major industries such as chemicals, mining, and manufacturing have created local talent and developed intellectual property (IP) to grow the industrial manufacturing base since the 1950s (Sasol, 2021). South Africa's tertiary and technical institutions continue to stay relevant on the global stage by adapting skills curriculums, developing world class research material, and attracting top talent from across the globe to increase the pool of talent available to South Africa's industries (Study Portals Masters, 2021). South Africa's foundational skills are shown at the bottom of Table 3.

Table 3. Localisation opportunities and skills prioritisation framework

Value chain	Localisation opportunity (Priority)	Skills required	Skills sourcing	Government can build local skills capacity by...
Renewable Energy generation	Hydrogen and renewable energy specialists **(High)**	Circular economy skills	Outsource	● **Incentivising the private sector to support local capacity** as they outsource for missing and limited skills. ● **Support educational institutions** with development and funding of training programmes focused on the GH industry. ● **Creating financial incentives for the private sector** to roll out upskilling initiatives.
		Green architecture and future cities planning skills	Outsource	
		Green engineering and tech skills	Local, but limited	
		Natural capital skills	Outsource	
		Sustainable agriculture skills	Local, but limited	
Electrolysers and Balance of Plant	PGM beneficiation **(High)**	Technical engineering (renewable, marine)	Local, but limited	**Incentivising the private sector to support local capacity** as they outsource for expertise specific to electrolyser manufacturing
	Recycling of used PGM products **(Medium)**	Circular economy skills	Local, and growing	**Supporting the roll out of upskilling initiatives** through funding and financial incentives to encourage quicker uptake by the private sector

Value chain	Localisation opportunity (Priority)	Skills required	Skills sourcing	Government can build local skills capacity by...
	CCM* and MEA* electrolyser component manufacture **(High)**	Circular economy skills	Local, but limited	● **Incentivising the private sector to support local capacity** as they outsource for technical engineering expertise specific to **CCM and MEA component manufacturing**, **green engineering**, and **circular economy integration**. ● **Support educational institutions** with development and funding of training programmes focused on the GH industry.
		Green engineering and tech skills	Outsource	
		Manufacturing and Assembly	Local, but limited	
Beneficiated Products	Fuel cell stack and systems manufacture **(Medium)**	Circular economy skills	Outsource	● **Incentivising the private sector to support local capacity** as they outsource for technical engineering expertise specific to **fuel cell stack manufacturing**, **green engineering**, and **circular economy integration**. ● **Support educational institutions** with development and funding of training programmes focused on the GH industry.
		Green engineering and tech skills	Local, but limited	

Value chain	Localisation opportunity (Priority)	Skills required	Skills sourcing	Government can build local skills capacity by...
		Manufacturing and Assembly	Local, but limited	
	Automotive manufacture **(Medium)**	Manufacturing and Assembly	Local, and mature	–
All	Systems Integration and Operations and maintenance **(High)**	Circular economy skills	Local, but limited	● **Incentivising the private sector to support local capacity** as they outsource for missing and limited skills. ● **Incentivising the private sector to roll out upskilling initiatives** to develop growing skills, through funding models and financial incentives. ● **Developing ecosystem and research partnerships** to diversify mature skills into other segments of the GH value chain and other industries.
		Environmental justice skills	Local, and growing	
		Green career pathways	Outsource	
		Green architecture and future cities planning skills	Outsource	
		Operation management and system integration skills	Local, and mature	
Foundational skills South Africa has developed strong expertise in				
Ancillary and support services/ Architecture and Engineering design services/ Business and Management services/ Construction/ Finance and Legal services/ Information and Communications Technology/ Insurance and Healthcare services/ Logistics and transport/ Manufacturing and Assembly/ Risk Management/ Skilled labourers/ Technical engineering				

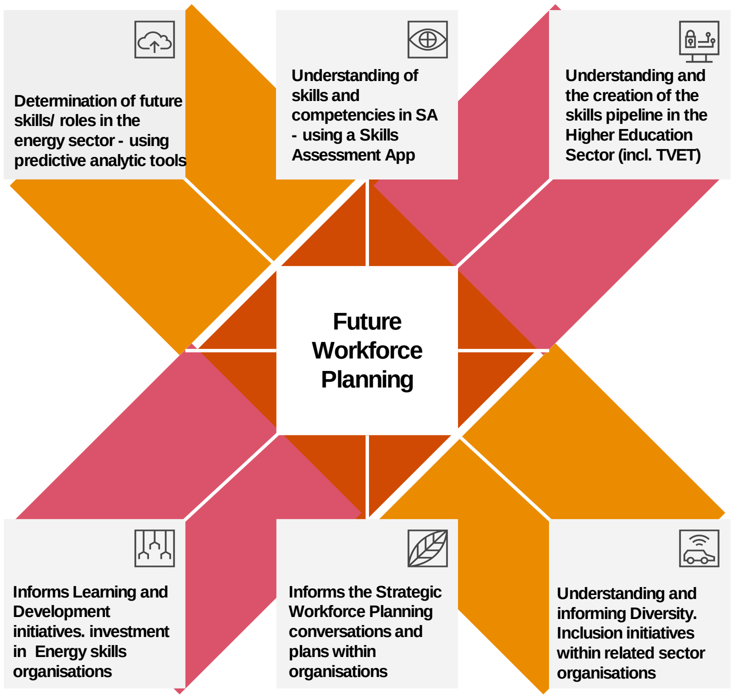
Climate change has profound links between the environmental challenge that South Africa faces and the social and economic stability of the country. Renewable energy and GH_2challenges the way in which South Africa have been dealing with environmental and social issues in the past, as it encourages a transition away from fossil fuels that has been the energy lifeblood of the South African economy and the employment source for thousands of South Africans for many decades. Potential job losses and social impacts of decarbonising South Africa's economy can therefore only be addressed through skills development in the renewable energy and GH_2 sectors. South Africa's updated NDC states that the government is currently in the process of finalising a Just Transition Plan which will define pathways compatible with pursuing efforts to limit temperature increase to 1.5 °C. As part of this plan, the upskilling of workers to enable a functioning GH_2 sector will be key.

A 2019 study by the Council for Scientific and Industrial Research and the Germany-based Institute for Advanced Sustainability Studies estimates that up to 1.6 million jobs can be created in South Africa through energy sector transformation by 2050. Sectoral job opportunities in the future GH_2 economy for skilled graduates are expected to range from operations, maintenance, management of PGM mining, refining and beneficiation, transportation, construction, to industrial manufacturing. A sectoral alignment with industry-specific requirements will also facilitate a just transition, where potential job losses in the traditional coal mining industry, for example, are mitigated through the upskilling, retraining and onboarding of workers in the green economy. A key aspect that would need to be developed by the government is a GH_2 jobs pipeline that will enable industry to plan and collaborate with educational institutions to create jobs and train the labour force needed for a GH_2 economy.

Future GH_2 workforce skills will not only focus on servicing a GH_2 economy but will also be flexible to service adjacent industries in a holistic manner related to climate mitigation and circular economies thereby aiding South Africa's just transition. These new skills include:

- **Green career pathways** - assessing the main opportunities for green careers in the local context, while investing in reskilling and upskilling initiatives to meet the current and future green skills gap.
- **Natural capital skills** - protecting and monitoring the earth's natural resources including environmentalists, hydrologists, and biochemists.
- **Green engineering and tech skills** - design and maintenance of solar panels, wind turbines, electrolysers, and other green technologies.
- **Green architecture and future cities planning skills** - constructing and integrating green buildings and green spaces into future cities.
- **Sustainable agriculture skills** - implementing digital solutions in agriculture such as organic farming, urban farming, and precision agriculture; all enabled through data, drone, and DNA technology.
- **Environmental justice skills** - managing the intersection of human rights and environmental rights to ensure that a just transition is possible, and diversity, equity, and inclusion forms a strong foundation for participation in the green economy for all.
- **Circular economy skills** - building processes and industries that fit into circular economy principles to support development of a green transition.
- **Operation management and system integration skills** - integrating the nodes of green economic development to be aligned and think as "one" (World Economic Forum, 2021; United Nations Industrial Development Organisation, 2021).

A holistic skills development approach should include the steps set out in the figure below:



The localisation opportunities identified across the value chain, the available local skills and green skills needed to service the GH_2 localisation opportunities are ranked in Table 6.1 according to South Africa's local capability.

All skills training should have reskilling or upskilling initiatives to build and grow local capacity; these initiatives can be incentivised through SETA funding with a long-term view to support upskilling in tertiary institutions. Government will also have to balance the need to outsource GH_2 value chain expertise to expedite GH_2 project development and local skills proliferation against local capacity building. A more detailed analysis of the potential job creation associated with the GH_2 sector is encouraged as part of the Commercialisation Roadmap. The additional interventions identified in Table 6.1 will support the uptake of green skills and green technology locally.

The identified skills action plan needs to be driven by working closely with the Department of Science and Innovation and Department of Higher Education and Training.

The Department of Science and Innovation will be critical to support the following:

- Drive innovation, R&D and skills development;
- Support commercialisation, together with dtic, of innovative products, processes and services that will reduce costs and enhance competitiveness of SA component production;
- Assist with management of patents and licences, both local and foreign;
- Co-ordinate research on critical mineral value chains and
- Research and insights into chemical value chains to support sustainability and global competitiveness

The Department of Higher Education and Training will be responsible for the following:

- Align to the identified skills and action plan in this commercialisation strategy;

- Co-create technical training courses to develop future skills requirement to support GH_2 and associated value chains;
- Focus on systems and design thinking to under-pin inter-related nature of GH_2 development;
- Co-ordinate funding and support for university-programmes;
- Support and coordinate skills development in industry;
- Bring SETA funding at industry level and
- Funding support for GH_2 PhD projects, programmes and scholarships.

Skills action plan

The creation of a hydrogen economy will require a new skill sets as well as an increase in capacity of a productive workforce. Access to adequate and appropriate skills is a key risk in the development of the GH_2 value chain, the ability to build the skills base to support the deployment of the initial GH_2 projects will create the potential for significant employment within the GH_2 value chain. Details of specific skills required and the associated action plan to source and build these skills are outlined in the skill action plan in the GHCS as shown in Figure 22.

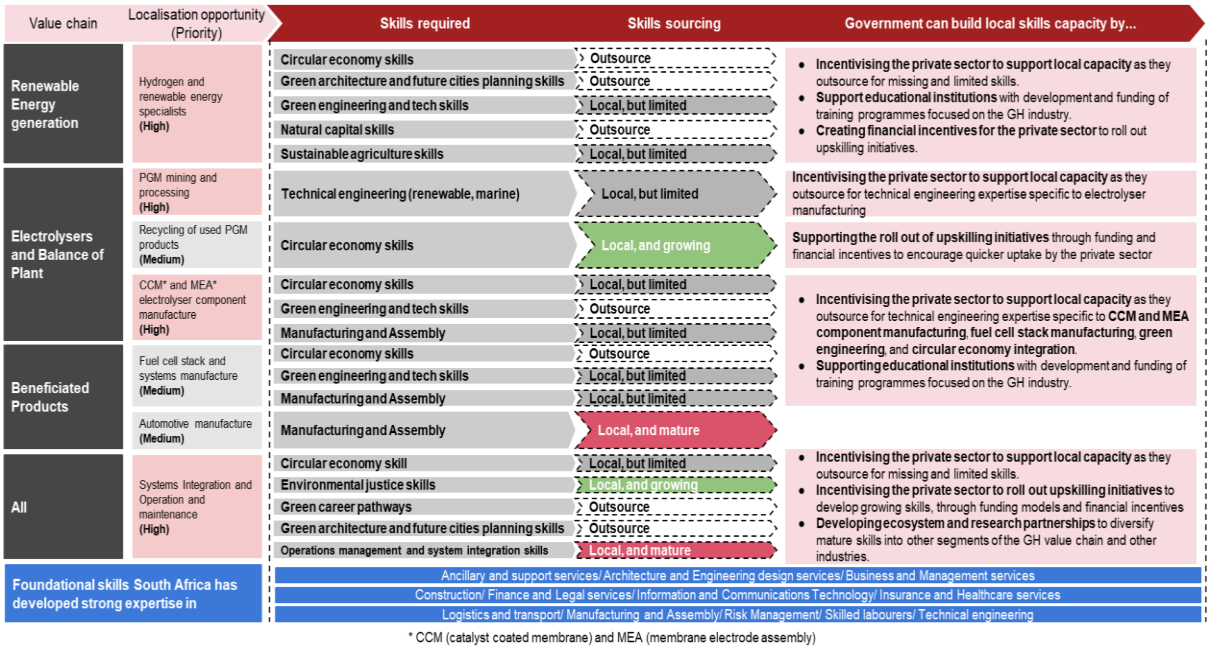


Figure 22:Skills Action Plan

10.3. Socio economic development and Just transition

Significant opportunity exists for economic development and social inclusion which should be pro-actively driven through the GHCS.

Gender equality and social inclusion

- The development of the hydrogen economy provides the opportunity to integrate gender equality at both an employee and ownership level.
- Women potential in GH_2 needs to be realized, and women need to be empowered to take leadership roles in green industries as entrepreneurs and / or industry professionals.

BBBEE including worker and community empowerment

- Opportunity to empower previously disadvantaged people by taking ownership in new businesses and by providing new job opportunities.
- Communities and workers can be empowered by shareholding in projects and by SMMEs contracting along the GH_2 value chain

Economic impact assessment

To estimate the economic impacts that will result from the implementation of the GHCS a high-level economic impact assessment (EIA) was carried out at the end of 2022. The EIA was conducted on the value chains as shown in Figure 23.

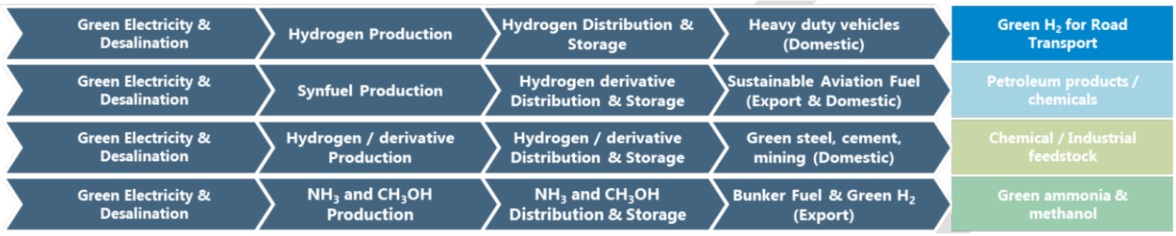


Figure 23 : EIA Value Chains

According to this assessment, implementation of the GHCS will have significant positive impacts on the economy including on GDP, investment, balance of payments, tax revenue, employment, and CO_2 emissions as depicted in Figure 24. By 2030, the GHCS is projected to increase South Africa's GDP by R188 billion and by R390 billion in 2050, by producing, using, and exporting green hydrogen. The GHCS is also expected to result in reduced CO_2 emissions and increased investment, as well as support 387 thousand jobs per annum by 2030 and 368 thousand by 2050 and generate substantial tax revenue. Although the study found the GHCS would initially lead to a negative balance of payments, it is expected to improve over time as exports increase and imports of equipment and fossil fuels decrease.

	2030	2040	2050
Gross domestic product (GDP)	R188 billion	R298 billion	R390 billion
Jobs Supported	387 774	423 090	367 912
Accumulated CO2 emissions reduction	67 mt	225 mt	493 mt
Fixed Investment	R 730 billion	R 1.4 trillion	R2 trillion
Tax Revenue	R29 billion	R34 billion	R32 billion
Balance of Payments	(R26 billion)	R18 billion	R64 billion
Green H_2 volumes	1,6 mt GH_2	3 mt GH_2	4 mt GH_2

Figure 24: High level estimation of the socio-economic benefits of the GHCS

10.4. Providing a clear and focused regulatory environment

Clear and stable regulation pertaining to hydrogen is essential in order to deliver certainty to developers and investors so projects and applications can be implemented with reduced risk. A clear and supporting regulatory framework that supports hydrogen development in South Africa will also foster investor confidence and financing, reducing the support burden on the government, particularly in the current restricted fiscal context.

Currently, South Africa's current regulatory framework does not meaningfully support the development of a national-level green hydrogen industry. Given the potential scale and scope for a fully developed hydrogen economy in South Africa, it will be a significant body of work to develop a regulatory framework that:

a) Defines what constitutes a green hydrogen projects across the value chain to provide regulatory clarity to current and potential investors into South African GH2 projects. This would also involve what is defined by the term "green"13 in GH2.
b) Clarifies the classification of hydrogen as a gas or energy source for the purpose of regulation, and the implication of the chosen classification.
c) Provides regulatory clarity around permits, licenses and assessments required for construction, connection to electricity grids, operating licenses and similar aspects.
d) Provides regulatory clarity and approaches to the compression, storage and transport of GH2 and beneficiated products such as green ammonia
e) Considers and addresses the many areas of law and policy that a fully developed GH2 economy may potentially affect and the potential amendments that will be required.
f) Considers the incorporation of global best practice14 regulatory approaches in countries ahead of South Africa to avoid reinventing the wheel, but also adapts regulatory approaches to the South African context.
g) Ensures the safety of the community and industry at all times.
h) Aligns, and is supported by South Africa's existing energy planning policies such as the Integrated Resource Plan (IRP) and Integrated Energy Plan (IEP)
i) Synchronises with South Africa's decarbonisation and just transition ambitions, through NDC contributions, mitigation pathways and JT policies.
j) Removes investment barriers and supports the investment in South Africa's GH2 economy.
k) Contemplates and allows for the breadth and complexity of the activities that a GH2 industry will undertake.
l) Is flexible and responsive to the dynamic nature of GH2 developments as they evolve from a technology, techno-economic, policy, regulatory, finance and investment perspective.
m) Based on these regulatory ideals, the purpose of this section is to:
n) Provide a summary of the current law and policy potentially relevant to the development of a GH industry in South Africa.
o) Provide initial recommendations on regulatory incentives that could be introduced to support the development of the hydrogen economy in South Africa.
p) To summarise the next steps to develop the law and policy required to facilitate a GH_2 industry in South Africa.

[13] This could quantify the CO_2 emissions of the process or set a cap on CO_2 emissions in the definition. Further, the approach could also look at whether to consider the life cycle emissions of production in the definition.
[14] Here reference is made, for example, to the recently released "Rules for renewable hydrogen" set out by the European Commission

10.5. South Africa's existing regulatory framework

South Africa does not currently have an explicit regulatory framework related to the development of a hydrogen economy.. Thus far, pilot projects have been implemented within the confines of South Africa's existing regulatory frameworks. In order for hydrogen to play a role in South Africa's energy transition, the hydrogen value chain would have to operate within three broad spheres of law, including Energy and Infrastructure, Environmental regulation, and Health and Safety provisions.[15] The integration across these areas is critical to support the development of a robust and coherent policy and regulatory framework including the masterplans currently under development by the Department of Trade, Industry and Competition, and the Public Private Growth Initiative.

From a regulatory perspective the adoption of a unified definition of green hydrogen for the purposes of regulatory clarity and the classification of green hydrogen as a gas or energy source is important. These definitions and classifications will provide certainty to project developers and investors and will have implications for succeeding regulations, standards and certification.

10.5.1. Energy law and policy

The hydrogen industry will need to access new and existing energy infrastructure - including electricity networks, gas networks, ports, roads and rail. Currently, South Africa's energy laws do not explicitly address the production of GH_2 but can be argued to implicitly support the uptake of GH_2 when considering certain sustainability provisions found in South Africa's primary energy law and policy.

The Department of Mineral Resources and Energy has indicated that under current legislation, renewable energy deployment related to GH_2 production will be exempted from both electricity policy planning (IRP) and regulation (licensing) as long as it is "islanded" from the grid. To date, no formal notice has been published in this regard. This will have an impact on GH_2 production economics in that there is a typical overbuild of wind and solar to ensure that optimal electrolyser load factors are achieved. Unless an alternative economic use for the excess renewable energy production can be found, plants will need to be curtailed during certain hours of the day. As indicated in Section 1, excess energy can be redirected to the grid to provide generation supply, however the regulatory complexities around this will have to be managed and planned for. The current approach from the DMRE precludes GH2 projects from feeding excess electricity back into the grid to support additional electricity supply.

Table 4. Energy law and policy relevant to GH

Law/Policy	Relevance to GH development
National Energy Act 34 of 2008	The National Energy Act is South Africa's overarching piece of legislation for the energy sector. Section 5 of the National Energy Act imposes a duty on the Minister of Energy to promote access to affordable, sustainable, and environmentally suitable energy and energy services to all people.

[15] This report has focussed on core energy and environmental laws in relation to GH. There are additional policies such as the Green Transport Strategy 2018 and the National Transport Master Plan 2016 that also implicitly support the uptake of GH.

Law/Policy	Relevance to GH development
	The Act requires the Minister in consultation with the Minister of Trade and Industry, the Minister of Labour and the Minister of Environmental Affairs, to *"adopt measures not contemplated in any other legislation, to minimise the negative safety, health and environmental impacts of energy carriers."* Section 19(1) of the National Energy Act provides a legal mechanism to introduce a set of regulations specifically aimed at regulating GH: *"The Minister may, after consultation with those Cabinet Ministers whose areas of responsibility will be affected by the proposed regulations, without derogating from his or her general regulatory powers, by notice in the Gazette **made regulations** regarding…* *(d) minimum contributions to national energy supply from renewable energy sources.* *(e) the nature of the sources that may be used for renewable energy contributions to the national energy supply.* *(f) measures and incentives designed to promote the production, consumption, investment, research and development of renewable energy;"* Considering the provisions above and the opportunities that GH presents, the government could consider introducing a set of regulations specifically aimed at promoting South Africa's GH economy. To date, government has not made use of these provisions and regulations to this effect have not been published.
Electricity Regulation Act 4 of 2006	Although the promotion of renewable energy and hydrogen is not explicitly mentioned in the objects of the Act, there are implicit references that can support the argument for increased renewables in the country's energy mix. This is evident when considering the references to sustainability and the acknowledgement that the interests of future electricity customers must be considered.
Integrated Resources Plan of 2019	The IRP does not currently provide renewable energy capacity specifically allocated for the development of GH_2. As the demand for GH_2 grows, the IRP must be reviewed and updated in order to allocate specific renewable energy to electrolysers located in GH_2 hubs.
Integrated Energy Plan 2016	The IEP aims to guide future energy infrastructure investments, identify and recommend policy development to shape the future energy landscape of the country. The National Energy Act requires the IEP to have a planning horizon of no less than 20 years – the last adopted version was in 2003 with a revision in 2016 that commenced however was not completed. It is an overarching plan that informs the development of future energy sector roadmaps, i.e., for security of supply (liquid fuels and

Law/Policy	Relevance to GH development
	electricity) and for diversity of supply (coal, gas and renewable energy. Eight key objectives were identified: ensure the security of supply, minimise the cost of energy, increase access to energy, diversify supply sources and primary sources of energy, minimise emissions from the energy sector, promote energy efficiency in the economy, promote localisation and technology transfer and the creation of jobs and promote the conservation of water. Hydrogen is mentioned in the existing version within the context of an alternative energy source and as an energy carrier "*The hydrogen economy is undergoing serious consideration in South Africa, in an effort to develop safe, clean and reliable alternative energy sources to fossil fuels."* The revision of the IEP remains outstanding and updating to capture the evolving energy policy landscape is required.

10.5.2. Environmental law and policy

Stringent air and water pollution control laws can determine the cost-effectiveness of using renewable sources of energy over fossil fuels. Similarly, land use planning and Environmental Impact Assessment laws can demonstrate the sustainability of wind and solar energy. However, the environmental regime in South Africa beginning with the environmental right in section 24 of the Constitutional to sector legislation is an underutilised driver of renewable energy and more specifically, GH. The table below outlines how South Africa's environmental laws can implicitly be applied to support the uptake of GH in South Africa.

Table 5. Environmental law and policy relevant to GH

Law/Policy	Relevance to GH development
National Environmental Management Act 107 of 1998	The principle of environmental management in section 2 of the NEMA has the potential, not only to discourage the use of fossil fuels, but crucially to promote renewable energy and the development of the GH industry. NEMA promotes and provides a normative framework that points towards a sustainable energy system in South Africa. This is evident when considering the sustainable development provisions set out in Section 2(4) of the Act that provide that: *"(v) that the use and exploitation of non-renewable natural resources is responsible and equitable and considers the consequences of the depletion of the resource.* *(vi) that the development, use and exploitation of renewable resources and the ecosystems of which they are part do not exceed the level beyond which their integrity is jeopardised."*
Draft Climate Change Bill	South Africa's Draft Climate Change Bill makes no reference to the phase out of fossil fuels or the decarbonisation of South Africa's energy sector. However, as part of the sectoral

	emissions target mechanism outlined in the Bill, GH could be introduced as a mitigation measure to achieve the sectoral emissions target that would have to be set by the Minister of Mineral Resources and Energy.
Environmental Impact Assessment Regulations, 2014	An area of planning that best illustrates how environmental planning can be used to promote the necessary renewable energy infrastructure for the production of GH is the EIA Regulations. As far as energy activities are concerned, the major issues have been the dilatory impact of the EIA process on energy projects.
Mineral and Petroleum Resources Development Act, 28 of 2002 (MPRDA)	The MPRDA is among the environmental legislation contemplated by s 24(b) of the Constitution of South Africa – to the extent that it is aimed at promoting sustainable development in the mining industry. Although not directly linked to the development of the hydrogen economy, the sustainable development provisions provided for in the act will be a key implicit driver to utilize South Africa's PGM resources.

In order to develop synergies between green hydrogen development and the JT, and to ensure that all protocols are followed, it is vital that public participation elements imbibed in the above legislation are prioritised such that the participatory justice[16] elements of the JT are supported when authorisations, approvals, permits or licences are granted. This includes adequately addressing the concerns of interested or impacted parties when embarking on green hydrogen projects across the value chain.

10.5.3. Health and Safety law and policy

Particular attention and priority should be given to develop technical safety standards in respect of hydrogen and the hydrogen industry - with a likely focus initially on interactions with the gas network and key gas industry stakeholders, hydrogen safety requirements related to storage, handling and transport, and adoption of hydrogen fuel cell technology (heavy vehicles and stationary applications).

By prioritising and developing technical standards in advance of regulatory responses being developed, the technical standards can be 'built into' law and policy in respect of the hydrogen industry. This will mean that safety compliance requirements will be consistent across the industry improving investor confidence in South Africa's ability to produce and trade with GH_2 in a safe manner.

With respect to the development of standards for GH in South Africa, in February 2023, the SABS established a local steering committee for hydrogen technologies with the aim of establishing relevant standards for the hydrogen industry. Given the breadth of the GH_2 value chain, a number of standards will have to be evaluated. The steering committee aims to prioritise the specific standards required taking guidance from key policy documents including the GHCS and Hydrogen Society Roadmap. Technical working committees are being set up currently to develop specific standards. It is envisaged that the initial focus will be on developing a green hydrogen standard for South Africa and focus on safety standards as a matter of urgency.

[16] Participatory justice, in terms of the Just Transition refers to the direct participation of impacted groups in the decision-making process itself and is a common and pivotal theme in the Just Transition approach.

10.6. Regulatory incentives

GH_2 faces barriers that prevent its full contribution to South Africa's energy transformation. Amongst others, barriers include those that apply to all shades of hydrogen, such as the lack of dedicated infrastructure, high production costs, energy losses, and credibility of the origin of GH_2. Although initial GH_2 initiatives are likely to be private sector driven, scenarios will be modelled to identify the economic, social and environmental impact of the GH_2 value chain development. These scenarios could then inform the potential for regulatory incentives in order to address these barriers and support the development of South Africa's domestic and export markets for GH_2. Some of the potential incentives have been outlined below.[17]

10.6.1. Domestic market incentives

Carbon pricing is a useful tool to guide investment decisions, especially those that will have long-term impacts on future emissions and can complement stimulus packages focusing on the increased uptake of GH_2. A progressively increasing carbon price alongside stimulus packages provided by the government will provide essential confidence for investment in long-lived, low-carbon infrastructure and research, development and demonstration of GH_2 technologies. Carbon pricing mechanisms coupled with effective revenue recycling mechanisms that support investment in clean energy options will be a key enabler to drive GH production forward.

10.6.1.1. Carbon pricing

Many countries have included carbon pricing mechanisms as key strategic drivers in their respective GH_2 strategies. These policies are aimed at equalising the cost competitiveness of GH_2 in comparison with fossil fuel-based sources. In many cases, countries have introduced either explicit carbon pricing mechanisms such as emission trading schemes or carbon taxes or have introduced implicit carbon pricing mechanisms such as fuel subsidy removals. In some cases, countries have implemented both explicit as well as implicit measures. The application of these mechanisms within the South African context are discussed below.

Explicit carbon pricing mechanisms:

GH_2 will bring major GHG emission reductions when used to replace fossil fuels for many ends uses. Reflecting environmental and climate costs in energy prices will be critical in order to support the uptake of GH_2. By increasing the costs associated with the externalities of GHG emissions, energy generators and consumers will be required to pivot to low-carbon energy sources such as GH in order to remain competitive.

In South Africa, the government introduced the Carbon Tax Act (Act 15 of 2019) as South Africa's primary explicit carbon pricing mechanism. An initial headline tax rate of R120 per ton carbon dioxide equivalent (CO_2e) was introduced in 2019, however, various tax-free allowances result in an effective tax rate that varies between R6.00 (US$0.4) and R48.00 (US$4.22) per ton of CO_2e. The World Bank reported that carbon prices of at least US$40–80/tCO2 by 2020 and US$50–100/tCO2 by 2030 are required to cost-effectively reduce emissions in line with the temperature goals of the Paris Agreement.[18] Based on the

[17] The regulatory discussion is not aimed at outlining a comprehensive regulatory framework for South Africa, but rather outlines high-level regulatory support mechanisms that can support South Africa's GH economy. Here, innovative and alternate approaches for GH development may also be considered. For example, the book and claim system can be used both domestically and internationally as a carbon offset mechanism to channel investments towards GH2 projects.
[18] World Bank. "State and Trends of Carbon Pricing 2020" (May), *World Bank, Washington, DC. Doi: 10.1596/978-1-4648-1586-7*.

aforementioned rates, it is evident that South Africa's carbon tax rate is significantly lower compared to the carbon price required to reach the climate change commitment target set out in the Paris Agreement. Although the government introduced the carbon tax at a low rate in order to maintain South Africa's competitiveness, based on international developments, the government would need to increase South Africa's carbon tax rate in order to signal its decarbonisation efforts to investors. An increased carbon tax rate will however only be viable if appropriate carbon tax revenue recycling mechanisms are put in place in order to foster investor confidence in the government's ability to inject carbon tax revenue back into the GH value chain.

When considering the mobility sector, the carbon tax associated with the use of petrol and diesel is currently charged in terms of Schedule 1 of the Customs and Excise Act. The carbon fuel levy associated with the use of petrol is currently set at 8 cents per litre and 9 cents per litre for diesel. Possible mechanisms to discourage the use of the aforementioned products will be to increase the carbon fuel levies of these fuel sources and stipulate that the use of GH will have a carbon fuel levy of nil, as is the case with biodiesel.

Although South Africa has implemented the Carbon Tax, the increase of carbon tax rates specifically aimed at developing the GH_2 sector, or the removal of fuel subsidies may have detrimental effects on the economy and socio-economic circumstances. As such, the implementation of more stringent carbon pricing mechanisms must be carefully considered and subject to an extensive socio-economic and economic impact analysis.

Implicit carbon pricing mechanisms:

Apart from explicit carbon pricing mechanisms, such as the carbon tax mentioned above, implicit forms of carbon pricing can also be considered by the South African government in order to support the development of the GH_2 economy. Fossil fuel subsidies are responsible for various fiscal, social and environmental problems. These problems include harmful impacts on energy markets and greater fiscal burdens on governments, as well as environmental impacts. Once fossil-fuel support measures have been identified and quantified as much as possible, measures for reform need to be prioritised.[19] Fossil fuel subsidy reform will help policy makers to close the economic gap with GH_2, while reducing market distortions and making the real price of fossil fuels clearer.

In a recent report published by the International Institute for Sustainable Development (IISD), South Africa was ranked as the second worst performer of the G20 non-OECD member countries, behind Saudi Arabia, for its lack of transparency and continued support for fossil production through fossil fuel subsidies.[20] However, the scale and allocation of fossil fuel subsidies in South Africa is not well known and as such, it is difficult to recommend where fossil fuel subsidies can be removed in order to implicitly support the uptake of GH_2. The transition to a low-carbon, climate resilient economy that is sustainable and inclusive means altering the structure of the economy and the flows of support that maintain the carbon intensive, energy intensive economy that we have today. Current fossil fuel subsidies therefore need to be assessed within the aforementioned context and redirected towards supporting the GH_2 economy in South Africa, subject to the relevant economic and socio-economic impact assessments being done. Within the South African context, energy subsidies should be used

[19] Little is known on fossil fuel subsidies in South Africa, and extensive research would need to be undertaken to establish to what extent fossil fuel subsidies exist and whether they can be reformed to support the GH sector.

[20] The report stated that South Africa spends R93-billion a year on direct support for fossil fuel use through subsidies to its predominantly coal-based electricity system - see IISD, Doubling Back and Doubling down: G20 scorecard on fossil fuel funding (November 2020).

to assist energy-vulnerable populations to access low carbon energy sources and to guarantee competitiveness of companies that aim to introduce low carbon energy solutions.

10.6.1.2. Tax incentives

The cost of GH_2 production could be lowered by reducing the taxes and fees within the GH_2 value chain. Lowering corporate, business and sales taxes on GH_2 could also improve revenues and the rate of return on projects. The introduction of clean energy tax incentives has historically been provided for in section 12 of the Income Tax Act and has resulted in increased renewable energy uptake and numerous energy efficiency measures. The regulatory measures provided for in the Income Tax Act and their possible application to the GH_2 sector are set out in the table below:

Table 6. Income Tax Act incentives relevant to GH

Description	Details	Section	Application to GH
Accelerated depreciation allowance (RE)	In respect of assets brought into use for the first time and solely for the production of renewable electricity. The allowance is based on the cost of the assets and 50%, 30% and 20% is granted in each of the first three years of use, respectively.	12B(1)(h)	Can be amended to also include assets brought in for the production of GH.
Energy savings allowance (EE)	National allowance for taxpayers that carry on a trade and that implement EE projects that successfully achieve energy savings. The allowance is calculated as 95 cents per kilowatt hour (kWh), or equivalent, of energy savings achieved during the year of assessment, made against a baseline measured at the beginning of the year. Independent, registered and accredited professionals need to measure and verify the value of the energy savings and the allowance is not granted if a concurrent EE savings benefit is received from government or a semi-government agency	12L	Applying similar provisions to Hydrogen would be difficult given the fact that hydrogen consumption is not considered an energy efficiency project.
Industrial policy project (IPP) allowance (EE)	Industrial policy projects that use improved EE and cleaner production technology, inter alia, are entitled to an allowance of 35% – 100% of the cost of new and unused manufacturing assets used in the project.	12I	GH projects could be classified as Industrial policy projects in order to receive the additional investment and training allowance set out in section 12I

Description	Details	Section	Application to GH
Exemption of proceeds (RE/EE)	When certified emission reductions from approved clean development mechanism (CDM) projects, registered before 31 December 2020, are disposed of, the proceeds are exempt. CDM projects could include RE or EE projects.[21]	12K	Similar provisions can be reintroduced for GOs in order to incentivise the trading of GH.
R&D allowance (RE/EE)	A 150% allowance in respect of expenditure incurred directly and solely on approved R&D activities undertaken in South Africa. The expenditure must be incurred in the production of income, in carrying on any trade. The allowance also extends to pre-trade expenditure incurred in respect of approved R&D activities.	11D; 11A	In order to encourage pilot projects, sections 11D and 11A could be extended to include GH R&D.
Accelerated depreciation allowance for R&D (RE/EE)	In respect of new and unused R&D machinery or a plant brought into use for the first time. The allowance is based on the cost of the assets and 50%, 30% and 20% is granted in each of the first three years of use, respectively.	12C(1)(gA)	Such provisions could apply to existing assets to be retrofitted for GH storage.
Depreciation allowance for R&D buildings (RE/EE)	The cost of a building used for R&D is allowed in equal portions over a period of 20 years	13(1)(b)	These provisions could apply to buildings that would be needed as part of R&D GH projects.

10.6.1.3. Import duties

As discussed in previous sections, the costs of manufacturing electrolysers in South Africa are significantly more when compared to the manufacturing costs that other countries have achieved. In order for GH_2 to be a viable option, GH_2 production companies would need to import electrolyser equipment in order to produce GH_2 at a cost competitive rate. However, customs duties (import duties) are imposed in terms of the Customs and Excise Act 91 of 1964 on imported goods and technologies. They are levied on imported goods with the aim of raising revenue and protecting the local market.

In order to reduce the costs associated with the production of GH_2, the opportunity for consideration to reduce or exempt the import duties and VAT which will be payable on imported GH_2 technologies is accommodated within terms of the Customs and Excise Act. For example, a reduction or rebate of import duties can be applied to the importation of electrolysers. In such a case, importers of GH manufacturing equipment would be required to

[21] With the introduction of the Carbon Tax Act 15 of 2019, this provision was repealed.

apply to the International Trade Administration Commission of South Africa (ITAC) for a certificate that qualifies them to import without being subject to burdensome import duties.

10.6.1.4. Permitting, licencing and authorisation

Stakeholders involved in the development of South Africa's GH_2 economy have repeatedly highlighted the fact that South Africa's licencing and authorisation processes are too timeous and delays the implementation of projects. Renewable energy companies have reported difficulties with land use and rezoning approvals among a host of other authorisations. This multi-approval process for development remains fragmented in the energy planning sector and is one of the barriers to expeditious approval of renewable energy projects needed for the production of GH_2. The problem is also compounded by the existence of provincial planning laws that may not always speak to national planning, environmental and energy legislation.

Some of the licenses and authorisations that would be applicable to GH_2 includes water use licenses, environmental authorisations comprising various impact assessments in terms of the Environmental Impact Assessment Regulations, as well as electricity generation licenses. The Department of Forestry, Fisheries and Environment, amended NEMA in 2019 to allow for Strategic Environmental Assessments (SEA) within defined Renewable Energy Development Zones (REDZs), which are intended to expedite environmental permissions. Assessment of other activities related to the deployment of GH project which could be excluded under NEMA should be considered.

The applicable authorizations are managed by different entities including the Department of Forestry Fisheries and Environment, NERSA, and the Department of Mineral Resources and Energy. In order to expedite the authorisation and licensing processes, the need exists to introduce a single "one-stop" mechanism to facilitate all the licensing and authorisation processes required as part of implementing a GH project. This would enable South Africa to move fast and take advantage of the opportunities that the hydrogen economy presents within a timely fashion.

10.6.1.5. Standards for the GH_2 mobility sector

GH_2 has been recognized as an alternative fuel for the mobility sector in the EU. In South Africa, hydrogen powered vehicles, in particular buses and heavy-duty vehicles, might play a significant role in climate change mitigation within the transport sector and the development of the GH_2 economy. Due to the lack of economies of scale and the dominance of electric vehicles in South Africa, Fuel Cell Electric Vehicles (FCEVs) are not a viable option for South Africa in the near future. In addition to the high purchase price, the lacking GH_2 refuelling infrastructure can be regarded as one the main economic barriers for the deployment of the fuel cell vehicles.

In order to accelerate the market penetration of heavy-duty fuel cell vehicles, a supportive national framework and financial incentives are needed. Various financial and non-financial incentives from direct purchase grants to tax and registration fee exemptions and zero VAT can push the deployment of these vehicles. The implementation of zero-emission vehicles targets could also create the initial demand for GH_2 refuelling stations which are pre-conditions for making heavy duty fuel cell vehicles a viable option for mining and logistics companies.

To help local officials deal with proposals for GH_2 fuelling stations, GH_2 codes and standards would need to be developed. The applicant looking to build a GH refuelling station should show compliance with all requirements set out in the standards. The standards should at a minimum, outline the following:

- General Fire Safety Requirements
- General Storage requirements
- GH dispensing technology requirements

- Hydrogen Fuel Quality standards for Fuel Cell Vehicles

In order to develop the above-mentioned standards, the following international standards can be used to inform the design of the standards:

- ISO 19880-1:2020 - Gaseous hydrogen
- SAE International standards (SAE J2601/2, "Fuelling Protocol for Gaseous Hydrogen Powered Heavy Duty Vehicles," and SAE-J2601, "Fuelling Protocols for Light Duty Gaseous)

10.6.2. Export market incentives

10.6.2.1. Special Economic Zone incentives

As highlighted in the sections above, the development and location of GH_2 SEZs will be a key enabler to support South Africa's GH economy. The regulatory basis for the development of SEZs is the Special Economic Zones Act 16 of 2014. In terms of section 21(1) of the Act the Minister of Trade and Industry may determine and implement support measures, including incentive schemes, for operators and businesses operating within Special Economic Zones. This provision can be used as a basis to provide tailored support mechanisms for GH SEZs. Some of the key incentive mechanisms that have been introduced include the following:

- The main tax benefit available to a qualifying company within a special economic zone is the reduced corporate tax rate from 28% (the standard corporate tax rate) to 15%.[22]
- Qualifying businesses operating within SEZs are also eligible for an accelerated depreciation allowance of 10% for buildings.
- VAT and Customs Relief – Businesses within customer-controlled areas will qualify for VAT and customs relief.
- Employment Tax Incentive – Employers that hire low-salaried staff (below R60 000 per annum) in any SEZ will be entitled to this incentive.

New as well as existing incentive mechanisms outlined above can be introduced in GH_2 SEZs or applied to REDZs. Ultimately, the Act aims to boost private investment (domestic and foreign) in labour-intensive areas in order to stimulate job creation, competitiveness, skills and technology transfer as well as increasing exports of beneficiated products. The provisions of the Act therefore also act as a basis to support South Africa's just transition.

10.6.2.2. Guarantees of Origin (GO)

As a response to the global commitment to reduce emissions in accordance with the Paris Agreement, many countries have introduced regulatory measures which encourage the increased uptake of renewable energy technologies by means of Guarantees of Origin (GO) systems. Where these systems have been properly implemented and enforced, they have been known to create a market for the environmental attributes associated with the renewable energy technologies and have resulted in increased renewable energy penetration rates. One way to prove the renewable origin of GH_2 is by means of a GO system, creating a credit-based chain of custody that provides hydrogen consumers with certainty pertaining to the green nature of the hydrogen.

[22] The Taxation Laws Amendment Act 23 of 2020 extended the tax incentives provided to SEZs until 31 December 2030.

The use of GOs was introduced in regional EU policy in the form of the EU Renewable Energy Directive. The Renewable Energy Directive mandates levels of renewable energy use within the European Union.[23]

The European Parliament recently proposed amendments to the Directive specifically aimed at improving the certification system associated with low-carbon fuels such as GH_2 and proposed that in order to strengthen the guarantees of origin system in the EU, certification of low-carbon fuels should be addressed in a separate legislative proposal such as the Hydrogen and Decarbonised Gas Market Package. This is an important development and signals the fact that guarantees of origin associated with hydrogen should potentially be handled separately from GOs emanating from renewable energy generation only.

However, certain requirements would have to be met in order for such a system to be functional. Some of these principles include the following:

- **Traceability** - The listing and retirement system should allow the environmental attribute to be tracked from the point of production to the point of consumption. One of the main criticisms of a credit-based chain of custody system is that it disassociates the GOs claim from the physical product. This means that an electricity producer using fossil fuels can still purchase GOs and then claim that the energy they sell is renewable. For example, a plant producing hydrogen from fossil fuel (grey hydrogen) can purchase GOs from a site of GH_2 production that uses solar panels, and on this basis claim that the energy produced is renewable. This problem could be solved if GOs associated with hydrogen were only to be traded within a specific closed system and linked to specific GH_2 offtake agreements.
- **Tradability** - GOs should comply with internationally recognised standards in order to be tradeable in the jurisdictional area it was built for, creating a liquid market whereby the environmental attributes of the GH_2 can be traded as part of the GH_2 itself.
- **Transparency** - GOs should accurately demonstrate to final customers the renewable energy sources linked to the GH_2. The system needs to avoid false or misleading claims and ensure that additionality is proven. For instance, limiting GH_2 GOs to generation capacity specifically allocated for GH production and to plants that do not form part of existing grid connected systems such as REIPPP.
- **Trustworthiness** - Once the above principles are implemented, final consumers will actively use GOs as a market instrument building GH_2 consumption and decarbonising economic activities.

GO schemes should be designed to allow the international trading of GH_2, helping to create a global market. Criteria to be considered in certification design:

- CO_2 threshold limit to be considered green,
- Technology agnostic or specify,
- End use sectors – all or specific applications (could impact the baseline reference)

[23] Article 55 of the Directive states that: “Guarantees have the sole function of showing to a final customer that a given share or quantity of energy was produced from renewable sources. A guarantee of origin can be transferred, independently of the energy to which it relates, from one holder to another. However, with a view to ensuring that a unit of renewable energy is disclosed to a customer only once, double counting and double disclosure of guarantees of origin should be avoided. Energy from renewable sources in relation to which the accompanying guarantee of origin has been sold separately by the producer should not be disclosed or sold to the final customer as energy from renewable sources. It is important to distinguish between green certificates used for support schemes and guarantees of origin.”

In South Africa, the concept of trading with GOs (known as Renewable Energy Certificates/RECs) has been introduced but is still in its nascent phase of development. zaRECs (Pty) Ltd administers the REC market in South Africa in accordance with the principles of the European Energy Certificate System (EECS) on behalf of members of the REC South Africa market participant's association (RECSA). The system in South Africa is therefore similar to that of other REC systems as the system follows international protocol but has only been implemented on a small voluntary scale to date. The system is also limited to guaranteeing renewable power generation and does not extend to the GH value chain.

In order for South Africa's GH export market to be competitive, the country would have to ensure that a GO System aligns with what import countries, such as Germany requires from a GO system. The system would also need to comply with the requirements of the EECS (European Energy Certificate System) in order to satisfy European GH investors. The EECS (European Energy Certificate System) is a standardization system for the European GOs. Aligning a possible South African GH GO system with the requirements of foreign registry systems will ensure that South Africa is able to compete in the export market.

10.6.2.3. The importance of international cooperation

The state has an important role to play in bilateral engagements with key trade partners and potential consumers of South African GH2 and beneficiated products. Here, government can play a strong role in negotiating win-win intergovernmental agreements to ensure market access for South Africa's green hydrogen product and derivatives in the global sphere, especially during the establishment of this nascent industry. Strong partnerships and flows of support between countries has certainly supported the development of GH2 industries. Australia, for example, has already established strong ties with Japan for the trade of hydrogen and future trade of GH2 and GH2 beneficiated products with funding support from Japan.

The government should identify trade partners for the GH2 economy and strategically understand what is required from these markets for market entry. An understanding of the standards and criteria used to assess imported hydrogen into these markets will allow South Africa to orients its own regulatory framework towards global best practice. For example, the Government can drive international advocacy on topics such as carbon accounting to ensure that South African GH2 products meet green certification standards while the GH2 value chain is being developed.

Another opportunity arises with existing regional and bilateral agreements that are close to review. These reviews provide an opportunity to enhance the trade of sustainable goods, with a particular focus on sustainable energy products to enhance demand for GH_2 and GH_2 beneficiated products.

Further, beyond just the GH2 value chain, the state should engage closely with key trade partners that are embarking on trade barriers that penalise carbon-intensive economies. The Carbon Border Adjustment Mechanism (CBAM) in the EU, for example, sets to penalise high carbon exporters, of which South Africa is a case. Here government advocacy and intergovernmental support can aid South Africa to maintain the competitiveness of its exports as it transitions production methods towards a lower carbon format.

These efforts will require a strong and concerted effort across multiple dimensions. A local and government champion to drive these engagements and development should be formed and can leverage the existing structures that exist with the Green Hydrogen Panel. Parallels can be drawn with the IPP Office and the role that that entity has in the REIPPP. Clear mandates and authority should be granted to such an entity or institution that aligns all stakeholders and is formally established.

10.6.3. Summary of key regulatory recommendations:

1. **Prepare a Regulatory Development Timeline:**
    - **a.** The timeline must, where practicable and relevant, detail the timing of the review of the relevant law and/or including the expected date for the promulgation of new law and policy based on actions outlined in the commercialisation roadmap.
    - **b.** Outline timed regulatory responses for the hydrogen industry in alignment with anticipated technological and commercial developments.
2. **Develop regulatory objectives for how the GH industry should be regulated.**
    - **a.** Agreeing on regulatory objectives would simplify coordination of regulatory responses across government departments given the overarching objective would be consistently across all sectors and departments.
    - **b.** A key element in this regard would be to ensure that integrated stakeholder management and advocacy processes are in place in order to align public and private sector opinions and inputs.
    - **c.** Conduct feasibility studies to establish the financial impact of possible GH regulatory incentives.
3. **Develop a set of regulations specifically aimed at creating enabling environment for GH**
    - **a.** Utilise section 19(1) of the National Energy Act to introduce regulations that regulate and support South Africa's GH economy and includes measures and incentives designed to promote the production, consumption, investment, research and development of GH.
    - **b.** Consider other existing laws and policies that could support the uptake of GH.
    - **c.** Develop GH standards and specifications related to production, storage, transportation and end-use applications based on international standards and best practice.
4. **Introduce regulatory measures to support South Africa's GH export market**
    - **a.** Introduce measures for SEZs to produce and export hydrogen at a cost competitive price.
    - **b.** Design and introduce a GO system to install investor confidence in key import nodes.
5. **Introduce regulatory measures to support South Africa's domestic GH market**
    - **a.** Introduce explicit and implicit carbon pricing mechanisms coupled with GH revenue recycling mechanisms
    - **b.** Build on existing regulatory tax incentives to support the GH value chain.
    - **c.** Introduce a single institutional body to expedite licensing processes and facilitate the development of the GH sector.
    - **d.** Introduce standards and codes to develop South Africa's GH mobility sector, including emission reduction targets in the transport sector and GH refuelling station standards.

10.7. Securing availability and low-cost finance

Although there is a movement amongst financiers globally away from funding carbon-based projects in favour of greener initiatives, given the size and complexity of the value chain and the anticipated scale of the GH economy in South Africa, financing GH projects will still require innovative financing structures sourced from multiple stakeholders. Ensuring that the financing landscape incentivises investment both from local and international sources is also critical.

The broad principles of traditional project finance are likely to still be applied, necessitating collaboration by government, international development finance institutions, multilateral financing agencies, local commercial lenders and private sector investors. Given the anticipated involvement of international OEMs, export credit agencies are another key stakeholder group in the funding universe. In addition to national government funding, it will be necessary for strong relationships to be developed with the governments of developed countries who have programmes in place to support developing countries in their climate change pursuits.

Globally, various forms of funding mechanisms are being applied to enhance the financing landscape, including:

a) direct public funding.
b) public-private partnerships.
c) leveraging funding from developed markets specifically set aside to support the green transition in developing/carbon intensive countries.
d) leveraging funding from export credit agencies.
e) green/project bond financing; and
f) blended finance mechanisms.

The above forms of funding, together with more traditional project financing approaches, can be categorised into three broad categories, as follows:

a) Government on-balance sheet finance.
b) Private finance; and
c) Development finance.

10.7.1. Government on-balance sheet finance

Direct public funding

Direct public funding includes an allocation of taxation revenue, budget surplus', borrowings globally etc. as a means of supplementing the financing requirements for a project to reduce the overall cost of financing. Some examples internationally include:

a) Asian and European governments have pledged direct public funding to 2030 for development of national hydrogen industries and economy.
b) Japan has committed some $1.5 billion to support zero-emission hydrogen production locally and overseas and to develop distribution infrastructure.
c) France plans to invest €7 billion by 2030 targeting industrial decarbonization, heavy duty transport, and R&D.
d) Germany has adopted a "package for the future" with €7 billion to speed up the market rollout of hydrogen technologies nationally, complemented by €2 billion to foster international partnerships.
e) the UK government is providing funding worth $238 million to support engineering and design studies for net-zero hubs, including blue and GH infrastructure projects, as part of their carbon removal strategy.

Globally, funds are also being directed from existing budgets to support energy transitions or innovation. For instance, the EU is using its Important Projects of Common European Interest (IPCEIs) support mechanism for R&D projects involving more than one Member State. Some national strategies are also including hydrogen within their post-COVID recovery plans to secure extra funds.

Green/project bond financing

Financing instruments linked to green initiatives have become more and more popular in recent years as the world transitions to a net zero economy. Green financing is an effective means of encouraging the development of infrastructure focussed on reducing carbon emissions and provides a form of de-risking by providing long-term grant and concessionary funding to an investment. While not yet as widely seen as PPPs within the hydrogen space (more a theme of general renewable energy), Europe is leading the way in sovereign green bond issuance and attracting international investment. The private sector is also raising green financing in the form of bonds as a means of financing private projects.

Internationally, green financing is often associated with pension funds, insurance agencies, government instruments, endowments and foundations. Public capital can be used to provide credit enhancements (by government-owned development finance institutions) that will attract private capital. DFIs or green banks can advance the minimum financing required to make the investment viable, with the remainder of the financing requirement contributed by private capital.

a) In 2012, South Africa established the green fund managed by the DBSA. The DBSA also announced the launch of its first green bond earlier this year. The €200m bond was issued through a private placement with the French development finance institution, the Agence Française de Développement (AFD).
b) The UK government's £500 million innovation fund will be used to support five hydrogen production projects.
c) Air Liquide has launched a specific green bond for hydrogen projects.
d) Germany issued a green bond to develop hydrogen capabilities and was 5x oversubscribed.
e) French car parts maker Faurecia issues green bond to fund hydrogen fuel cell capabilities.
f) The UK's Northern Gas has issued a green bond to support its transition to hydrogen.
g) Plug Power Inc – a private space hydrogen player in the US, has issued a green bond to raise financing for project capabilities.

10.7.2. Private finance

In addition to traditional sources of private finance such as direct equity investments, lending by commercial banks etc., private funding can be stimulated by developing, for example, public-private partnerships.

Public-private partnerships

The public-private partnership model is already well understood in South Africa. Combining public and private sector involvement by partnering government with key private stakeholders, including infrastructure developers, renewable energy companies, research institutions, vehicle manufacturers, and infrastructure focussed private equity funds, are key themes in this space globally.

Some examples include:

Fukushima10 Hydrogen Energy Research Field, is funded by the Japanese government and three private project developers—Tohoku Electric, Toshiba, and Itwatani.

a) Fukushima10 Hydrogen Energy Research Field, is funded by the Japanese government and three private project developers—Tohoku Electric, Toshiba, and Itwatani;
b) In China, there exists the Chinese Hydrogen Alliance, and is supported by China Energy Corporation and 18 other sponsors, including companies, universities, and research institutes, invests globally in research and development of fuel cell technology;
c) Germany has H2Mobility, the Scandinavia Hydrogen Highway Partnership and the California Fuel Cell Partnership.
d) The Dutch government aims to invest up to €338 million in GH projects in addition to planned investments of €9 billion of which most are private.
e) Australia's Asian Renewable Energy Hub14 project, which is being developed by a consortium of developers and investors - Intercontinental Energy, CWP Renewables, Vestas, and Pathways Investments - plans to invest $36 billion to develop renewable power, storage, and transport infrastructure for hydrogen production.
f) Toshiba, Kawasaki, and Mitsubishi, and automakers like Toyota, Nissan, and Honda anchor hydrogen associations and groups that invest alongside government in the development of fuel cell technology in Japan; and
g) The EU has created the European Clean Hydrogen Alliance to help build up a clear and robust pipeline of viable investment projects, which aims to coordinate investments and policies along the hydrogen value chain and promote cooperation across private and public stakeholders.

10.7.3. Development finance

Leveraging funding from developed markets

A number of larger, developed countries have set aside or have committed to setting aside funding specifically to support the decarbonisation initiatives of developing countries. Taking advantage of those additional pockets of funding will support the development of larger scale projects locally, which will enhance efficiencies and ultimately reduce pricing.

a) The United Kingdom has several initiatives to support developing country decarbonisation:
    - UK Government Investment into Africa:
        i. Invested £50 million in African renewable energy projects.
        ii. These projects are based on winners of the energy catalyst competition and include Solar farms in Kenya, Geothermal power stations in Ethiopia, energy storage in SSA.
        iii. The UK government will assist them with funding and attracting further investment for wind and solar farms.
    - The UK's Ayrton Fund
        i. £1 billion Ayrton Fund announced by PM Boris Johnson to help developing nations reduce fossil fuel emissions.
        ii. The Fund will focus on research, development, and demonstration into clean energy for low/middle income earning developing nations and will run for 5 years from April 2021.

    iii. The Fund will further be supported by the UKs International Climate Finance (ICF) increasing the funding to £11.6bn
    iv. The UK investment to help phase out coal in developing countries
- The UK plans to use COP26 to drive the phasing out coal and help developing countries adopt renewable energy:
    i. £72.3 billion of funding to be used in this regard

b) IRENA/Abu Dhabi Fund for Development (ADFD):
- Jointly collaborated to support and fund renewable energy in developing countries for a combined total of $630 million for 21 renewable energy projects.
- To date ADFD has held 7 funding cycles raising $214 million.
- The $420 million comes from government funding sources, the private sector and development funds.
- Current project countries include Cuba, Cabo Verde, Mauritania, Mali, Niger, Iran, Solomon Islands, Antigua and Barbuda, Senegal, Samoa, Argentina, Rwanda, Burkina Faso, Maldives, and Seychelles.

c) European Union
- The EU (ex UK) and the European Investment Bank have availed funds of €21.9 billion to support climate action in developing countries.
- The investment currently focuses on Argentina, Canada, Chile, China, India Kenya and Morocco.
- Likewise, in 2019 the European commission provided €2.5 billion to developing countries for climate adaptation activities.
- The European Investment Bank provided €3.1billion for developing countries focused on projects in Africa and other regions.
- Global Climate Change Alliance+:
    i. The main channel for EU support targeting climate action in developing countries
    ii. Backed by grant funding up to the value of 420 million
- EU Green climate Fund:
    i. Set up in 2010 to help developing countries reduce greenhouse gas emissions.
    ii. Funding sat at $9.78bn in 2019 and to be used until 2024.

The South African government should seek to position itself strongly with key representatives from the UK and the European Union, setting out a clear vision of decarbonising one of the world's largest carbon emitters, to encourage a portion of these funds to be directed towards initiatives locally.

Leveraging funding from export credit agencies

Export credit financing is often used to fund infrastructure projects (especially those in the developing world) in conjunction with, or as an alternative to, more traditional project financing. It enables project companies to obtain more flexible (and often cheaper) financing arrangements. In addition to financing, export credit financiers may also provide insurance, particularly political risk insurance that is either unobtainable or prohibitively expensive in the commercial marketplace, which incentivises investment by international financiers.

Given the anticipated involvement of international OEMs, obtaining export credit financing from financiers in the home countries of those OEMs is a compelling source of financing and/or insurance in the context of an emerging industry in South Africa.

Blended finance mechanisms

a) On-lending structures: public financiers like DFIs use their high credit rating to access funding at lower rates to allow projects requiring significant infrastructure investment to be more cost-competitive.
b) Subordinated debt can be issued by multilateral development banks or DFIs and can help attract and insulate senior debt investors, such as institutional investors, from certain risks inherent in renewable projects.
c) The DBSA's Infrastructure Fund has specifically been set up to arrange, coordinate, structure and engage with financial institutions and the markets to develop financial instruments that will enable investments in large-scale infrastructure projects, by:
    - contributing fixed capital.
    - improving bankability by addressing market failures/shortcomings; and
    - maximise participation by the private sector, institutional investors, development finance institutions and multilateral development banks.

10.7.4. Financing Recommendations

Governments globally are looking to various mechanisms in order to unlock the financing of GH_2 projects and accelerate development by mitigating specific investor risks, for example:

a) developing strong relationships with the governments of developed countries who have programmes in place to support developing countries in their climate change pursuits.
b) providing partial guarantees.
c) providing blended concessional finance; and/or
d) providing grants and/or subsidies to pilot projects.

Broadening relationships with the IPG in the JET partnership and establishing relationships with countries outside the IPG will be key in enabling the above relationships and sourcing the specified funding instruments above.

The development of the GH_2 will be led by private sector funding while leveraging the JET funding available for this value chain. In addition, blended finance vehicles will be pursued in order to leverage in commercial lenders to meet the capital requirements. Over the next 12 months, the dtic and the IDC will deepen the modelling around the various development scenarios in order to understand the social, environmental and economic impact of the various scenarios to identify whether there could be value in accelerating the development of GH_2 through specific levers including incentives following normal government budgetary processes.

Levers introduced by other countries include:

a) introducing special, marginal levies on existing carbon fuel consumption (e.g., additional levy on fuel at the pumps) which could generate a pool of funding which could be applied to the country's movement towards greener fuels;
b) redirecting income from carbon taxes towards green initiatives;
c) special economic zones tax incentives; and
d) Income Tax provisions and deductions.

11. Strategic implementation

11.1. The role of Government and the private sector

Stronger partnerships will need to be built between Government, the private sector and civil society to create an enabling environment. Implementation should also drive international partnerships while protecting national interest.

Government's role is to create a conducive investment environment to attract investment into this industry. This will entail:

- Position of GH_2 as a key early contributor to decarbonization and a just transition in the country programme of work being collated by the JET-IP Task Team ensuring a fair proportion of climate finance is sourced to enable development of this industry.
- Prioritize the execution of the green hydrogen commercialisation strategy and the development of a national GH_2 infrastructure plan
- Drive the required policy and regulatory changes required to sustain long term growth of the new hydrogen industry.
- Mobilise and coordinate the Government support required to support the development of this new industry for South Africa.
- Drive the implementation of infrastructure by partnering with the private sector. This will include port, rail, pipeline and electrical transmission and re-fuelling infrastructure.
- The Department of Science and Innovation will continue to monitor global developments and opportunities for innovation in a drive to commercialise home grown technologies and improve cost effectiveness of GH_2.

Details of the proposed responsibilities of specific government departments are listed in Appendix F clearly highlighting the "all of government" approach to delivery of the GH_2 value chain and unlocking the social and economic potential of this industry.

The role of the private sector will include the initiation, development and execution of green hydrogen projects along the value chain for domestic consumption and export. This will include:

- Applying project development best practices to successfully de-risk projects;
- Be open to crowding in funding and to partnerships;
- Increase project pipeline in tranches;
- Be flexible to changing market needs;
- Source funding for projects and
- Show that South Africa is action oriented and deliver tangible results on projects.

11.2. Capturing the export market

Analysis of global net exporters has been completed using the 1.9 mtpa scenario or about 7% of the global import market as a SA base. If technology and learning rates advance significantly to bring GH_2 costs down to 2050 the production of grey hydrogen could be entirely constituted of GH_2. Based on the estimates, South Africa has the potential for close to 7% market share. South Africa will likely compete directly with Morocco, Russia, Chile and the UAE, and at more than 15% with Saudi Arabia and Australia. **Southern Africa, mainly**

Namibia and South Africa, could tap into a 10–22 mt of hydrogen equivalent export market.

Without support, South Africa faces a trade disadvantage compared to other countries to compete in markets such as Japan and South Korea. This is due to closer geographical proximity allowing for lower transport costs, early mover advantage, and the already strong established relationships. Forecasts predict a South African price evolution from approximately $4/kg in 2025, to $3/kg in 2030, to $2.5/kg in 2035, to $1.5/kg in 2040, to $1/kg in 2050. Although South Africa is forecast to be one of the lowest cost producers of GH_2, the competitor countries will be able to reach low cost production before South Africa. South Africa will differentiate itself by using proprietary Fisher Tropsch technology to target export of sustainable aviation fuel and will manufacture electrolysers and fuel cells using PGMs available locally. Additionally, South African projects will benefit from additional Government support in the form of incentives in the short term to reach lowest cost of production sooner than projected in order to be globally competitive.

South Africa can benefit from the fact that importing countries may seek to diversify supplies of energy, and South Africa could target GH_2 sales to East Asian markets. Blue hydrogen will compete with GH_2 in the Japanese market, as Japan has already commenced importing blue ammonia. Many global GH_2 value chain participants are already active in South Africa and are investigating participation in the GH_2 value chain in South Africa. South Africa's primary market will most likely be the EU and the United Kingdom. There are significant initiatives already undertaken by the EU to enable and facilitate GH_2 imports, including with South Africa. The European Union, notably Germany, have already introduced policy and have indicated a willingness to pay a premium price through the implementation of long-term (10 year) supply agreements to stimulate GH_2, ammonia and Power-to-X market development. Namibia, due to its historical ties to Germany also has an opportunity to collaborate with South Africa. However, there is a risk that the EU delegated acts (RED II) are too onerous for developing nations on the renewable energy and sustainable carbon sourcing requirements for green hydrogen which needs to be addressed by projects intending to export to the EU.

The following strategic objectives should be considered in pursuit of South Africa's GH_2 export market ambitions:

- Export Markets: secure long-term global market share and competitive trade position by strategically positioning South Africa as a preferred and reliable provider to key markets, specifically EU/UK, Japan and South Korea leveraging trade relationships and government support.
- Secure global market and offtake MoUs with national procurement programmes such as H2 Global.
- Expedite an export pilot project to ensure SA is seen as a serious global player and achieves early market entry.
- Progress international strategy to comprehensively understand global demand by country and the extent to which South Africa can increase market share.

11.3. Domestic market - price trajectory and penetration of industry

In GH_2 production, electricity accounts for 60-70% of costs, and the costs of electrolysers and balance of plant account for 30-40% of costs. Currently the production cost of GH_2 is not cost competitive with other hydrocarbon-based fuels. Carbon taxes can aid in reducing the cost differential between GH_2 and incumbent fossil fuels. While the declining cost of GH_2 production coupled with increasing carbon taxes is predicted to achieve GH_2 price parity from 2025 to

2027, this doesn't account for the overall higher cost of energy to end-users or capital costs of transitioning energy assets. A more realistic or market view of achieving local price parity may therefore be closer to 2030. Declining GH_2 prices will unlock opportunities across key sectors to decarbonise industry.

Consideration should be given to tax and other incentives to accelerate investments in, particularly, decarbonisation of export value chains to ensure that regulations in place in export markets do not inhibit the export of South African goods.

Noting the above considerations, and adopting the more aggressive demand view the key drivers of future South African demand between 2023 and 2050 are forecast to be:

- 2023-2025: Road transport, primarily Fuel Cell Vehicles (FCVs), including chiefly Heavy-Duty Vehicles (HDVs). Mobility represents a significant opportunity for South Africa, but this will be sequenced based on economic viability, which will be dictated by volume and carbon emissions. Mining represents the best early adopter of hydrogen for mobility, followed by heavy duty logistics (trucks and buses).

- 2023-2025: Refining and processing, which consumes significant amounts of hydrogen for the production of petroleum products and chemicals. Many refining and process plants that currently consume or produce grey or blue hydrogen have active projects to switch to GH_2.

- 2025-2030: Chemical and Industry, notably the non-ferrous metals, green steel, and cement sectors, which will need to decarbonize to remain globally competitive.

- 2028-2030: Green ammonia and methanol, which will replace current production from grey and blue hydrogen and add new production from new use cases.

- +2030: Power Storage and Balancing, which will see GH_2 being used for long duration storage based on daily, monthly, and cross-seasonal balancing requirements. With greater renewable energy penetration into the global energy system, the need for hydrogen as a means to store curtailed/surplus renewable energy is anticipated to increase.

To achieve ambitious domestic demand in the >3mtpa range, will require supportive policies and incentives. This will require specific coordination and interventions between the public and private sector. **Further detailed studies will be needed to consider the overall economic cost-benefit impact and value for money proposition of deeper government support and interventions to achieve more aggressive market demand.**

The strategic objective that should be considered in pursuit of South Africa's GH_2 Strategic vision outlined above is to stimulate the domestic demand for GH_2, by demonstrating the feasibility of GH_2 applications in hard-to-abate sectors such as non-ferrous metals, green steel, sustainable aviation fuel, fertiliser and cement in order to foster short term pilot projects and long-term commercialisation.

11.4. Equipment manufacturing

Establishing local industrial capability and equipment manufacturing is a key enabler of longer-term competitive advantage and the following strategic objectives should be considered:

- Support initiatives and intellectual property for local GH_2 production and inputs such as electrolysers, catalysts, fuel cells and the integral components that comprise these. These components include membrane electrode assembly (MEA), and catalyst coated membranes (CCM) for example.
- Understand the potential for industrialization of the renewable energy manufacturing supply chain through an aggressive GH_2 strategy. This should involve alignment of the masterplans in process in the renewable energy, steel and automotive sectors as well as relevant Phakisa processes (e.g. oceans).
- Create partnerships and joint ventures to secure investment, technology partnerships, and long term demand off-take agreements.

11.5. Catalytic project development and successive ramp up

Establishing such a new long-term industrial capability will require staged, pragmatic and ambitious policy and government support aligned to support private sector driven investment in infrastructure. This will have to occur in a context where South Africa faces challenges related to low economic growth, electricity supply and a constrained fiscal space with competing priorities and the technology surrounding GH_2 production, use, transport, and storage is still maturing and competitiveness and cost-parity with incumbent fossil-based routes has yet to materialise.

Formulating a roadmap is a crucial step in order to plan future pathways and ensure that a holistic approach is adopted. The roadmap provides a level of market certainty and buy in from multiple stakeholders towards achieving certain milestones and development of the value chain for both export and domestic markets. The roadmaps are distinguished into short term (2023-2027) and longer-term objectives (2023-2050) for the purposes of the commercialisation strategy. Responsibilities are allocated by segmenting actions identified for the public sector and the private sector within each time frame. The roadmaps are followed by the indicative short-term funding requirements.

Based on the above elements of the value chain, the total cost to the end user of the GH_2 is approximated as the sum of the component costs along the value chain pathway. This cost will vary based on the form of GH_2 required in the end use and conversion processes required, and the method of transport. **On the basis of a scenario of 1.9 Mt GH_2 for export and 1.9 Mt GH_2 for domestic consumption to 2050, significant investments in estimated installed capacity for renewable energy and electrolysers are required.** It is estimated that a combination of 56 GW of solar and 24 GW of wind will be required as an electricity input, combined with an aggregate electrolyser capacity of 41 GW to meet the demand anticipated in this scenario.

Long term growth aspirations could exceed 7mtpa of production by 2050. This potential ramp up, associated costs and CO_2 displaced is shown in Figure 25.

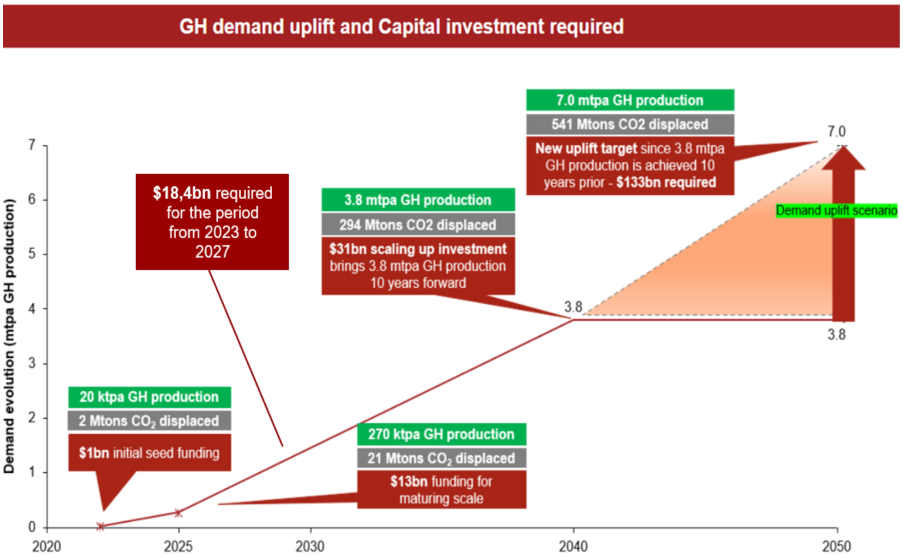


Figure 25 : GH2 demand uplift and capital investment required.

- $1bn investment could expedite GH_2 export of 20 ktpa.
- Within three to five years, several GH_2 projects, both export and local, will come online increasing GH_2 scale to 270 ktpa, requiring capital of $13bn, displacing carbon emissions by 21 Mtons of CO2.
- The target of 3.8 mtpa by 2040 will require total investment of $164bn by 2040.
- Between 2040 and 2050, South Africa can aggressively pursue deeper decarbonisation by seeking a GH_2 demand uplift to 7 mtpa. This will displace 541 Mtons of CO_2 and increase investment support to $133bn.
- Emissions calculated from the investment date to the end of the decade (assuming 3 years of development and 7 years of operations) could result in annual emissions reduction of between 18 to 20 % of South Africa's annual carbon emissions.

11.6. Regional integration and supporting the development of hydrogen hubs and valleys

The concept of a hydrogen hub has become a popular policy and planning tool in order to ignite the GH_2 industry. It is important to note that provincial government efforts have played a strong role in highlighting and identifying opportunities for development in the GH_2 value chain and potential hubs. Here, it is vital that national level plans and strategies align with provincial plans in order to identify synergies and avoid duplication. The Northern Cape, Western Cape, Eastern Cape, eThekwini regions and Gauteng regions have all embarked on ambitious plans to develop GH_2 within their provinces.

It is important to create focus and prioritisation in the initial design and planning of these hubs. This has also been identified by international OEM's as well as in the literature review as global best practice. It is therefore proposed that the identified locations in the GHCS be promoted for longer term development as the GH_2 sector develops in South Africa.

Regional GH_2 integration in Africa

GH_2 has the potential to enable African countries to become more energy independent and promote zero-carbon industrialization. Additionally, the development of the GH_2 economy in Africa will create both economic growth and new jobs, as well as help to enable and accelerate the deployment of RE across the continent, a necessary step to increase energy access and affordability.

Africa has immense renewable energy endowments and is equipped to take full advantage of the hydrogen opportunity. It is estimated that Africa's exports of GH_2 and derivatives could reach 20-40 mtpa by 2050 (AGHA, 2022).The northern and southern regions of Africa, due to the excellent RE resources, could emerge as key export hubs. While in Eastern and Western Africa, solar and wind profiles are less optimised for exports and these regions are more likely to be focussed on domestic demand. Realising these ambitions will require collaboration between African nations.

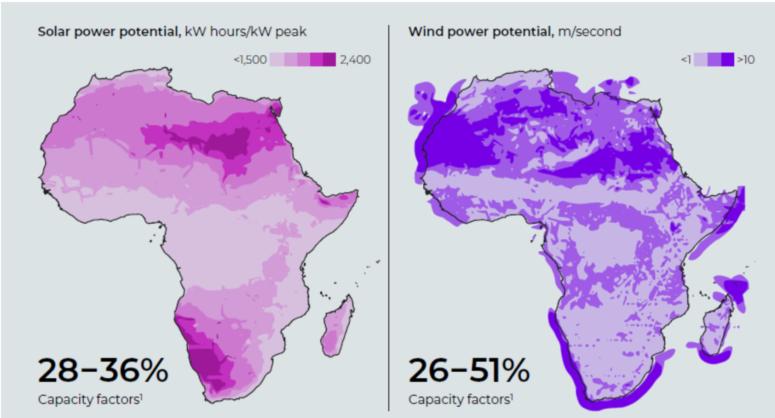


Figure 26 : Africa's renewable energy endowments source AGHA, 2022.

The President has championed an African-focused Green Hydrogen development plan, focused on unlocking opportunity in the first phase along the south-western seaboard, incorporating South Africa, Namibia and Angola, with a view to this forming the core of a southern African export hub of green hydrogen.

The African Green Hydrogen Alliance (AGHA) was formed in May 2022 and consists of the following members Egypt, Kenya, Morocco, Mauritania, Namibia, Ethiopia, Angola and South Africa.

There is potential for this type of intra-government forum or entity to drive the African GH_2 opportunity. In parallel a local DFI could be nominated to drive co-ordinated project development efforts across the region.

12. Public Consultation and Social Acceptance

The GHCS was approved by Cabinet in November 2022 for release to the public for comments. The period for comments was closed on 31 March 2023. The PCC also provided comments to the GH_2 section of the JET-IP. The GHCS was presented to NEDLAC on 24 August 2023. The GHCS was updated with inputs from public comments, PCC comments on the JET-IP and presentation at NEDLAC. A summary of the comments and how the concerns were addressed is shown below.

Theme	Concern Raised	How concerns are addressed

Energy Security	GH_2 should not compete with South Africa's energy crisis. Eradicating energy poverty is a more pressing priority.	GHCS updated to provide assurance that GH_2 can help alleviate the electricity crisis by feeding power into the grid, feeding power into micro grids for the community and by grid infrastructure upgrades allowing other RE projects to feed into the grid.
Funding	GH_2 should not direct critical grant funding away from the energy crisis and other pressing issues.	GH_2 implementation plan does not seek to obtain grants from the IPG offer already earmarked for other sectors. Grant funding will be sourced from dedicated global funds mandated for supporting GH_2 initiatives on a global level.
Workforce skills	Insufficient local workforce skills to deliver the pipeline of projects.	GHCS provides a reskilling framework that will be developed in to a skills development plan.
Transparency	Governance that provides transparency on progress and fund use is required.	GH_2 implementation dashboard will be developed and made publicly available.
Infrastructure	Lack of coordination on infrastructure build for GH_2	New governance structures will be set up that will allow improved coordination between government entities and private sector

13. GH_2 Commercialisation Roadmap and Funding Plan

Formulating a roadmap is a crucial step in order to plan future pathways and ensure that a holistic approach is adopted. The roadmap provides a level of market certainty and buy in from multiple stakeholders towards achieving certain milestones and development of the value chain for both export and domestic markets. The roadmaps are distinguished into short term (2023-2027) and longer-term objectives (2023-2050) for the purposes of the commercialisation strategy. Responsibilities are allocated by segmenting actions identified for the public sector and the private sector within each time frame.

13.1. Short term actions (2023 – 2027)

Public sector
Public sector commitments comprise enabling action, enhancing capabilities, providing strategic direction and identifying leading projects (See **Figure 27** and **Figure 28**).

13.1.1. Enablers

Enablers focus on improving skills and R&D, providing and appropriate regulatory focus, and securing finance.

- Skills & R&D: Actions focus on creating the necessary skills and capabilities that are required in the value chain. Here the roadmap focuses on leveraging existing technical and vocational institutions, SETAs and universities to create the skills that the value chain will demand. There is also a focus on the intersection between the JET and green hydrogen development. This involves identifying areas where JET policy tools can be used in order to support the value chain. This includes reskilling and retraining efforts in fossil-intensive production activities and pooling in displaced labour into new and sustainable GH_2 activities.

- Regulations: The regulatory approach involves developing timelines and a regulatory approach that is specific to South Africa's context and existing regulations. Key policy documents that need to be updated will be reviewed and the necessary regulatory changes enacted. These include the Integrated Resource Plan 2019, SAREM, Gas Utilisation Master Plan, and Eskom's Transmission Development Plan among others. Industrial policy tools become a feature beyond 2025, with the institution of support measures including subsidies and tax incentives, as well as guarantees of origin for the international market.

- Finance: From a finance perspective, the short-term roadmap envisions efforts to raise finance for distribution into early and catalytic projects, with a focus on using increasing access to green financing mechanisms as well as accessing and deploying JET-IP funds.

13.1.2. **Capabilities**

Enhancing capabilities include technology partners, manufacturing and raw materials.

- Technology Partners: Prior to 2025, the roadmap envisions the establishment of key relationships with industrial partners for electrolyser production, including identifying where localisation opportunities manifest. Once terms for localisation have been identified, the roadmap envisions the establishment of a 1GW per year PEM electrolysis facility.

- Manufacturing: An important focus is placed on developing domestic manufacturing capabilities. In the short term, prior to 2025, this focus is informed by detailed market potential studies that examine the local assembly of plant, equipment, and components via OEM localisation. This also includes the investigation of the market potential for local CCM/MEA manufacturing, where there currently exists firm activity. Focus is also placed on pilots that test the commercial case for domestic manufacturing of fuel cells and their underlying components. Beyond 2025, the focus is oriented towards scaling up the proven test cases and establishing a local manufacturing plant along with a fuel cell commercial manufacturing facility.

- Raw materials: Raw materials cover the essential inputs into the value chain and comprise the assessment of existing PGM potential and GH2 market demand for PGMs. This also includes a study on the local resource potential for equipment and components for all GH value chain technologies and assessing the level of integration with the planned value chain.

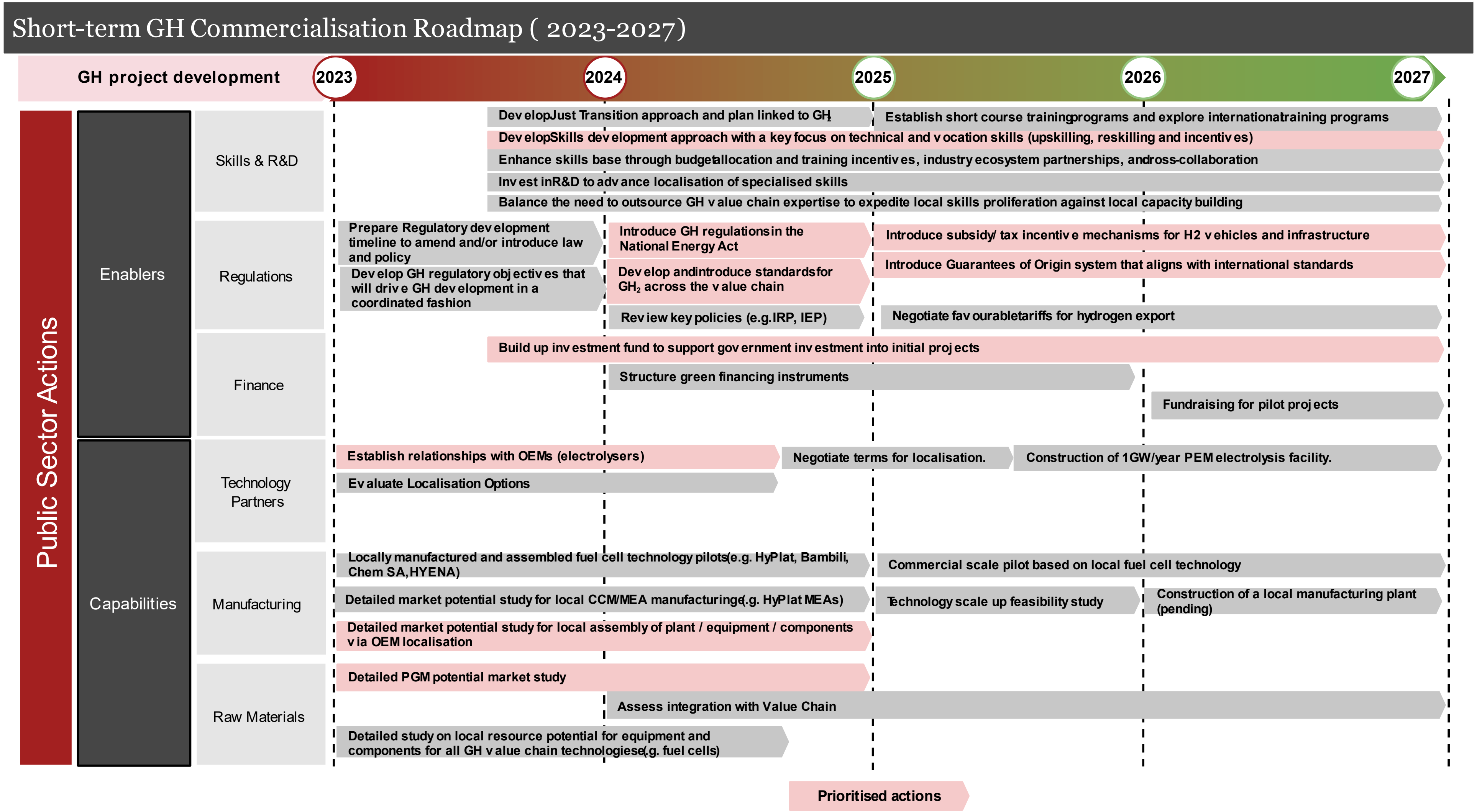


Figure 27. Public-sector Short-Term Roadmap (2023-2027)

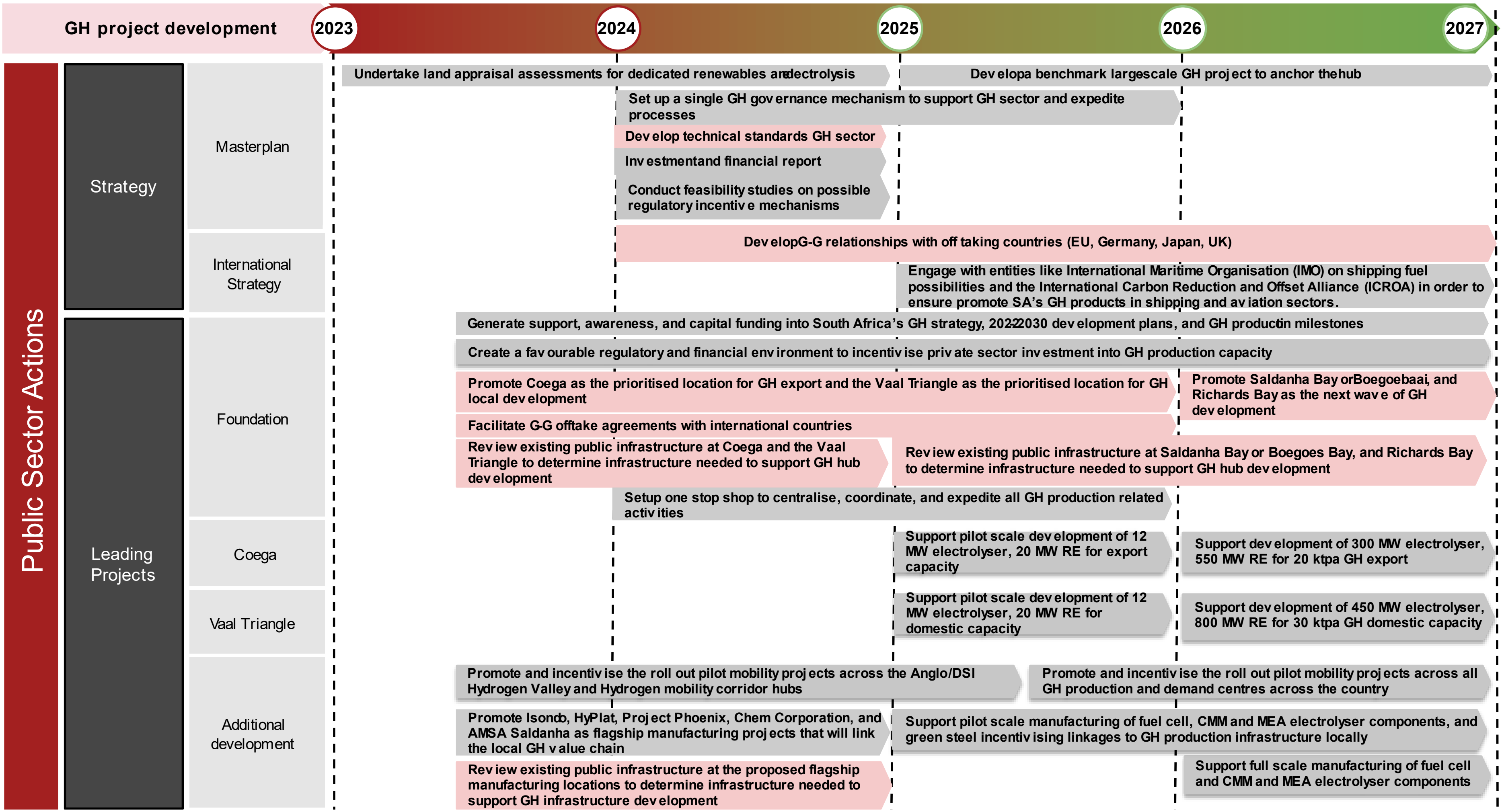


Figure 28. Public-sector Short-Term Roadmap (2023-2027)

13.1.3. Strategy

Strategy elements comprise actions for masterplans and international strategy

- Masterplans: here the roadmap envisions immediate actions (prior to 2025) assessing land availability for renewables and electrolyser infrastructure, financial and investment requirements, technical standards, and feasibility studies for regulatory mechanisms. After 2025, actions focus on developing regulatory mechanisms and the establishment of a benchmark large-scale GH_2 project to anchor a selected hub.

- International Strategy: The international strategic actions comprise developing relationships with potential importers of South African GH_2, such as the EU, UK, Germany, and Japan. Beyond 2025, actions include partnering with international organisations to understand value-chain specific transformation and uses of GH_2. This includes targeting maritime and aviation value chains.

13.1.4. Leading Projects:

Leading projects consist of foundation projects, Coega, the Vaal Triangle, and additional development.

- Foundation: here the roadmap envisions the promotion of key hubs (Coega, Vaal Triangle) and crowding in investment into these hubs, including from international sources. Beyond 2026 focus is placed on other potential hubs in the country. Important to this process is the identification of infrastructure needs at the various hubs identified. From 2024 onwards, the process of setting up a one-stop shop to centralise and coordinate all GH_2 activities in the country.

- Coega & Vaal Triangle: Beyond 2025, actions focus on supporting pilot projects to demonstrate domestic and export supply.

- Additional development: The additional actions consider specific portions of the value chain and specific GH_2 use cases. Actions leverage the existing projects and initiatives in the country around mobility, fuel cells, and green steel, among others. Immediate priority is placed on reviewing the public infrastructure connected to each of these private projects and determine the needs for successful integration with projects. Beyond 2025, focus is placed on supporting pilot projects that target the manufacturing of essential manufacturing inputs such as fuel cells, electrolysers, CCMs, MEAs

Private sector

Private sector commitments comprise actions required by the private sector in order to achieve the goals of the strategy an consist of enablers, leading projects, regulatory and policy enablers, domestic use, refuelling and distribution, production, beneficiation, and exports.

13.1.5. Enablers

Enablers focus on skills and foundational elements:

- Skills: The roadmap envisions private investment into developing skills and capabilities within projects and investment into R&D for localisation prior to 2027

- Foundation: The availability of international financing for GH_2 projects implies that private sector participants will access this funding to support domestic GH_2 projects. Projects are also expected to involve offtake agreements for export to key destinations.

13.1.6. **Leading Projects:**

Leading projects consist of a focus on Coega, the Vaal Triangle, additional development, Hydrogen Valleys, and manufacturing

Coega: To achieve an investment decision beyond 2026, actions require a feasibility study on sites, pilot projects, and off-take agreements with international/domestic partners

Vaal Triangle: To achieve an investment decision beyond 2026, actions require a feasibility study on sites, pilot projects, and off-take agreements with international/domestic partners

Additional development: Additional value chain actions involve demonstration of GH_2 in mobility applications and the development of local manufacturing of input components

Hydrogen Valleys: Here focus is placed on the existing GH_2 valleys being developed. Demonstration of GH_2 buses in the identified valleys in Durban and Johannesburg is assumed to continue until 2026.

Manufacturing: Manufacturing action include the setting up of input manufacturing facilities, and domestic linkages with international OEMs being set up.

13.1.7. **Regulatory and Policy enablers**

Regulatory and policy enablers include capital subsidies and tax exemptions for GH_2 vehicles and infrastructure until 2027. Here lowering the cost of borrowing for projects is also an imperative. The availability of regulatory frameworks and standards in specific uses becomes a feature from 2023 onwards.

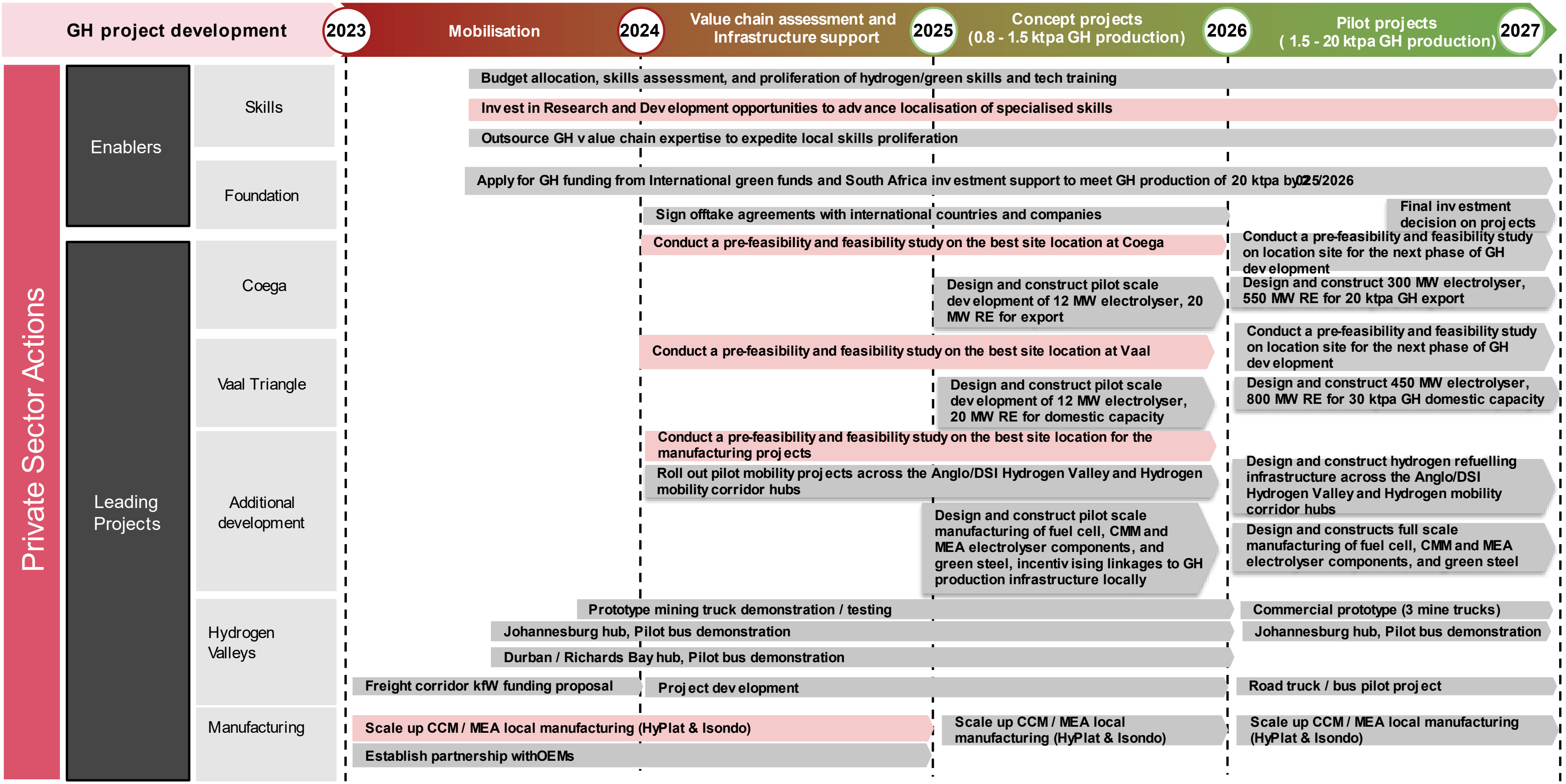


Figure 29. Private Sector Short Term Roadmap (2023-2027)

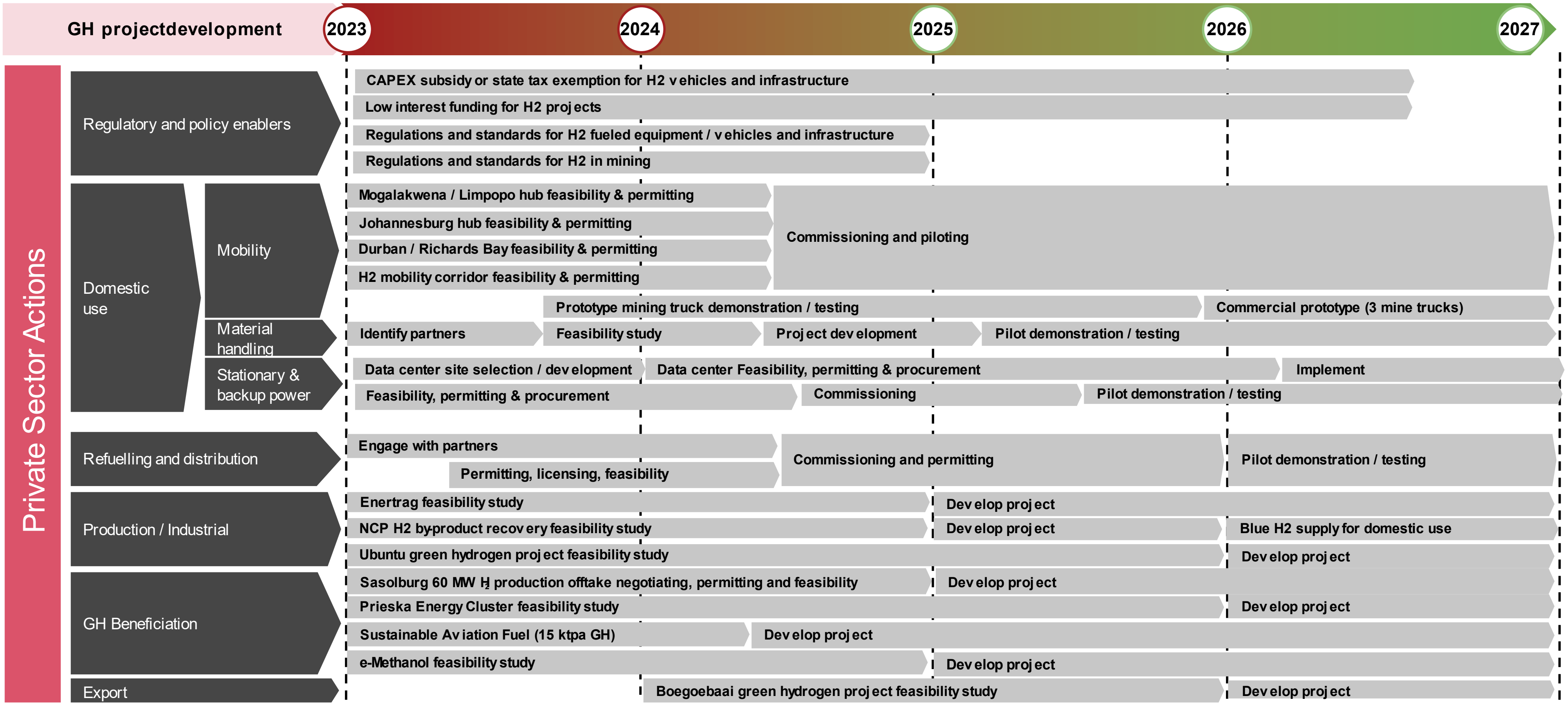


Figure 30. Private Sector Short Term Roadmap (2023-2027)

13.1.8. Domestic use

Domestic use cases comprise mobility, material handling and stationary power. Prior to 2025, the roadmap envisions testing the cases for mobility applications along the various identified GH_2 corridors, with projects coming online after 2025. From beyond 2025, the test cases for mining trucks are also anticipated. From a material handling perspective, pilots are identified beyond 2025, with pre-feasibility work conducted prior. Stationary power applications are targeted for data centres until 2027.

13.1.9. Refuelling and distribution

Pilots for refuelling and distribution infrastructure are targeted beyond 2025, with pre-feasibility work, commissioning and permitting completed by 2026.

13.1.10. Production

The roadmap targets the development of projects from 2025 onwards, with current initiatives by Enertrag, NCP and Ubuntu in the feasibility stage.

13.1.11. GH2 Beneficiation

Beneficiation actions target project development from 2025 onwards, leveraging the existing projects examining sustainable aviation fuel, Sasolburg GH_2 production, and e-methanol production, among others.

13.1.12. Export

The immediate export actions target export from Boegoebaai, with development beyond 2026, and the current actions focused on the feasibility assessment.

13.2. Long term actions (2023 – 2050)

Long term actions are segmented into similar elements as the short-term actions, and identify longer term action required in order to grow the GH_2 value chain in South Africa.

Public sector

Public sector commitments comprise enabling action, enhancing capabilities, providing strategic direction and identifying leading projects (See Figure 31 and Figure 32).

13.2.1. Enablers

Enablers focus on improving skills and R&D, providing and appropriate regulatory focus, and securing finance.

- Skills & R&D: The skills actions protract the initial short-term actions with a continued focus on enhancing domestic skills and capabilities through continued partnerships, focusing on technical and vocational skills, along with prioritising JET initiatives.

- Regulations: Up to 2030, it is anticipated that key policy plans such as the IRP and IEP will be updated, and the appropriate regulatory and policy frameworks are finalised. Support mechanisms such as tax breaks and reduced import duties continue. After 2030, as the industry matures, incentives begin to decline with carbon penalties increasing in quantum to channel resources towards GH2 activities and projects.

- Finance: Up to 2030, focus is placed on negotiating favourable tariffs in export markets, building a fund base to support investment into catalytic projects, and developing green finance mechanisms. Beyond 2030, actions focus on long-term offtake agreements as the market matures.

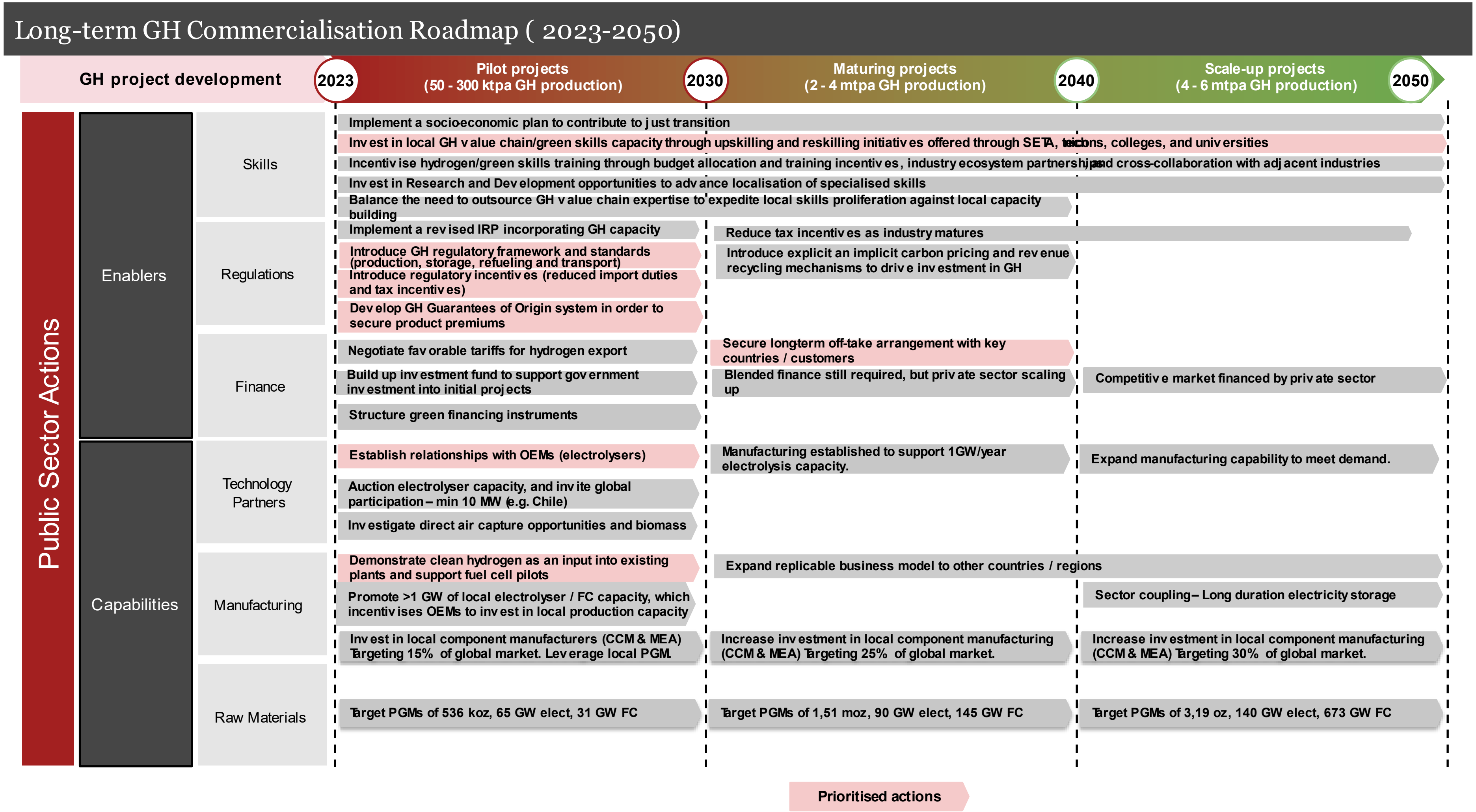


Figure 31. Public-Sector Long-term Roadmap (2023-2050)

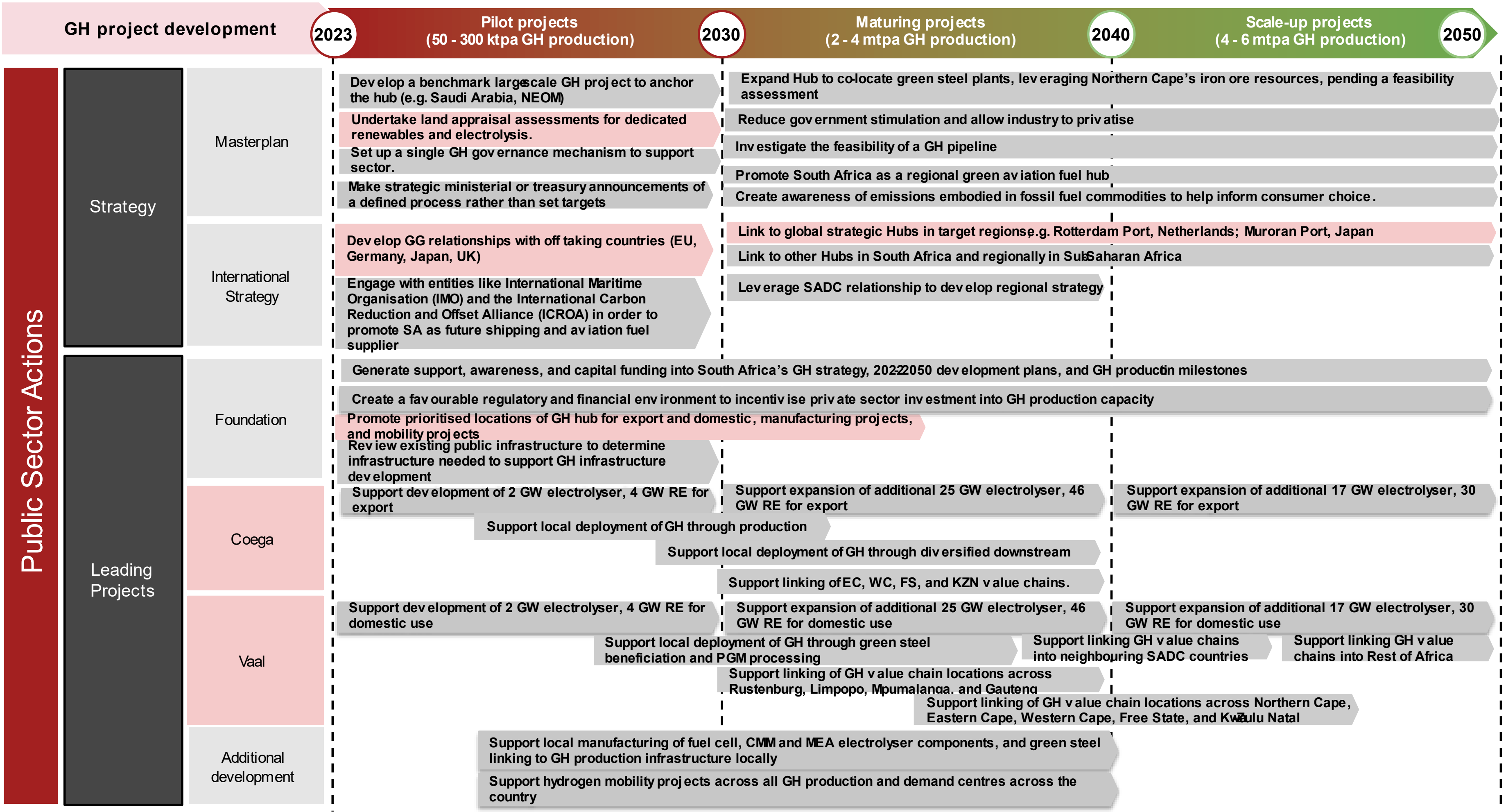


Figure 32. Public-Sector Long-term Roadmap (2023-2050)

13.2.2. **Capabilities**

Enhancing capabilities include technology partners, manufacturing and raw materials.

- Technology Partners: Prior to 2030, action pursue the establishment of relationships with OEMs, inviting global participation in electrolyser projects and investigating opportunities in direct air capture and biomass integration. Beyond 2030, manufacturing capacity of 1GW/year of electrolysis capacity is achieved and expanded until 2050

- Manufacturing: Up to 2030, actions aim to promote investment into inputs, demonstrate GH_2 integration into existing facilities, and the promotion of more than 1 GW of domestic electrolyser capacity. Beyond 2030, investments into domestic manufacturing capabilities are increased to capture greater global market share, combined with sector coupling beyond 2040.

- Raw materials: With a PGM focus, the use of PGMs are steadily ramped until 2050.

13.2.3. **Strategy**

Strategy elements comprise actions for masterplans and international strategy

- Masterplans: Prior to 2030, actions continue from the short term and include assessing land availability for renewables and electrolyser infrastructure, ensuring the appropriate governance mechanisms, and the establishment of a benchmark large-scale GH_2 project to anchor a selected hub. Beyond 2030, the roadmap aims for targeting of transport infrastructure (pipelines), expanding successful hubs, and promoting South Africa as a green aviation fuel hub as sustainable aviation fuel case is demonstrated as commercially viable.

- International Strategy: Up to 2030, actions include developing relationships with potential importers of South African GH_2, and partnering with international organisations to understand value-chain specific transformation and uses of GH_2 (maritime, aviation). Beyond 2030, regional links begin to manifest and secure relationship are established with global importers in identified ports.

13.2.4. **Leading Projects:**

Leading projects consist of foundation projects, Coega, the Vaal Triangle, and additional development.

- Foundation: from 2023 up until 2050, the roadmap envisions the promotion of key hubs (Coega, Vaal Triangle) and crowding in investment into these hubs, including from international sources. Important to this process is the identification of infrastructure needs at the various hubs identified. The creation of a favourable regulatory and financial environment remains a consistent long-term action.

- Coega & Vaal Triangle: Actions focus on supporting pilot projects to demonstrate domestic and export supply. Beyond 2030, actions aim to scale up production and value chain diversification.

- Additional development: The additional actions consider support of the development of the local manufacturing value chain for manufactured inputs including MEAs and CCMs, along with developing specific GH_2 applications in mobility.

Private sector

Private sector commitments comprise actions required by the private sector in order to achieve the goals of the strategy an consist of enablers, leading projects, regulatory and policy enablers, domestic use, refuelling and distribution, production, beneficiation, and exports.

13.2.5. **Enablers**

Enablers focus on skills elements:

- Skills: The roadmap envisions continued private investment into developing skills and capabilities within projects and investment into R&D for localisation up to 2050

13.2.6. **Leading Projects:**

Leading projects consist of a focus on foundational aspects, Coega, the Vaal Triangle, and additional development

Foundational: The foundational actions combine international and domestic support for the value chain to ramp production. Up to 2030, the pre-feasibility assessments are concluded, proving the commercial cases for the identified hubs, with the development of downstream value chains beyond 2030.

Coega: Up to 2030, actions focus on the design and development of 4GW of electrolyser capacity. Beyond 2030additional electrolyser capacity is installed, with downstream beneficiation.

Vaal Triangle: Up to 2030, actions focus on the design and development of 4GW of electrolyser capacity. Beyond 2030additional electrolyser capacity is installed, with downstream beneficiation.

Additional development: Additional value chain actions involve demonstration of GH_2 in mobility applications and the development of local manufacturing of input components, prior to 2030. Beyond 2030, the scale up of hydrogen refuelling infrastructure is targeted.

13.2.7. Domestic use

Domestic use cases comprise mobility, material handling and stationary power.

Prior to 2030, the roadmap envisions testing the cases for mobility applications along the various identified GH_2 corridors/valleys, with projects coming online after 2030, where the commercial cases are proven. From beyond 2030, the hubs are envisioned to be scaled up and expanded. From a material handling perspective, pilots are identified beyond 2030, with pre-feasibility work conducted prior and the test cases for certain application (e.g. forklifts) being developed. Stationary power application pilots using fuel cells are targeted for data centres and office buildings until 2030.

13.2.8. Refuelling and distribution

Pilots for refuelling and distribution infrastructure are targeted by 2030, with expansions along the identified corridors beyond 2030.

13.2.9. Production

The roadmap targets the development of projects by 2030 onwards, including the Enertrag, NCP and Ubuntu projects. Beyond 2030 these projects are expected to scale up and newer project applications taking place including green steel and commercial sustainable aviation fuel exports.

13.2.10. GH_2 Beneficiation

Beneficiation actions target project development from 2025 onwards, leveraging the existing projects examining sustainable aviation fuel, Sasolburg GH_2 production, and e-methanol production, among others. From 2030 these projects are anticipated to grow in scale and diversity of offering.

13.2.11. Export

The actions target export from Boegoebaai, with development beyond 2026, and the development of e-methanol and pipeline infrastructure.

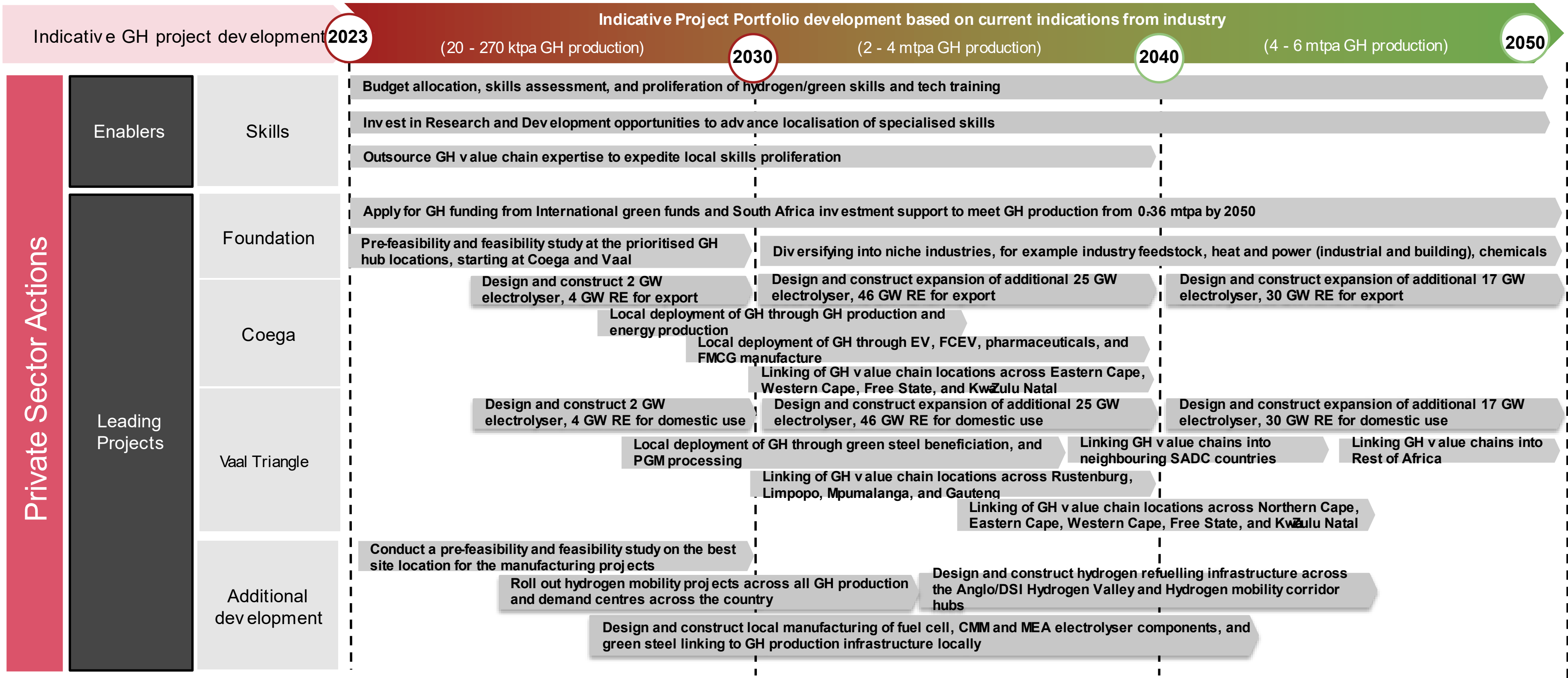


Figure 33. Private Sector Long term Roadmap (2023-2050)

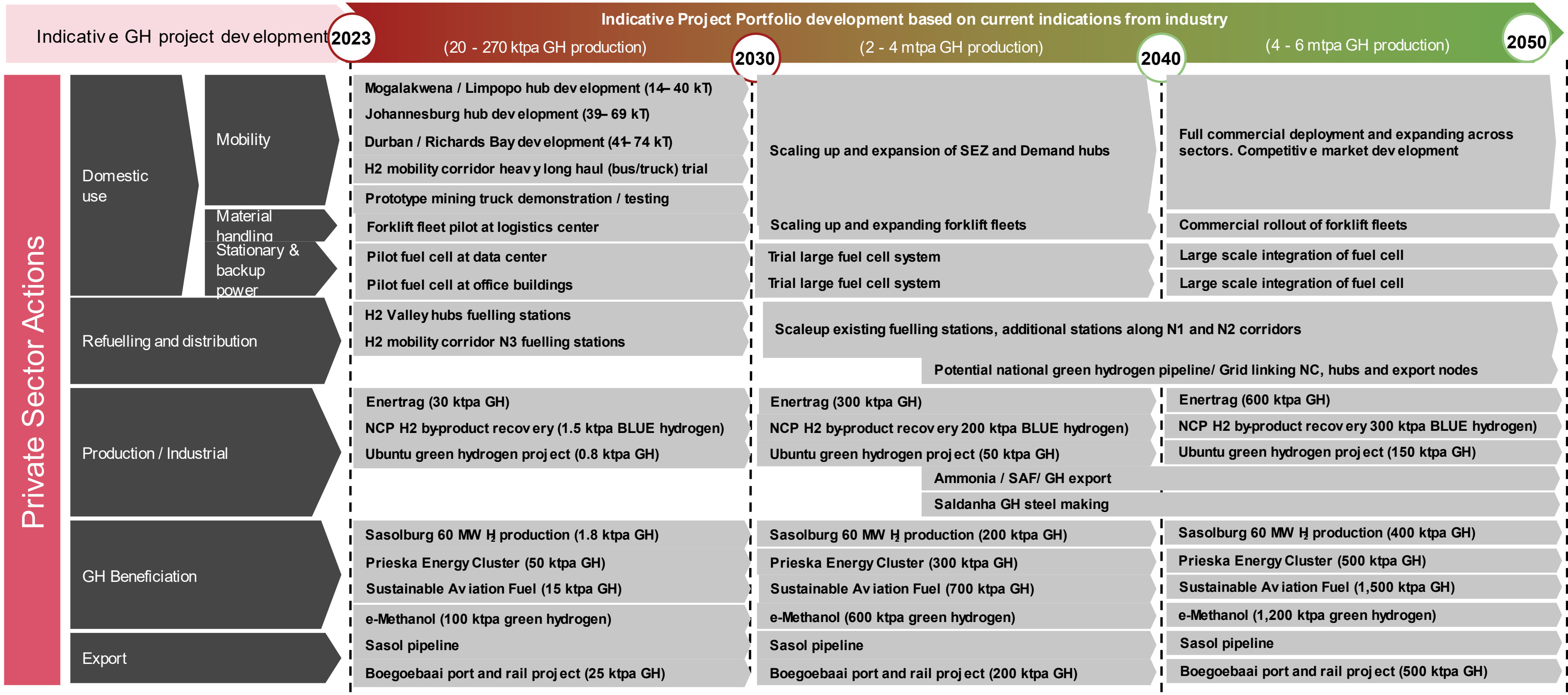


Figure 34. Private Sector Long term Roadmap (2023-2050)

13.3. Short term funding plan (2023-2027)

Securing international support and financing through bi-lateral and commercial arrangements where developed nations need to secure long-term security of GH_2 supply will be key to the country securing an early mover market position. This will have to be supported by South Africa's need to drive economic recovery through green economic infrastructure that will also address the triple challenges.

Based on the projected production targets, required projects and the roadmap actions, investment needs for the period from 2023-2027 is summarised below.

It is envisaged that most of the projects will be private sector driven with the exception of the port development and infrastructure which will be public sector driven.

Funding for project development (pre-feasibility and feasibility studies)	
Description	**ZAR billion**
Sustainable Aviation Fuel Production	0.10
e-methanol Production	0.12
Fuel Cell Manufacturing	0.16
GH and Green Ammonia Production	3.70
Green Steel Production	0.20
Hydrogen Mobility	0.10
Infrastructure	0.13
Port project development	1.00
TOTAL	**5.51**
Capital Costs for the implementation of the above projects	
Description	**ZAR billion**
Sustainable Aviation Fuel Production	8.00
e-methanol Production	12.00
Fuel Cell Manufacturing	1.40
GH and Green Ammonia Production	109.30
Green Steel Production	13.20

Hydrogen Mobility	6.60
Infrastructure*	13.00
Port infrastructure capital	150
TOTAL	**313.5**
TOTAL FOR PROJECT DEVELOPMENT AND CAPITAL COSTS FOR IMPLEMENTATION	**319.01 ($18,4bn)**

13.4. Summary of Commercialisation Strategy

The successful implementation of the commercialisation strategy will depend on the execution of the six key elements :

1 PRIORITISE EXPORTS	2 STIMULATE DOMESTIC MARKET	3 SUPPORT LOCALISATION	4 SECURE FINANCING	5 PROACTIVE SOCIO ECONOMIC DEVELOPMENT
Target exports of green hydrogen and green chemicals by leveraging on South Africa's proprietary Fischer Tropsch technology and utilising financing support mechanisms including grants, concessional debt and contract for difference / price subsidies to improve the financial viability of these projects	In parallel to the export strategy, develop projects along the value chain to stimulate demand for green hydrogen in South Africa. "Low hanging fruit" opportunities to be prioritised to provide confidence in the domestic market. Examples include green steel, hydrogen valley mobility programme and sustainable aviation fuel projects.	Develop local industrial capability to produce fuel cells, electrolyser, ammonia cracking and balance of plant equipment and components by leveraging on South Africa's PGM resources. Together with demand stimulation this will drive longer term GH_2 price reduction allowing penetration in various sectors.	"Crowd in" and secure funding from various sources and in various forms including grants, concessional debt and contract for differences.	Maximise development impact (incl. skills and economic development and social inclusion). Ensure gender equality, BBBEE and community participation. Maximise job creation and alternative options for potential job losses.

6 ROLE OF GOVERNMENT IN POLICY AND REGULATORY SUPPORT

Position GH_2 as a key early contributor to decarbonization and a just transition in the country programme of work being collated by the JET-IP Task Team ensuring a fair proportion of climate finance is sourced to enable development of this industry.

Prioritize the execution of the green hydrogen commercialisation strategy and the development of a national GH_2 infrastructure plan

Drive the required policy and regulatory changes required to sustain long term growth of the new hydrogen industry.

Mobilise and coordinate the Government support required to support the development of this new industry for South Africa.

14. Conclusion

The GHCS presents a strong business case for South Africa to develop a GH_2 industry that will support both economic and social ambitions for the country. In order for the 2050 vision to materialise the defined action in the GHCS will need to have a prioritised implementation with focus on the following actions:

- Clear policy support from Government including implementing regulatory changes as defined in the GHCS action plan.
- Development of the different scenarios for funding, taking account of JET-IP and private sector funding, to determine the extent of public incentives required at the appropriate time to support the short and medium term ramp up of this new industry, and decarbonisation of heavy industries and agriculture, leading to the achievement of the GHCS 2050 targets.
- Establishing a regulatory and market framework around new[24] GH_2 manufacturing, production, use, transport and storage to drive investment in South Africa's GH_2 economy.
- Establish bilateral engagements and agreements between South Africa and key international consumers.
- Mobilise a task team to investigate the social, economic and environmental impact of various scenarios and determine the value that could be derived by acceleration of the GH_2 value chain. This would include an assessment of the enabling levers including tax incentives, grant schemes and reduced import surcharges on technology options, production incentives and demand stimulation incentives to support the short erm objectives of the GHCS.
- Assessment of the current infrastructure requirements in terms of transmission grid, renewable energy, transport infrastructure (pipelines, ports, roads, rail) and the investments required in order to support the development of the value chain and ensure that private projects are able to access key infrastructure. Specifically undertake a pre-feasibility study on potential new GH_2 pipelines.
- Developing and securing funding instruments and disbursing specific funds such as international grants, specific hydrogen concessional funds and pricing subsidies to support the current catalytic projects and potentially newly initiated projects.
- Support of the development of the projects that have been granted SIP status as Gazetted in December 2022 towards reaching final investment decisions.
- Initiate and develop additional projects aligned to the medium term ramp up targets of the industry.
- Support the development of the identified GH_2 hubs and valleys to ensure accelerated impact in developing the new GH_2 industry and associated green industries.
- Analyse and plan for a Just Transition, ensuring appropriate public and social dialogue and understanding.
- Engage in a social dialogue between workers and their unions, employers, government and communities in order to ensure that GH2 development contributes to climate change mitigation as well as adaptation. Ensure appropriate training and skills development programmes to limit job losses and support employment as industry sectors decarbonise.

It is anticipated that a series of business plans and implementation plans will be periodically released with specific responsibilities identified in order to address resource availability with

[24] Here reference is made to the establishment of a regulatory framework beyond which (grey) hydrogen is currently regulated.

both public and private sector backed initiatives. Annual feedback will be provided to Cabinet on progress achieved and interventions recommended to accelerate development of the GH_2 value chain.

The National Green Hydrogen Commercialisation Strategy will build on momentum of HySA programme and the Hydrogen Society Roadmap to position South Africa as a global player in GH_2, green chemicals and green manufacturing. The development of this new GH_2 industry will support South Africa's Economic Reconstruction and Recovery Plan. Implementation of the action plans should ensure a Just Transition tackling skills development, job creation, gender equality and social inclusion, addressing the triple challenge of poverty, inequality and unemployment. Stronger partnerships will be built between Government, the private sector and civil society by creating an enabling environment. Implementation should drive international partnerships while protecting national interest. South African should be rebranded as a destination for sustainable investment incorporating Environmental, Social and Governance principles.

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16. Appendix A: Hydrogen Demand and Supply Estimation and Benchmarking

Overview of hydrogen and ammonia demand today

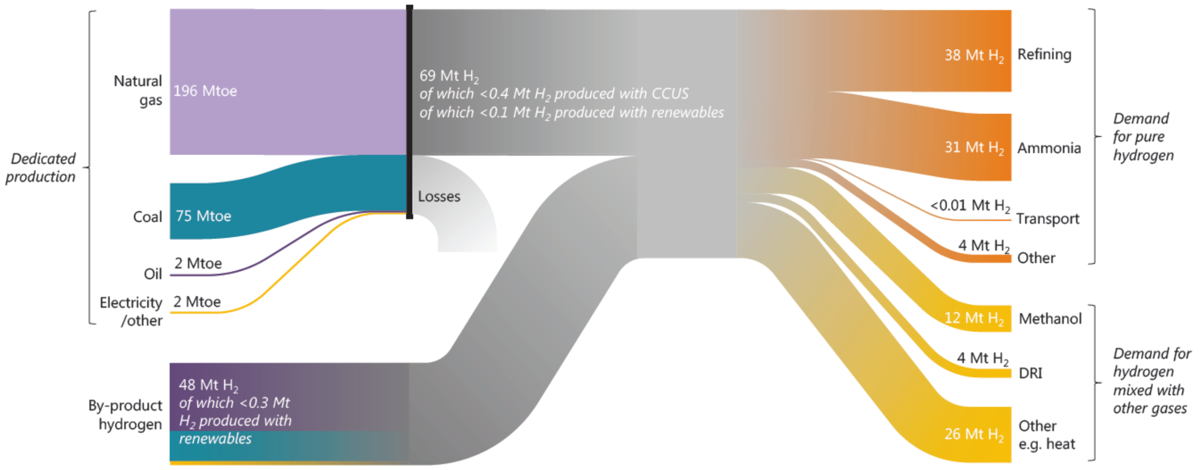

Figure B.1: Hydrogen and Use Cases

In 2020, demand for hydrogen was 90 Million tonnes (Mt), mainly produced from fossil fuels (mostly natural gas) and emitting close to 900 Mt CO_2. This worldwide demand is for “pure” hydrogen, with “pure” meaning that the specific applications require hydrogen with only small levels of additives or contaminants tolerated (Figure B.1). The main applications for this hydrogen are oil refining and ammonia production, mainly for fertilisers. A further 45 Mt of demand exists for hydrogen as part of a mixture of gases, such as synthesis gas, for fuel or feedstock. The main applications for hydrogen as part of a mixture of gases are methanol production and steel production. While one-third of hydrogen demand today is for transport sector applications in a broad sense – in refineries and for methanol used in vehicle fuel – less than 0.01 Mt per year of pure hydrogen (less than 0.03 Million tonnes of oil equivalent, Mtoe) is used in FCEVs, most of which is derived from natural gas.

The overwhelming majority of hydrogen produced today is from fossil fuels, and around 60% of it is produced in “dedicated” hydrogen production facilities, meaning that hydrogen is their primary product. Most of this is produced from natural gas, though some comes from coal, and a small fraction comes from water electrolysis (a process that produces hydrogen from water and electricity).

One-third of global supply is “by-product” hydrogen, meaning that it comes from facilities and processes designed primarily to produce something else. This by-product hydrogen often needs dehydrating or other types of cleaning, and can then be sent to a variety of hydrogen-using processes and facilities. Most hydrogen is currently produced near to its end use, using resources extracted in the same country.

Overall, less than 0.7% of current hydrogen production is from renewables or from fossil fuel plants equipped with Carbon Capture Utilisation and Storage (CCUS). In total, hydrogen production, which is mainly blue and grey hydrogen, today is responsible for 830 Mt CO_2/yr.

Trading of hydrogen and ammonia today

In order to assess the future markets for hydrogen and ammonia, data on current hydrogen and ammonia production and trading was sourced and analysed.

The current market for the export of hydrogen is small. In 2019, the top 10 exporting countries exported ~85 kt (kt) (Figure B.2) of hydrogen and just two countries make up 82% of the total imported hydrogen at ~70 kt. The top 10 importing countries imported ~56 kt (Figure B.3) of hydrogen and the EU and USA make up 93% of the total imported hydrogen at ~54 kt. These numbers reflect the current use cases for hydrogen as an industrial gas and not the energy vector that it will become over the next few years as the global economy transitions to lower carbon alternatives. It must also be noted that international trade in energy products takes time to develop, with the Liquified Natural Gas (LNG) market taking a period of 30 years to reach the scale as Qatar and Australia became large-scale exporters of LNG. To date there has been no trade in hydrogen using a vessel dedicated to shipments of pure hydrogen.

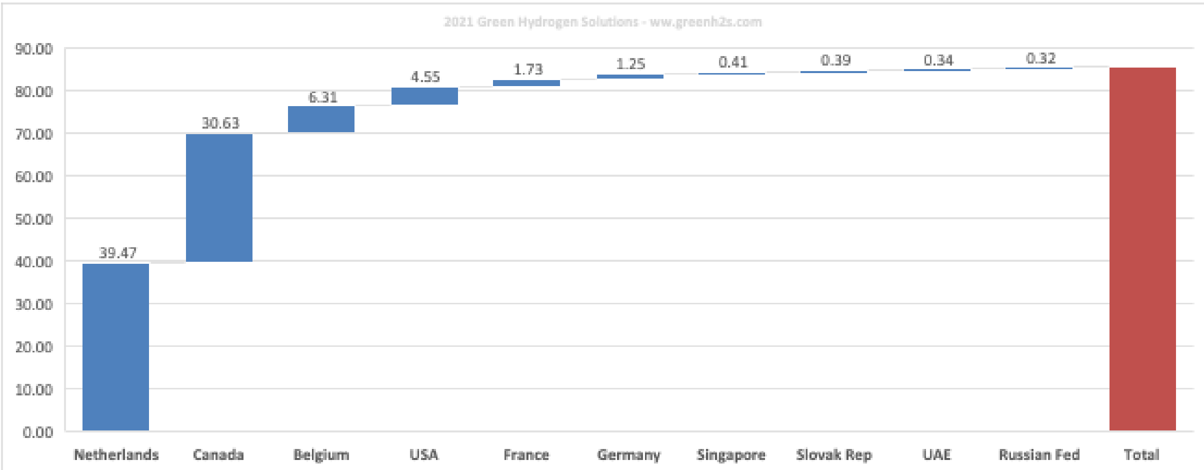

Figure B.2: 2019 - Hydrogen Exports by Country (top 10) – kt

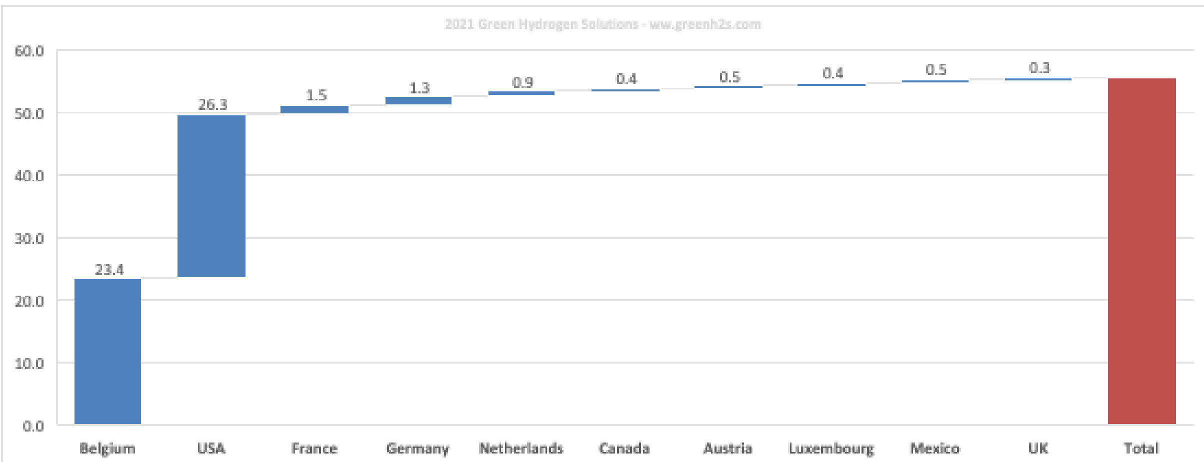

Figure B.3: 2019 - Hydrogen Imports by Country (top 10) – kt

The international market for ammonia is well developed, having commenced international trading as early as the 1960s. In 2019, the top 10 exporting countries exported ~14 Mt of ammonia containing ~2.5 Mt of hydrogen (Figure B.4) and the top 10 importing countries imported ~16 Mt ammonia containing ~2.8 Mt of hydrogen (Figure B.5). Total global trade in ammonia is ~16.9 Mt of ammonia containing ~ 3 Mt of hydrogen. Exports are dominated by Saudi Arabia and the Russian Federation, which make up ~66% of the total exports. Imports are dominated by the EU, India, USA and South Korea. The current EU demand makes up ~29% or ~4.6 Mt of ammonia containing ~ 0.8 Mt of hydrogen. These numbers reflect the current use cases for ammonia as an industrial chemical and not the energy carrier and director energy vector that it will become over the next few years as the global economy transitions to lower carbon alternatives. The maritime industry sees ammonia as pivotal to achieving decarbonisation targets, replacing diesel, heavy fuel oil and other carbon-based fuels.

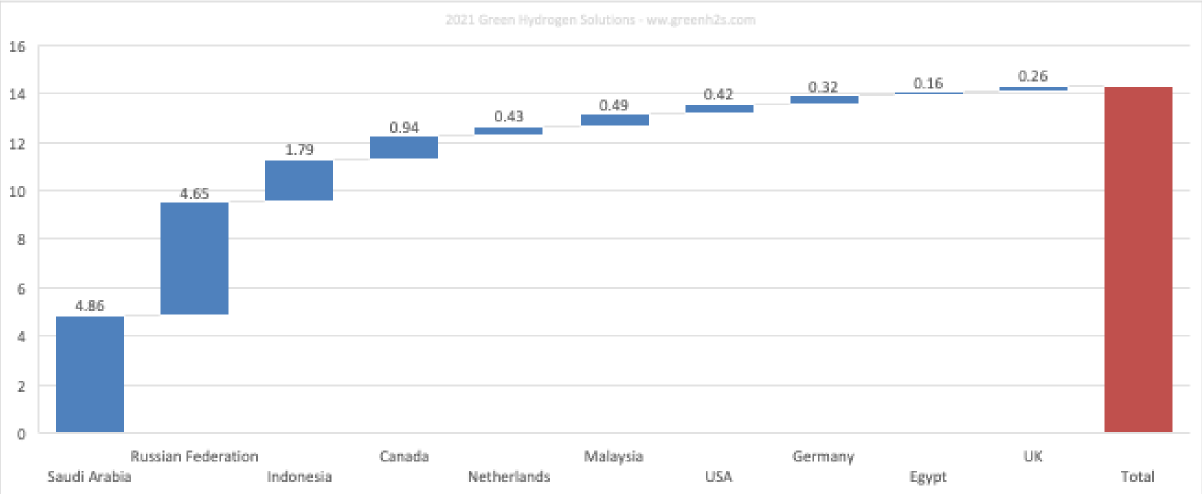

Figure B.4: 2019 - Ammonia Exports by Country (top 10) – Mt

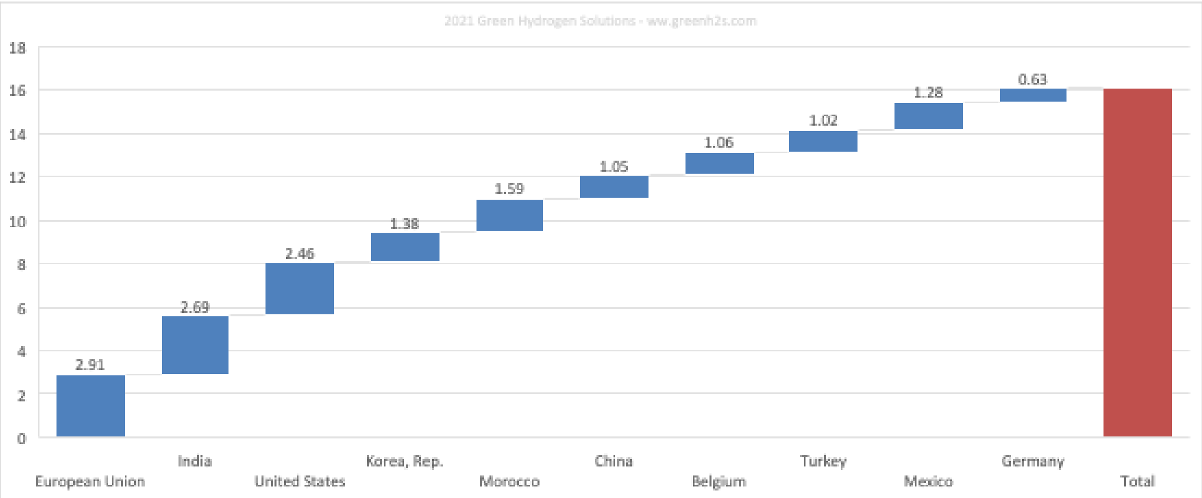

Figure B.5: 2019 - Ammonia Imports by Country (top 10) – Mt

Export demand drivers

The size range for the import market will be between 18 and 27 Mt of GH, refer to Figure B.6.

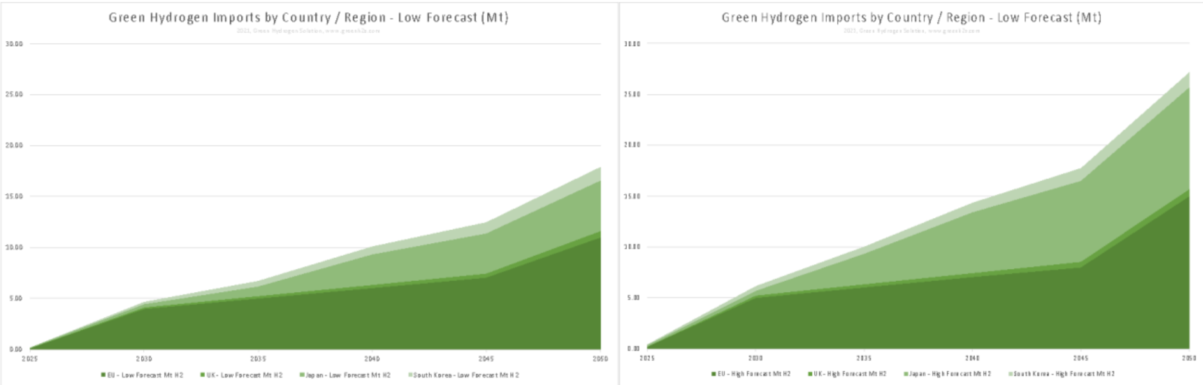

Figure B.6: Import Market Size Range (low and High) – 2025 to 2050

The demand profiles of the countries from 2025 to 2050 in five-year increments are presented in Figures B.7 and B.8.

GH costs will evolve over time as countries implement pilot projects followed by large scale projects to gain practical experience and capitalise on efficiencies through learning curves and scale effects on production equipment, such as electrolysers. Refer to Figures B.9 and B.10.

To supply the demand of between 18 and 27 Mt of GH in 2050, and assuming that all logistics will be undertaken with ammonia, the total investment required by all countries will be between US$0.5 to $0.8 trillion to 2050 based on a declining cost curve, which reflects learning rates for renewable energy (wind, solar), hydrogen and ammonia production (electrolysers and balance of plant) and transmission infrastructure. In 2021 money terms and costs, the installed costs total between $0.7 and $1.2 trillion to 2050. To supply the 2025 target of 200 to 400 kt of GH will require between $15 and $31 billion by 2025. Refer to Table B.1.

All exporting countries will need to make significant investments to meet the import demand.

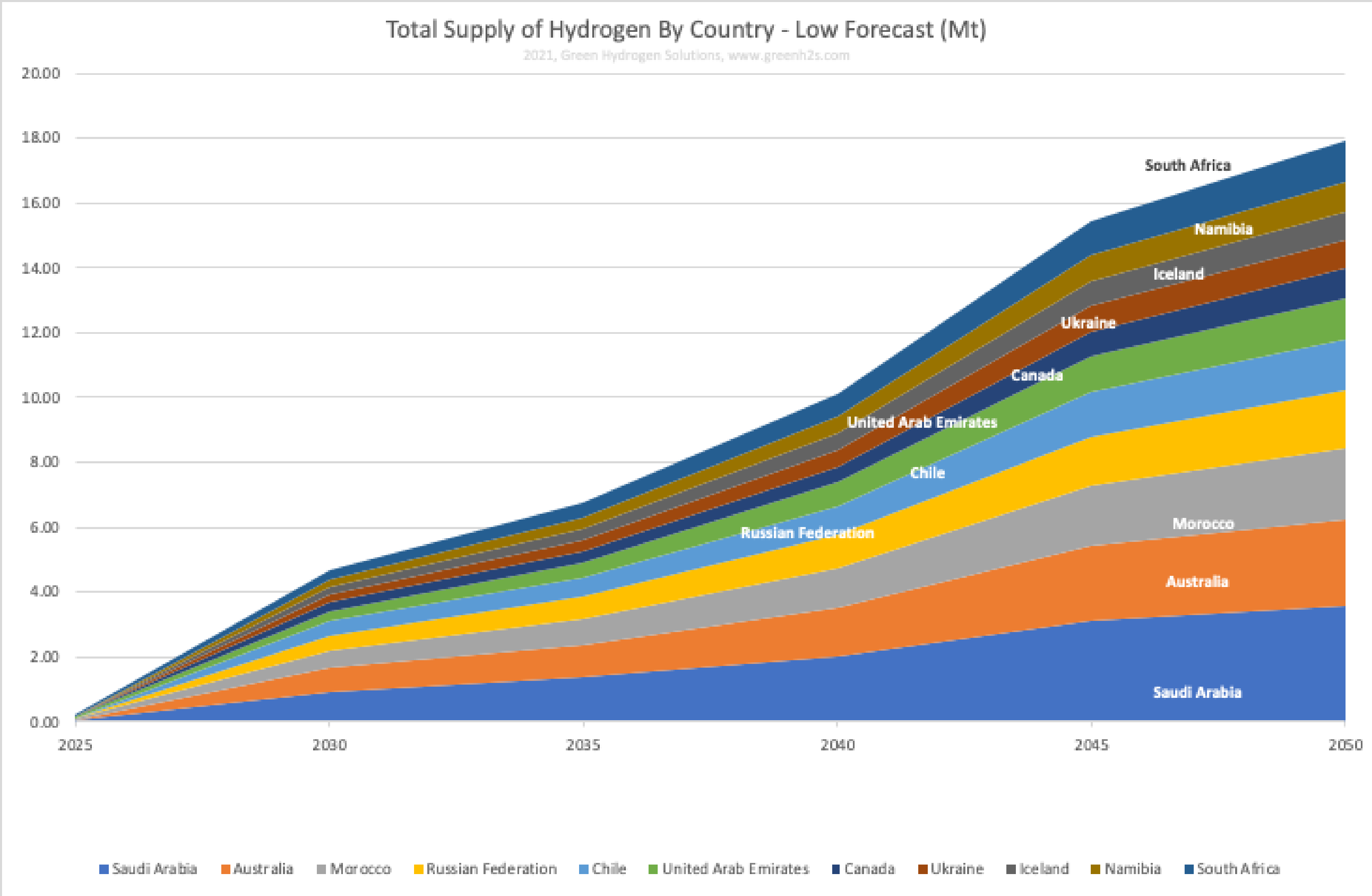

Figure B.7: Total Supply of Hydrogen By Country - Low Forecast (Mt)

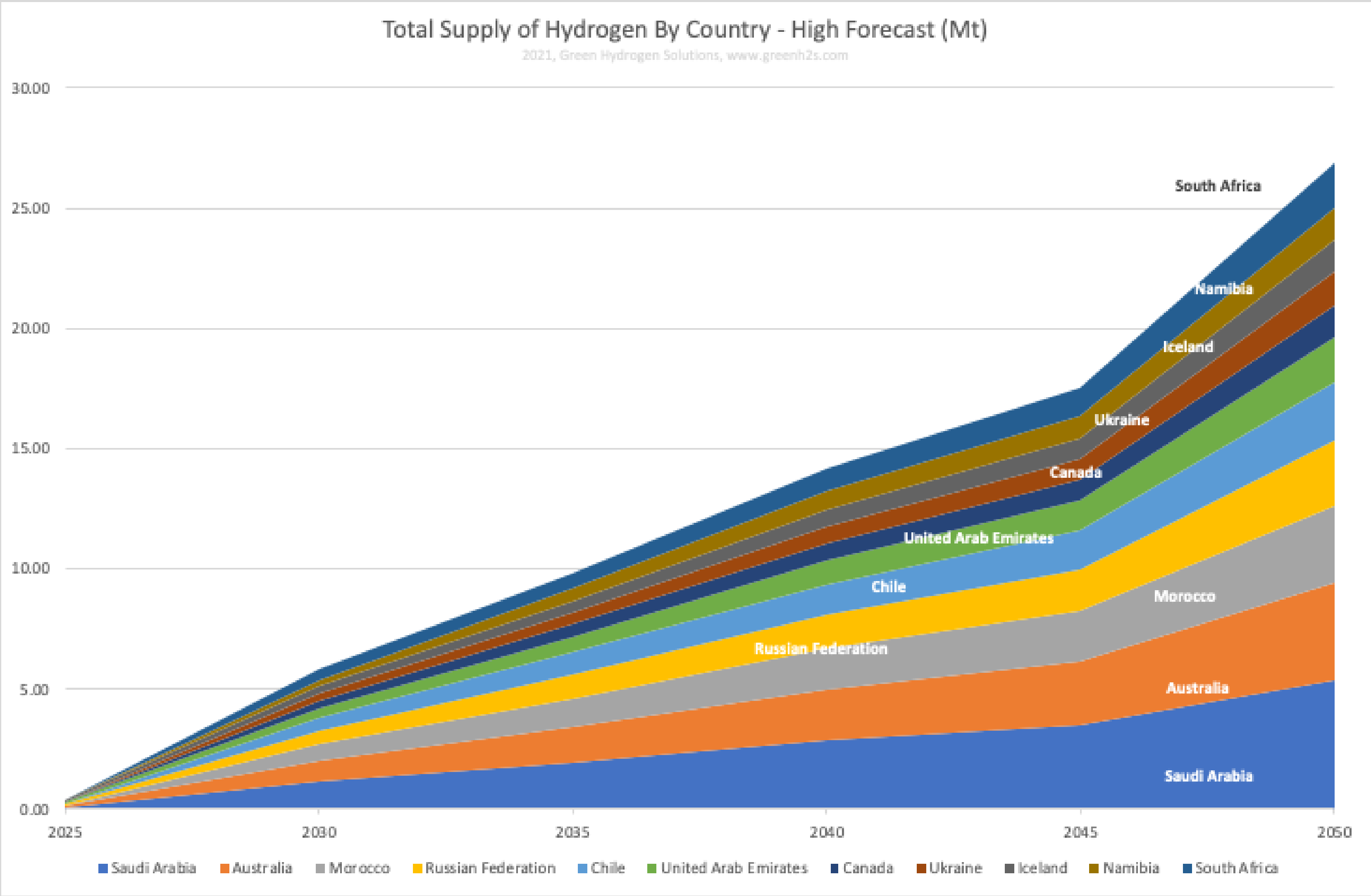

Figure B.8: Total Supply of Hydrogen By Country - Low Forecast (Mt)

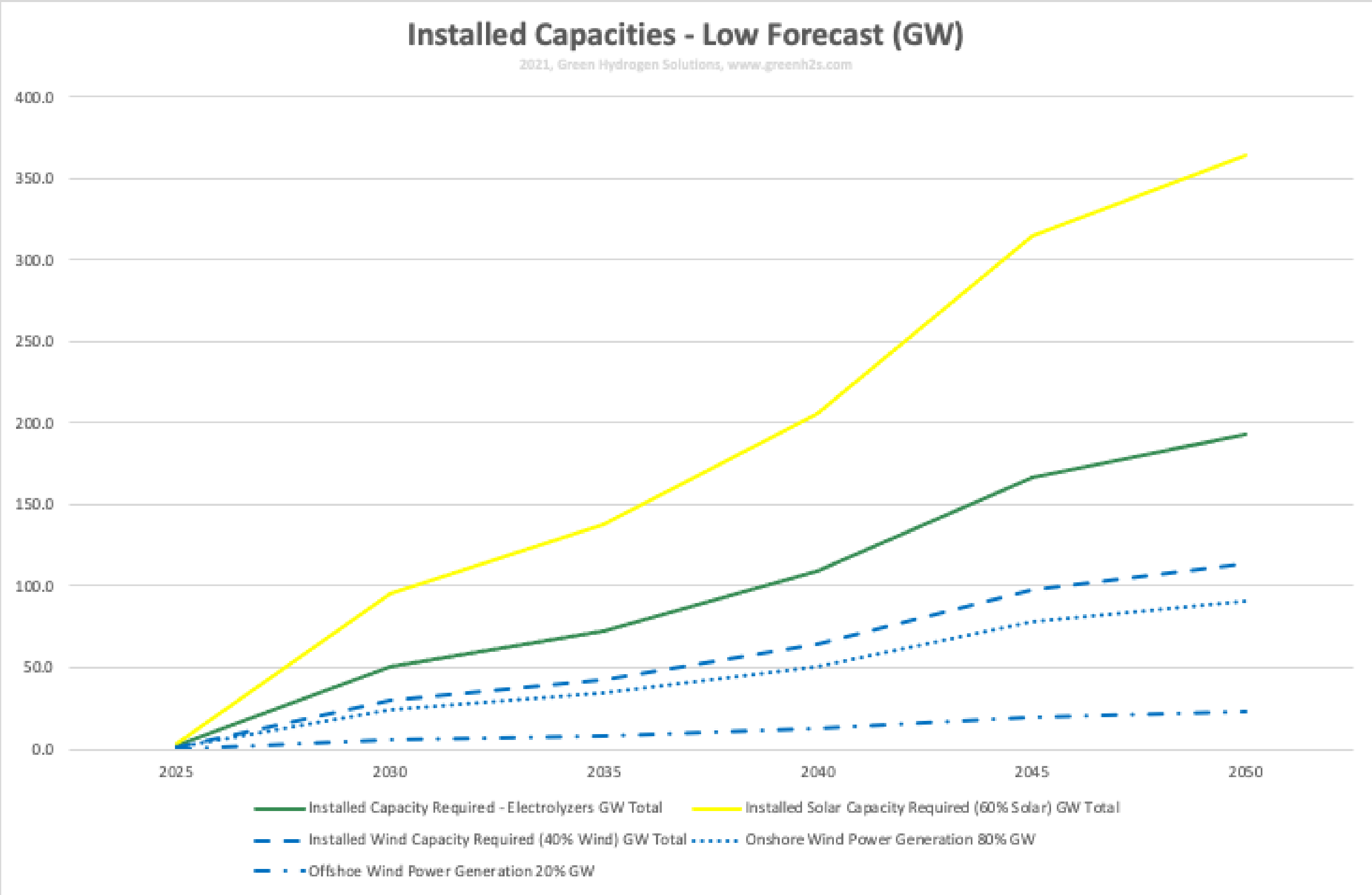

Figure B.9: Global Installed Capacities - Low Forecast (GW)

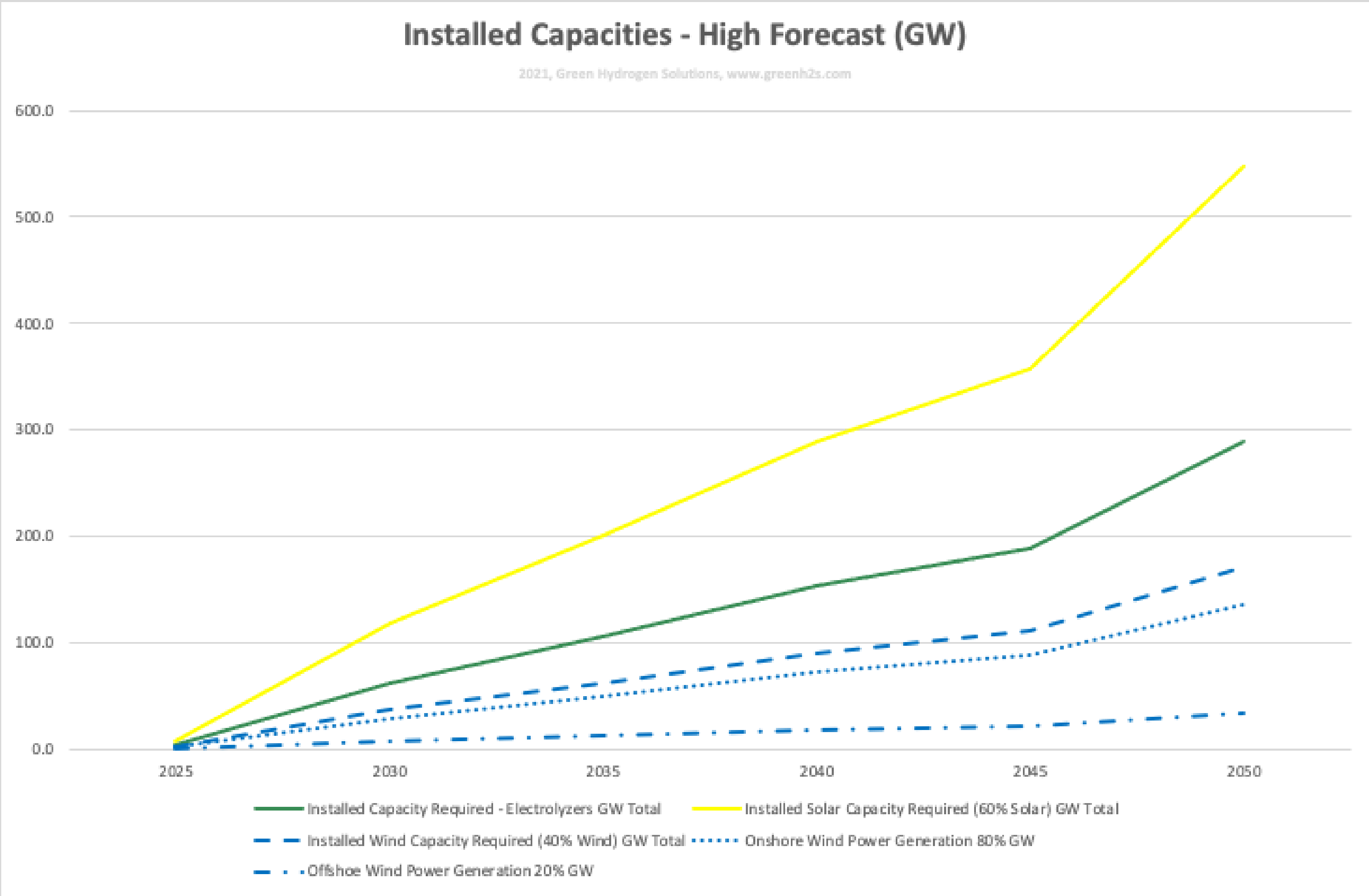

Figure B.10: Global Installed Capacities – High Forecast (GW)

Table B.1: Global Installed Costs Required to Meet Demand

INSTALLED COSTS BUILD-UP (CAPEX) - 2021 Terms		Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
Electrolysis and Balance of Plant	**$/kW**	740	888	650	780	480	576	360	432	270	324	200	240		
Electrolysis and Balance of Plant	**$ B**	1.6	3.8	31.5	45.3	10.6	25.1	13.0	20.2	15.5	11.7	5.3	24.2	**77**	**130**
Installed Cost - Solar	**$/kW**	696	766	592	651	503	553	428	470	363	400	309	340		
Installed Cost - Solar	**$ B**	2.8	6.2	54.2	71.6	21.0	45.6	29.2	41.7	39.6	27.3	15.4	64.7	**162**	**257**
Installed Cost - Wind	**$/kW**	1 606	1 767	1 365	1 502	1 160	1 276	986	1 085	838	922	713	784		
Installed Cost - Wind	**$ B**	2.0	4.5	38.9	51.3	15.1	32.7	20.9	29.9	28.4	19.6	11.1	46.4	**116**	**184**
Installed Cost - Ammonia	**$ / t** NH_3	994	1 094	900	990	850	935	800	880	706	776	588	647		
Installed Cost - Ammonia	**$ B**	1.1	2.5	22.9	30.2	9.8	21.4	15.1	21.6	21.3	14.7	8.1	34.2	**78**	**125**
Installed Cost - Transmission	**$ M / km**	1.3	1.3	1.2	1.2	1.2	1.1	1.1	1.1	1.0	1.0	1.0	0.9		
Installed Cost - Transmission	**$ B**	7.0	13.5	6.6	12.7	6.2	12.0	5.8	11.3	5.5	10.6	5.1	10.0	**36**	**70**
Total Capex	**$ B**	15	31	154	211	63	137	84	125	110	84	45	179	**471**	**766**

Installed Costs are based on a declining cost curve, which reflects learning rates for renewable energy (wind, solar), hydrogen and ammonia production (electrolysers and balance of plant) and transmission infrastructure. In 2021 money terms, the installed costs total between $0.7 and $1.2 trillion.

Maritime demand for hydrogen and ammonia

Figure B.11 provides details of Maritime Demand for Hydrogen and Ammonia from 2025 to 2050.

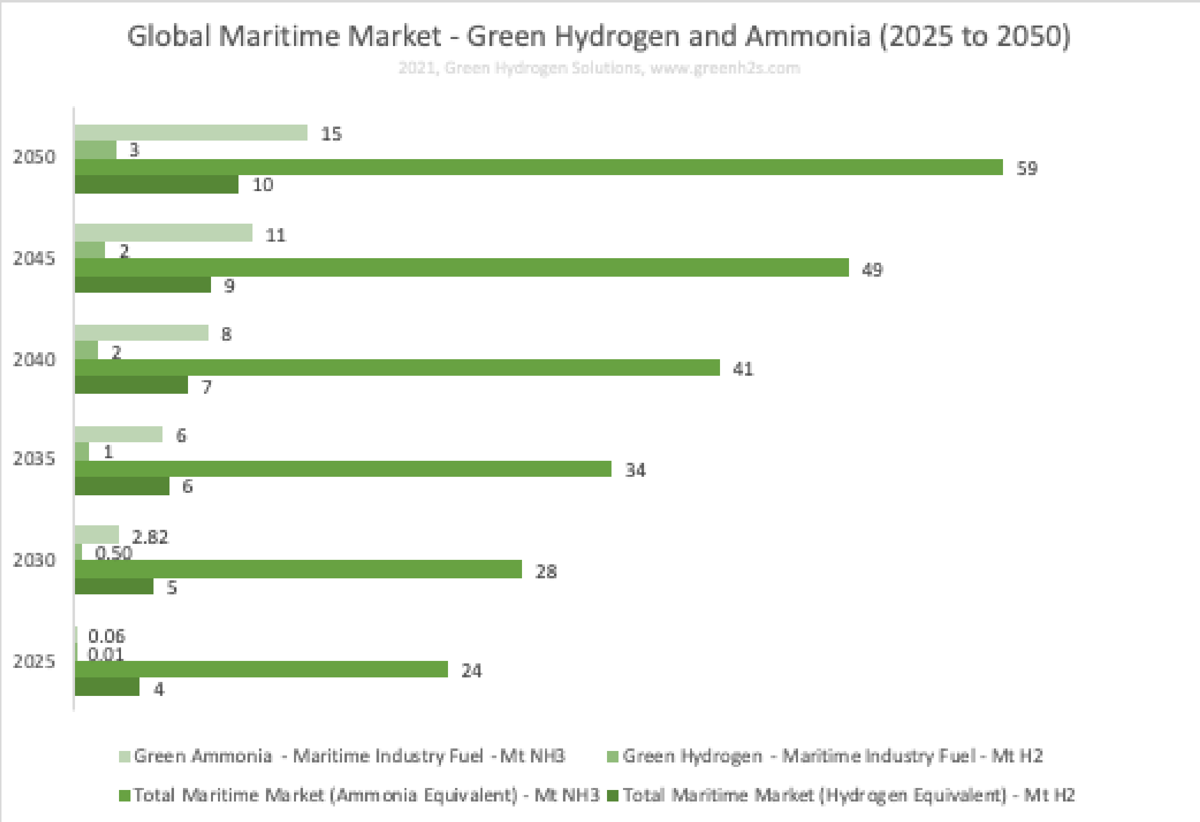

Figure B.11: Maritime Demand for Hydrogen / Ammonia – 2025 to 2050

South Africa key statistics

GH costs will evolve over time as South Africa implements pilot projects followed by large scale projects to gain practical experience and capitalise on efficiencies through learning curves and scale effects on production equipment, such as electrolysers. To supply 1.7 to 2.2 Mt of GH (Figures B.13 TO B.16) for the domestic market will require a total investment between US$68 to $100 billion (R1.0 to 1.5 trillion) to 2050 based on a declining cost curve, which reflects learning rates for capital equipment (US$82 to $122 billion or R1.2 to 1.8 trillion in 2021 money terms and costs). Refer to Table B.2 and B.3.

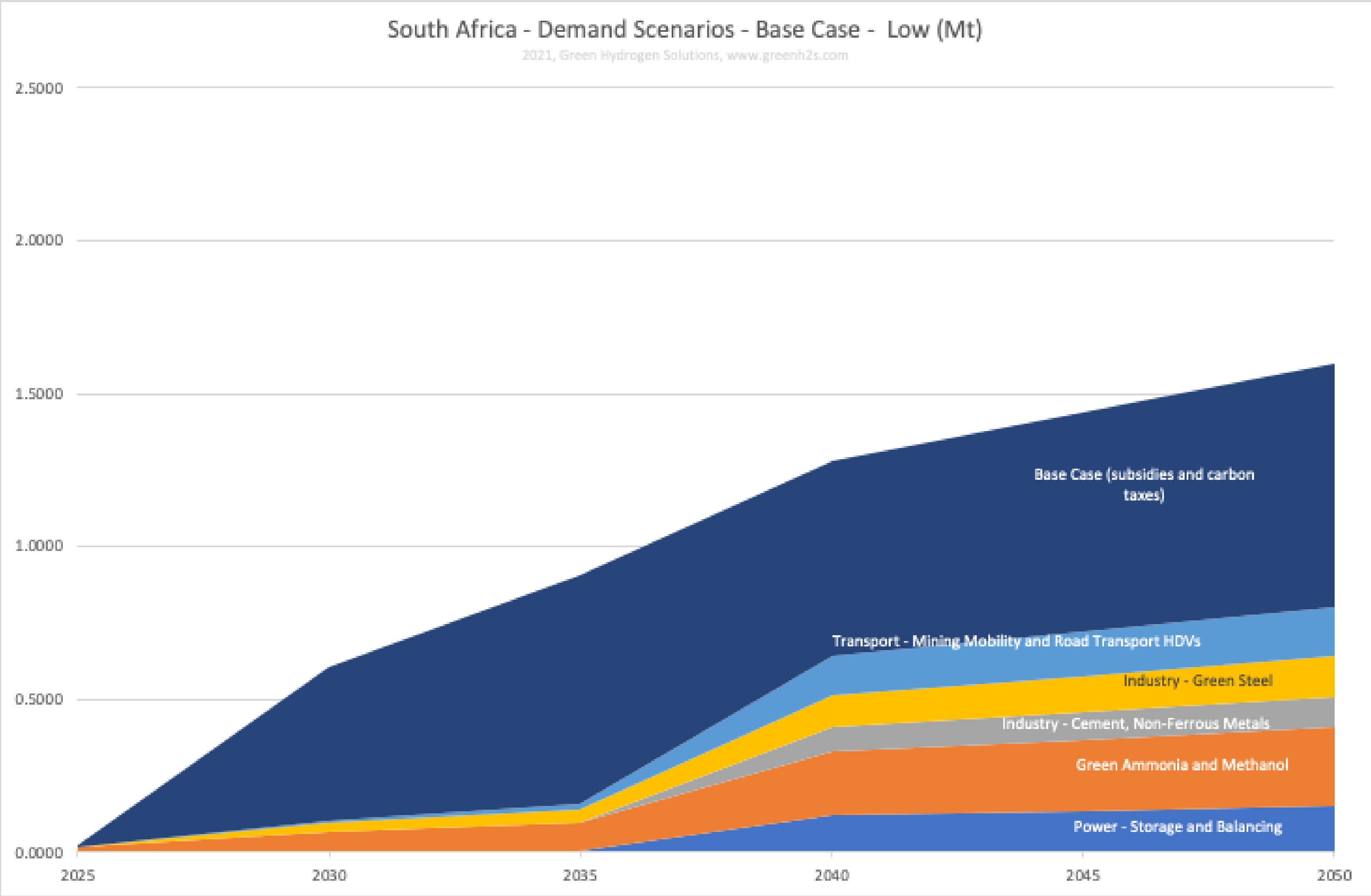

Figure B.13: South Africa Domestic Demand Scenario – Base Case – Low

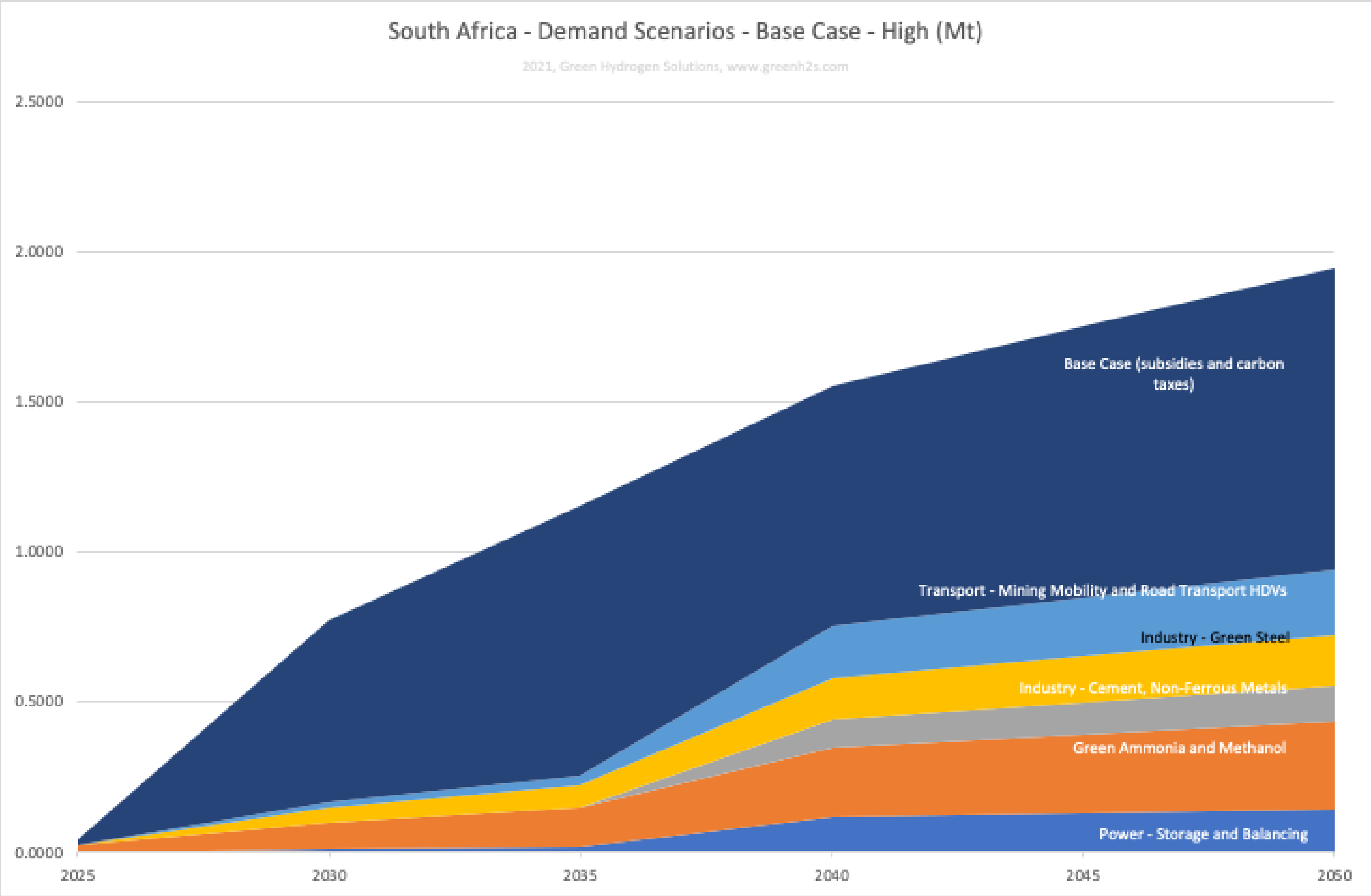

Figure B.14: South Africa Domestic Demand Scenario – Base Case - High

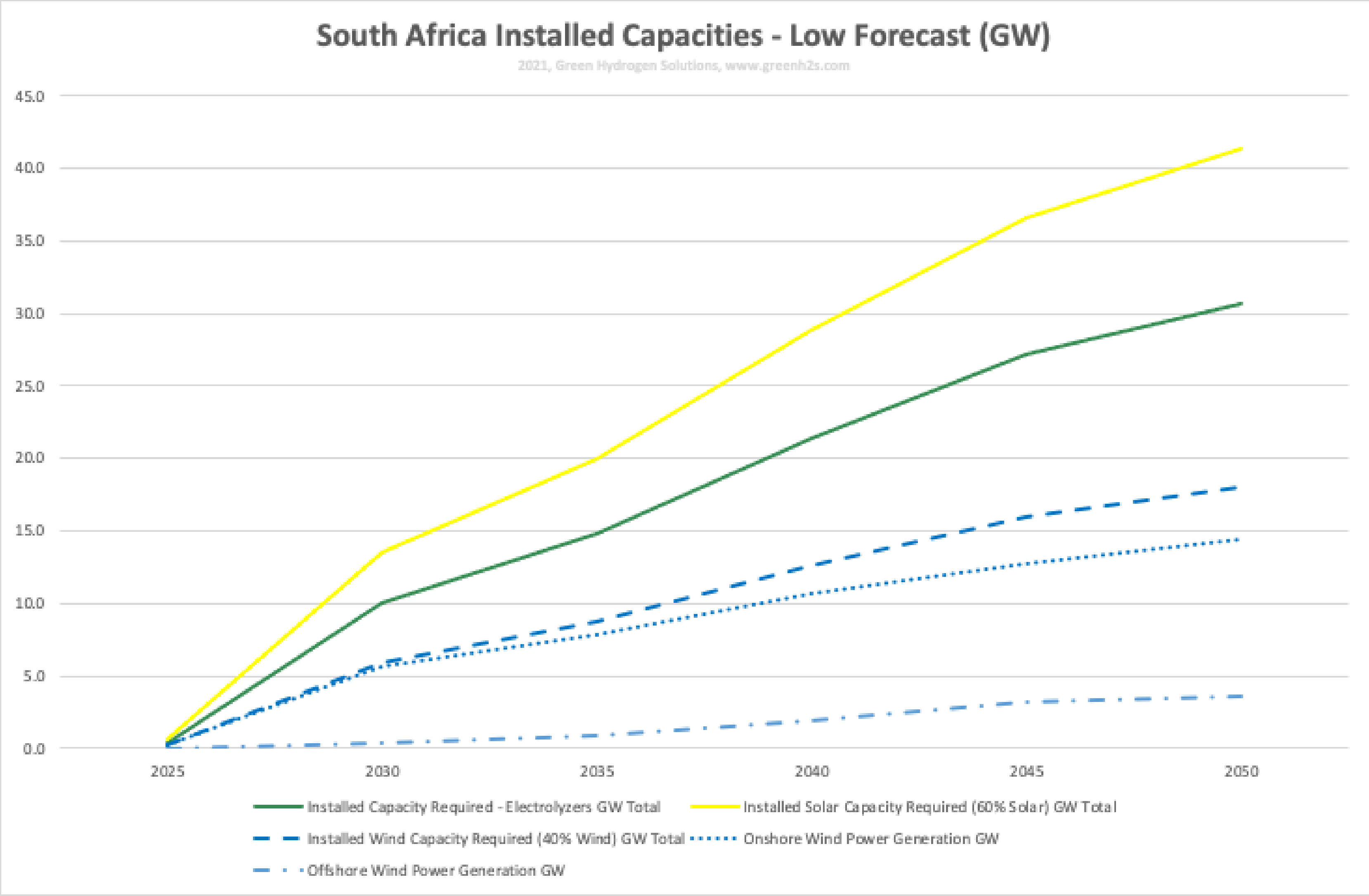

Figure B.15: South Africa Installed Capacities – Base Case – Lo

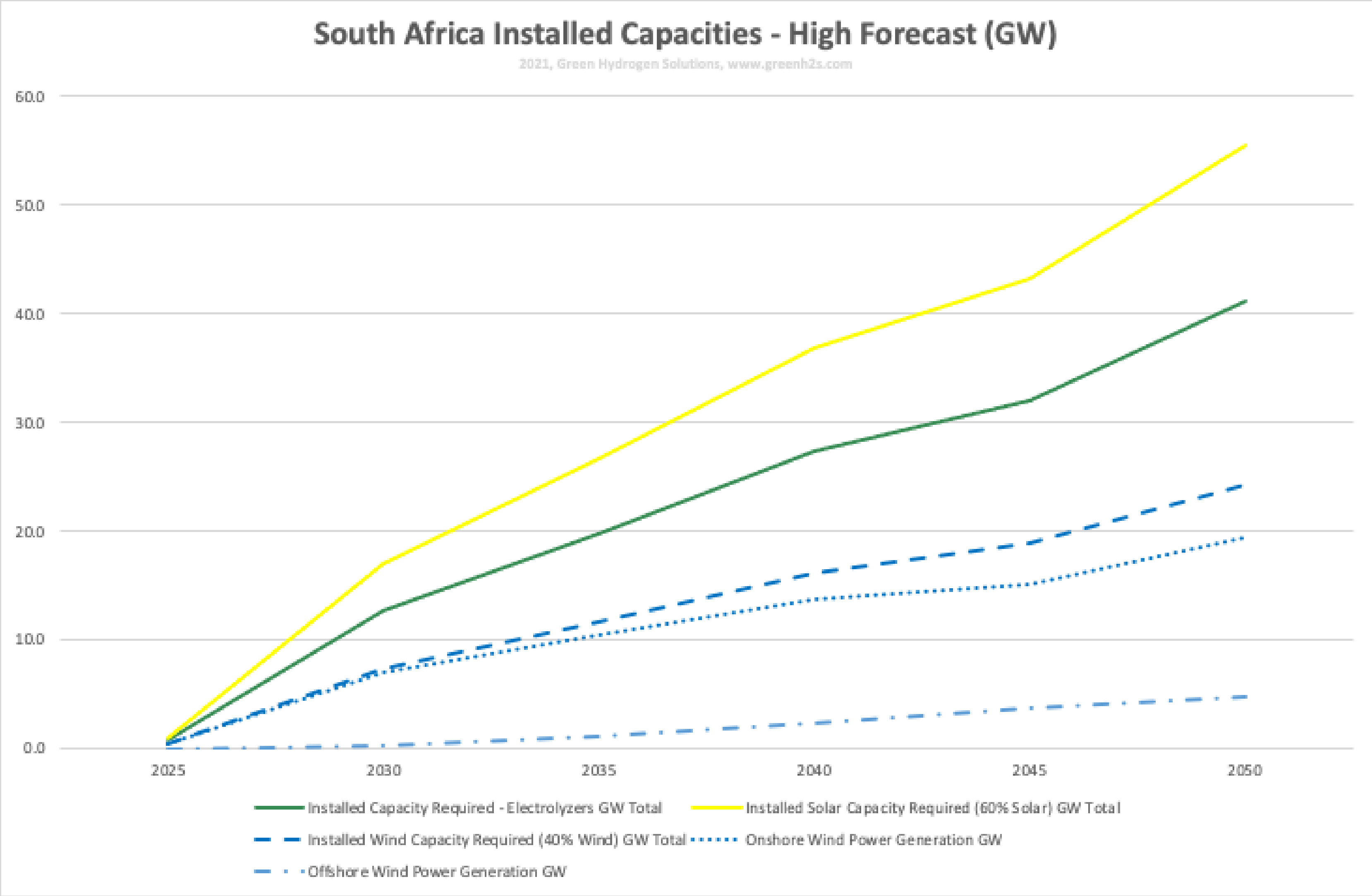

Figure B.16: South Africa Installed Capacities – Base Case – High

Table B.2: South Africa – Installed Costs Required to Meet Demand – US$

DOLLAR CAPITAL COSTS 2021, Green Hydrogen Solutions	www.greenh2s.com	2025		2030		2035		2040		2045		2050		Total	
INSTALLED COSTS BUILD-UP (CAPEX) - 2021 Terms		Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
Electrolysis and Balance of Plant	**$/kW**	740	888	650	780	480	576	360	432	270	324	200	240		
Electrolysis and Balance of Plant	**$ B**	0.3	0.7	6.3	9.3	2.3	4.1	2.4	3.3	1.6	1.5	0.7	2.2	**13**	**21**
Installed Cost - Solar	**$/kW**	696	766	592	651	503	553	428	470	363	400	309	340		
Installed Cost - Solar	**$ B**	0.4	0.8	7.7	10.4	3.3	5.4	3.8	4.8	2.8	2.5	1.5	4.2	**19**	**28**
Installed Cost - Wind	**$/kW**	1 606	1 767	1 365	1 502	1 160	1 276	986	1 085	838	922	713	784		
Installed Cost - Wind	**$ B**	0.4	0.8	7.7	10.5	3.3	5.4	3.8	4.8	2.8	2.5	1.5	4.2	**20**	**28**
Installed Cost - Ammonia	**$ / t NH_3**	994	994	900	900	850	850	800	800	706	706	588	588		
Installed Cost - Ammonia	**$ B**	0.1	0.2	1.7	2.1	0.8	1.5	1.3	1.6	1.5	1.0	0.6	2.2	**6**	**9**
Installed Cost - Transmission	**$ M / km**	1.3	1.2	1.2	1.2	1.1	1.1	1.1	1.0	1.0	1.0	0.9	0.9		
Installed Cost - Transmission	**$ B**	1.8	3.4	1.7	3.2	1.6	3.0	1.5	1.4	1.4	1.3	1.3	1.3	**9**	**14**
Total Capex	**$ B**	3	6	25	36	11	19	13	16	10	9	6	14	**68**	**100**

Installed Costs are based on a declining cost curve, which reflects learning rates for renewable energy (wind, solar), hydrogen and ammonia production (electrolysers and balance of plant) and transmission infrastructure. In 2021 money terms, the installed costs total between $82 and $122 billion for 1.7 to 2.2 Mt per year.

Table B.3: South Africa – Installed Costs Required to Meet Demand – R

RAND CAPITAL COSTS 2021, Green Hydrogen Solutions	www.greenh2s.com	2025		2030		2035		2040		2045		2050		Total	
INSTALLED COSTS BUILD-UP (CAPEX) - 2021 Terms		**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**
Electrolysis and Balance of Plant	**R/kW**	11 008	13 209	9 669	11 603	7 140	8 568	5 355	6 426	4 016	4 820	2 975	3 570		
Electrolysis and Balance of Plant	**R B**	4.6	10.0	93.1	138.0	34.3	61.6	35.0	48.7	23.1	22.2	10.6	32.6	**201**	**313**
Installed Cost - Solar	**R/kW**	10 357	11 393	8 804	9 684	7 483	8 231	6 361	6 997	5 407	5 947	4 596	5 055		
Installed Cost - Solar	**R B**	5.9	11.6	114.2	155.1	48.4	79.7	55.9	71.4	41.9	37.0	22.1	62.2	**288**	**417**
Installed Cost - Wind	**R/kW**	23 892	26 281	20 308	22 339	17 262	18 988	14 672	16 140	12 472	13 719	10 601	11 661		
Installed Cost - Wind	**R B**	5.9	11.7	115.1	156.3	48.7	80.4	56.4	72.0	42.2	37.3	22.2	62.7	**291**	**420**
Installed Cost - Ammonia	**R / t NH_3**	14 788	14 788	13 388	13 388	12 644	12 644	11 900	11 900	10 500	10 500	8 750	8 750		
Installed Cost - Ammonia	**R B**	1.8	3.3	25.5	31.1	11.3	21.9	19.7	23.7	23.0	14.8	9.1	33.1	**90**	**128**
Installed Cost - Transmission	**R M / km**	19	18	18	17	17	16	16	15	15	14	14	13		
Installed Cost - Transmission	**R B**	26.2	50.7	24.6	47.7	23.2	44.9	21.8	21.1	20.5	19.9	19.3	18.7	**135**	**203**
Total Capex	**R B**	44	87	372	528	166	289	189	237	151	131	83	209	**1 005**	**1 482**

Installed Costs are based on a declining cost curve, which reflects learning rates for renewable energy (wind, solar), hydrogen and ammonia production (electrolysers and balance of plant) and transmission infrastructure. In 2021 money terms, the installed costs total between R1.2 trillion and $1.8 trillion for 1.7 to 2.2 Mt per year.

17. Appendix A: Renewable resources and stakeholder responsibilities

Value Chain Dependencies

South Africa possesses good renewables conditions (see Figure 35 and Figure 36). In order to understand South Africa's resources for GH, Table 7 matches elements required for GH, with the extent to which the country has control of the element and the relevant stakeholders that can influence the element. An assessment of the relevant finance, permitting and policy landscape is also undertaken, and the relevant state-owned entities and government departments responsible for managing this landscape are identified.

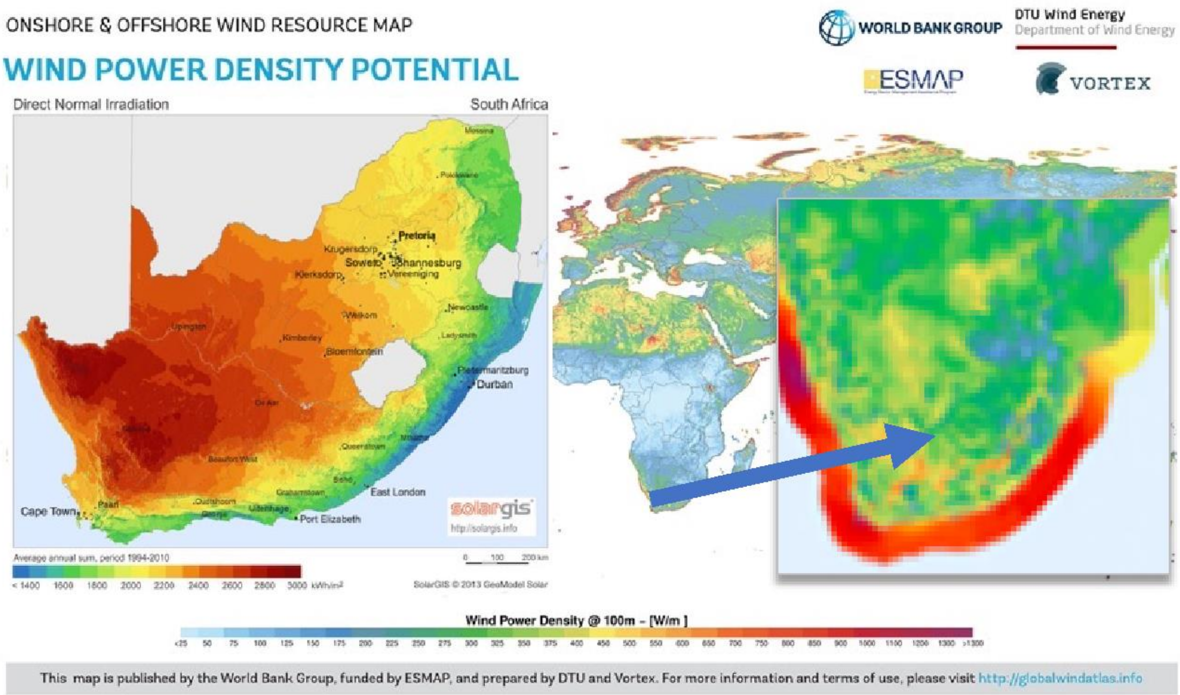

Figure 35: South Africa – Wind Resources

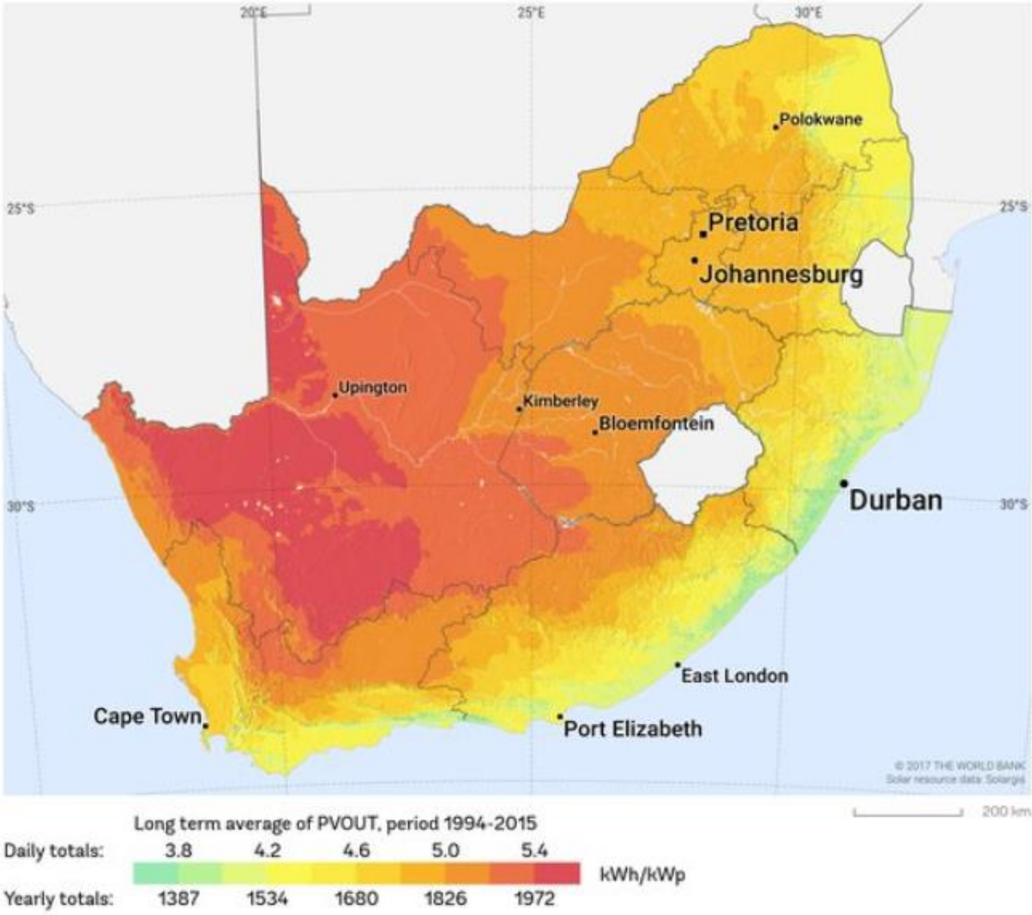

Figure 36. South Africa - Solar PV Resources

Table 7. GH Value Chain Dependencies, Optimization and Critical Role Players in South Africa

Element	Within South Africa's Control (maximization strategy for optimal value chain)	Not Within South Africa's Control (minimization strategy for optimal value chain)	Critical Role Players to enable the GH value chain (non-exhaustive)
Natural Endowment – Sea Water Resources and Freshwater Resources	South Africa has a large coastline with access to sea water. Freshwater can be managed for GH use. Mine water, Acid Mine Drainage water and waste water can also be processed.		water & sanitation Department: Water and Sanitation REPUBLIC OF SOUTH AFRICA agriculture, forestry & fisheries Department: Agriculture, Forestry and Fisheries REPUBLIC OF SOUTH AFRICA environmental affairs Department: Environmental Affairs REPUBLIC OF SOUTH AFRICA human settlements Department: Human Settlements REPUBLIC OF SOUTH AFRICA
Natural Endowment – Sun Hours	Solar hours are higher than global average . Here solar resources can be maximised by incentivizing investments in resource rich areas		
Natural Endowment – Wind Hours	Wind hours both onshore and offshore offer a significant opportunity to supplement solar hours. Here wind resources can be maximised by incentivizing investments in resource rich areas.		
Natural Endowment – Proximity to Atlantic and Indian Ocean	Proximity enables exports to the Western and Eastern hemispheres. Strategic entry into markets should be defined.		

Element	Within South Africa's Control (maximization strategy for optimal value chain)	Not Within South Africa's Control (minimization strategy for optimal value chain)	Critical Role Players to enable the GH value chain (non-exhaustive)
Renewable Electricity – Solar and wind	Regulations, taxes, permitting and other operational items to maximize benefits to incentivize investment.	The installed costs of solar and wind equipment, which is reliant on imports and subject to the exchange rate. Here local manufacturing options by OEMS should be evaluated.	the dtic Department: Trade, Industry and Competition REPUBLIC OF SOUTH AFRICA mineral resources & energy Department: Mineral Resources and Energy REPUBLIC OF SOUTH AFRICA national treasury Department: National Treasury REPUBLIC OF SOUTH AFRICA nersa NATIONAL ENERGY REGULATOR OF SOUTH AFRICA
Electrolysis and Balance of Plant	Regulations, taxes, permitting and other operational items (maximize benefits to incentivize investment)	The installed costs of electrolyser equipment, which is reliant on imports and subject to the exchange rate. Here local manufacturing options by OEMS should be explored and the PGM value chain should be leveraged the to maximize local content.	
Fischer-Tropsch (FT) and catalysis IP	Sasol is one of the few companies with the capacity to produce industrial scale P2X product. In addition, the company has the potential to use the IP of its catalyst book and experience of building, licensing and operating large-scale FT plants to produce P2X products elsewhere in the world.		

Element	Within South Africa’s Control (maximization strategy for optimal value chain)	Not Within South Africa’s Control (minimization strategy for optimal value chain)	Critical Role Players to enable the GH value chain (non-exhaustive)
GH and Ammonia Prices		In a regulated market sectors, price will be driven by cost of compliance until supply can meet demand. In a competitive market position, price of GH will be set by the lowest locational cost producer (use incentives, carbon subsidies and preferential funding to lower costs)	the dtic Department: Trade, Industry and Competition REPUBLIC OF SOUTH AFRICA mineral resources & energy Department: Mineral Resources and Energy REPUBLIC OF SOUTH AFRICA national treasury Department: National Treasury REPUBLIC OF SOUTH AFRICA nersa NATIONAL ENERGY REGULATOR OF SOUTH AFRICA
Ammonia Plant	Regulations, taxes, permitting and other operational items (maximize benefits to incentivize investment)	The installed costs of ammonia equipment (e.g., air separation unit), which is reliant on imports and subject to the exchange rate (evaluate local manufacturing options by OEMs)	

Element	Within South Africa's Control (maximization strategy for optimal value chain)	Not Within South Africa's Control (minimization strategy for optimal value chain)	Critical Role Players to enable the GH value chain (non-exhaustive)
Export Infrastructure – Rail, Ports	Infrastructure availability, tariffs, regulations, taxes, permitting and other operational items	The relative cost competitiveness of different transport modes	
Import Infrastructure – Rail, Ports (in importing countries)		Competition for import terminal allocations and tariffs will be fierce (proactively develop relationships with importing countries (government to government relationships) and GH import hubs)	

18. Appendix B: Identification, and assessment of strategic hydrogen hubs

The hub locations have been assessed according to the technical requirements of a hydrogen hub:

- Access to a renewable energy resource.
- Availability of renewable energy development zones (REDZ).
- Market positioning of the hydrogen hub; export, domestic, or both.
- Existing infrastructure including logistics networks, transmission corridors, and port access.
- Existing industries which could serve as anchors for the local deployment of hydrogen i.e., demand proximity.
- Access to resources, including human capital, components, and equipment.
- Purpose of the hydrogen hub, which could either be:
    a. To serve an export market.
    b. To develop a domestic market alongside the export infrastructure.
    c. To anchor local hydrogen deployment in the PGM industry.

Figure 37 below shows the assessment framework and the rating of each location. Figure 38 shows the hydrogen hub locations, and provides an overview of each location's relative advantages, risks and purpose. Figure 39 shows the visual representation of the GH hub locations, as well as the demarcated REDZ, existing infrastructure, and industrial activity.

	West Coast		Central (Inland)	Southeast coast		
	Boegoes Bay	**Saldanha Bay**	**Vaal**	**Coega**	**eThekwini**	**Richards Bay**
Renewable energy resource*	**Solar - 2,100 kWh/m²** Wind - 6.3 m/s	**Solar - 2,100 kWh/m²** Wind - 7.7 m/s	**Solar - 2,100 kWh/m²** Wind - 4.4 m/s	Solar - 1,800 kWh/m² **Wind - 8.0 m/s**	Solar - 1,700 kWh/m² Wind - 6.7 m/s	Solar - 1,700 kWh/m² **Wind - 7.9 m/s**
REDZ	*REDZ8 - Springbok 1.5 Mha available 200 km away*	*REDZ1 - Overberg REDZ2 - Komsberg 0.53 Mha & 0.88 Mha available 290 km & 360 km away*	*REDZ9 - Emalahleni REDZ10 - Klerksdorp - 200 km & 130 km away*	*REDZ3 - Cookhouse 0.74 Mha available 150 km away*	*REDZ4 - Stormberg 1.2 Mha available 640 km away*	*REDZ4 - Stormberg 1.2 Mha available 810 km away*
Market outlook	*Domestic (hydrogen) Export*	*Domestic (ammonia, hydrogen) Export*	*Domestic (various)*	*Domestic (hydrogen) Export*	*Export*	*Domestic (ammonia, hydrogen) Export*
Existing infrastructure*	*N1 road corridor Northern tx corridor Kimberley Airport (830 km) - -*	*N1 road corridor Western and Central tx corridor Cape Town Int'l Airport (150 km) Port - 21 m depth Storage facilities - 8 km from port*	*N3 road corridor Central tx corridor OR Tambo Int'l Airport (85 km) - -*	*N2 road corridor Eastern tx corridor Port Elizabeth Int'l Airport Port - 18 m depth Future storage - 790,000 m³*	*N2 and N3 road corridors Eastern tx corridor King Shaka Int'l Airport Port - 12 m depth -*	*N3 corridor - Richards Bay Airport Port - 12.5 m depth -*
Existing industries	*Agriculture Mining (iron, manganese) Manufacturing (cement, steel)*	*Agriculture Mining (zircon, rutile, ilmenite) Manufacturing (steel)*	*Manufacturing (agri-processing, (petro)chemicals, plastics, steel) Tourism*	*Manufacturing (automotive, FMCG, pharmaceuticals) Property development Tourism*	*Mining (coal, quarry) Manufacturing (automotive, cement, chemicals, paper, steel)*	*Mining (titanium) Manufacturing (fertiliser)*

Figure 37. GH hub assessment framework (Solargis, 2021; Vortex, 2021; Transnet National Port Authority, 2021) *

* Best renewable energy resource in South Africa: Solar - 2,400 kWh/m2 and Wind - 10.6 m/s
Tx - transmission
All locations have a sustainable water source

	West Coast		Central (Inland)	Southeast coast		
	Boegoes Bay	**Saldanha Bay**	**Vaal**	**Coega**	**eThekwini**	**Richards Bay**
Advantages	▪ *Potential R13bn investment into iron ore/manganese export port infrastructure* ▪ *Access to the Americas and Europe market* ▪ *Option to upscale freely for future production* ▪ *Incentivised renewable energy production* ▪ *Possibility to anchor local hydrogen uptake through the mining industry*	▪ *Best quality renewable energy resource* ▪ *Access to the Americas and Europe market* ▪ *Option to upscale freely for future production* ▪ *Possibility to anchor local hydrogen uptake through industrial activity* ▪ *Easy access to resources* ▪ *Can fulfill short-term export trading requirements*	▪ *Incentivised renewable energy production* ▪ *Possibility to anchor local hydrogen uptake through the PGM and manufacturing industry* ▪ *Well established existing infrastructure* ▪ *Very easy access to resources*	▪ *Access to the East and West markets without incurring additional costs* ▪ *Option to upscale for future production freely* ▪ *Incentivised renewable energy production* ▪ *Possibility to anchor local hydrogen uptake through the manufacturing industry* ▪ *Very easy access to resources*	▪ *Access to the East market* ▪ *Possibility to anchor local hydrogen uptake through the mining industry* ▪ *Very easy access to resources*	▪ *Access to the East market* ▪ *Possibility to anchor local hydrogen uptake through ammonia production* ▪ *Easy access to resources*

Figure 38. ***Potential GH hub locations***

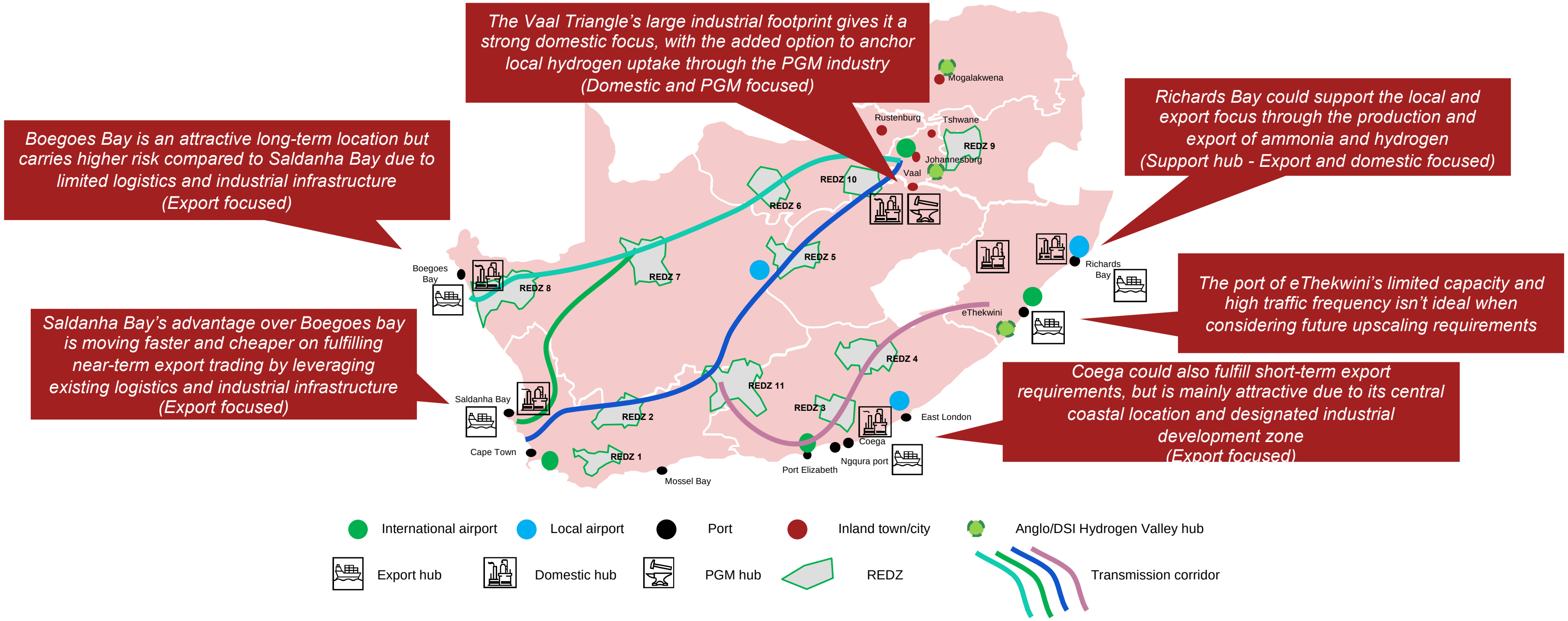

Figure 39. Visual representation of potential GH hub locations

South Africa's Natural Endowments

South Africa possesses a unique combination of advantages which place it in a good position to enter the future global hydrogen market.

South Africa has ideal weather conditions for solar and wind generation, which are the renewable energy options typically deployed in GH production. High solar and wind availability factors increase the utilisation factors of the hydrogen electrolysers, ultimately lowering the cost of clean hydrogen production and make investments attractive to investors (Polity, 2019).

According to the CSIR, South Africa has excellent conditions for wind and solar energy, which can be generated and then stored using hydrogen as a medium. South Africa's combined solar and wind power could provide a hydrogen production capacity factor of almost 100% during daylight hours (Engineering News, 2019a). In the evening, wind generation could be harnessed to produce hydrogen at a capacity factor of about 30%, which exceeds the international norm of approximately 22% (Engineering News, 2019a).[25]

For details on South Africa's relative endowments of sun hours and wind hours refer to Figures C.1 to C.2.

South Africa can leverage its strategic location and infrastructure to access GH import markets and to accelerate the growth of use of GH in marine transport, refer to Figure C.3 indicating marine traffic in the Indian and Atlantic Oceans in proximity to South African waters.

South Africa has close proximity to platinum supplies, which can reduce the costs of transport and the other costs associated with importation of key materials. The proximity to platinum, which is an essential component of the PEM system, allows costs advantages to filter to the final hydrogen production price, increasing the competitiveness of South African GH. [26]

For details on South Africa's platinum endowment refer to Figure C.4.

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[25] TIPS - GREEN HYDROGEN: A POTENTIAL EXPORT COMMODITY IN A NEW GLOBAL MARKETPLACE, November 2020

[26] TIPS - GREEN HYDROGEN: A POTENTIAL EXPORT COMMODITY IN A NEW GLOBAL MARKETPLACE, November 2020

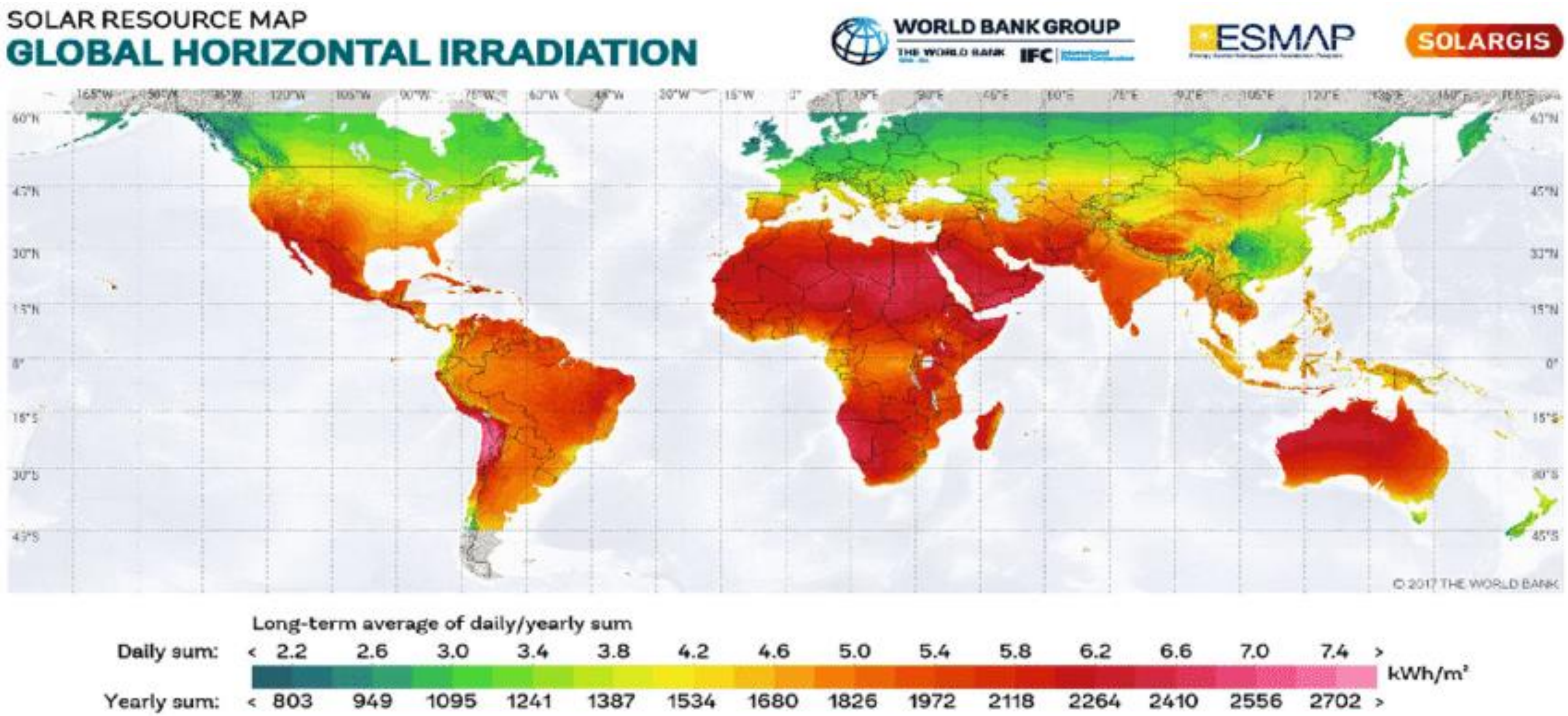

Figure C.1: South Africa – Relative Solar Resources

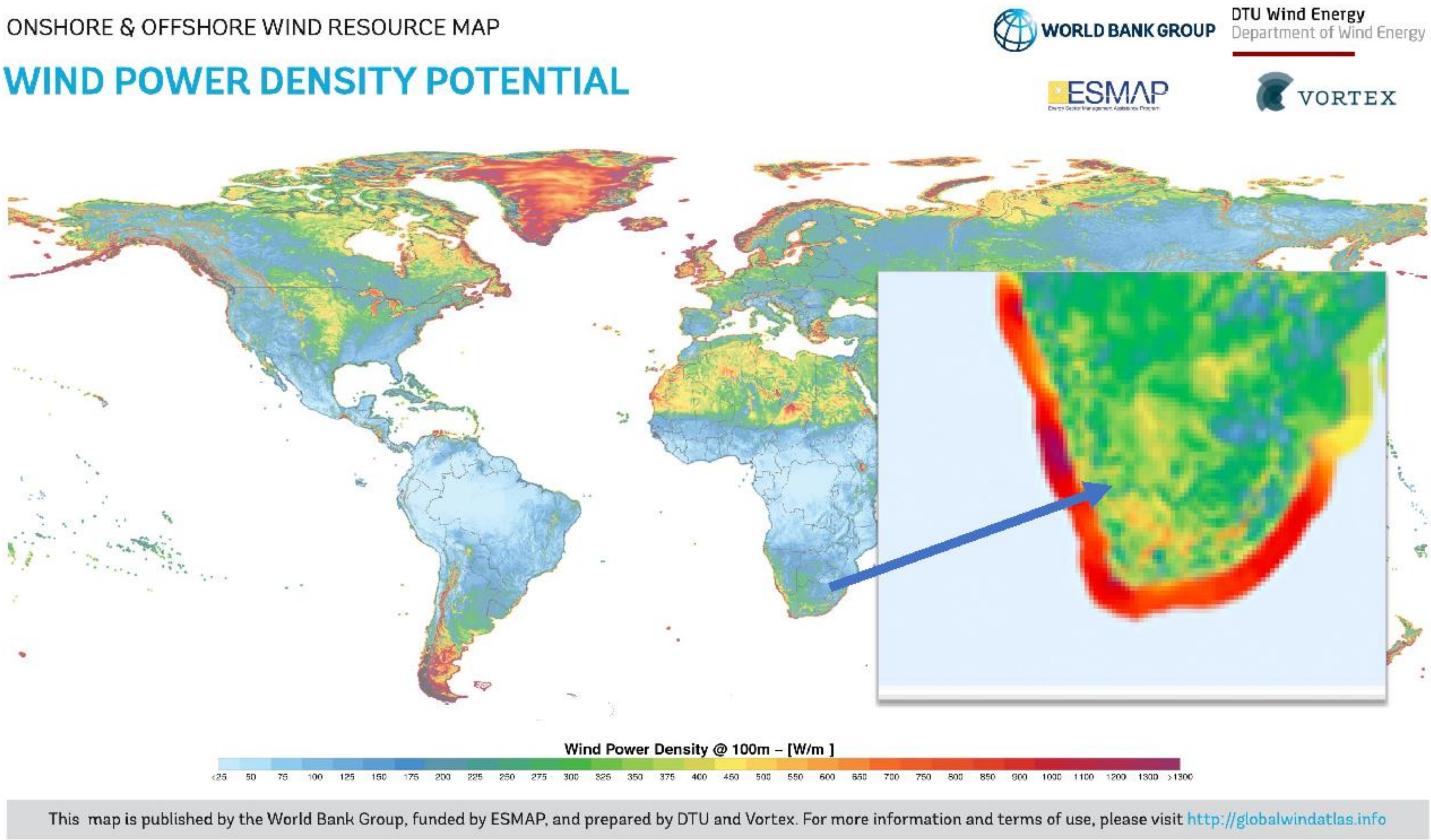

Figure C.2: South Africa – Relative Wind Resources

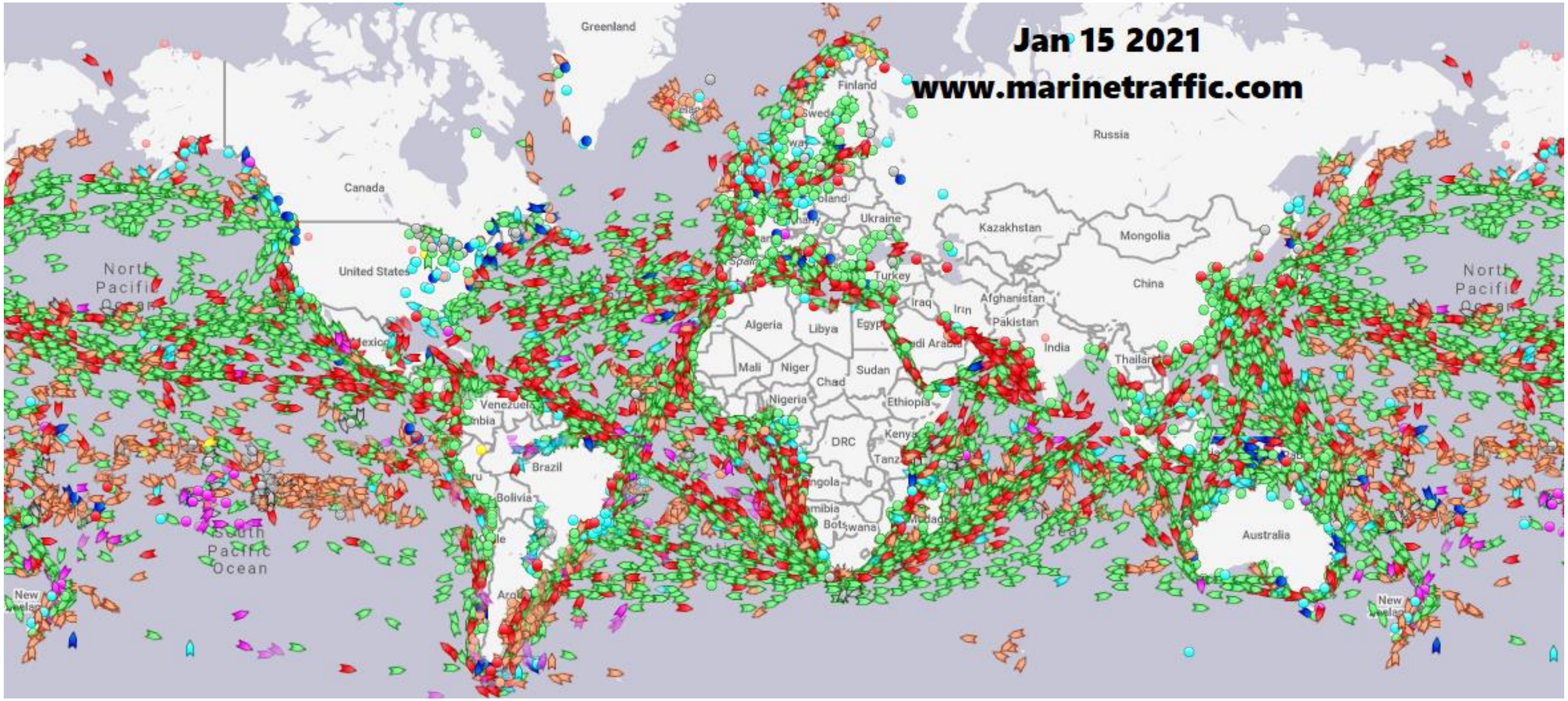

Figure C.3: South Africa – Ocean Resources and Shipping Traffic

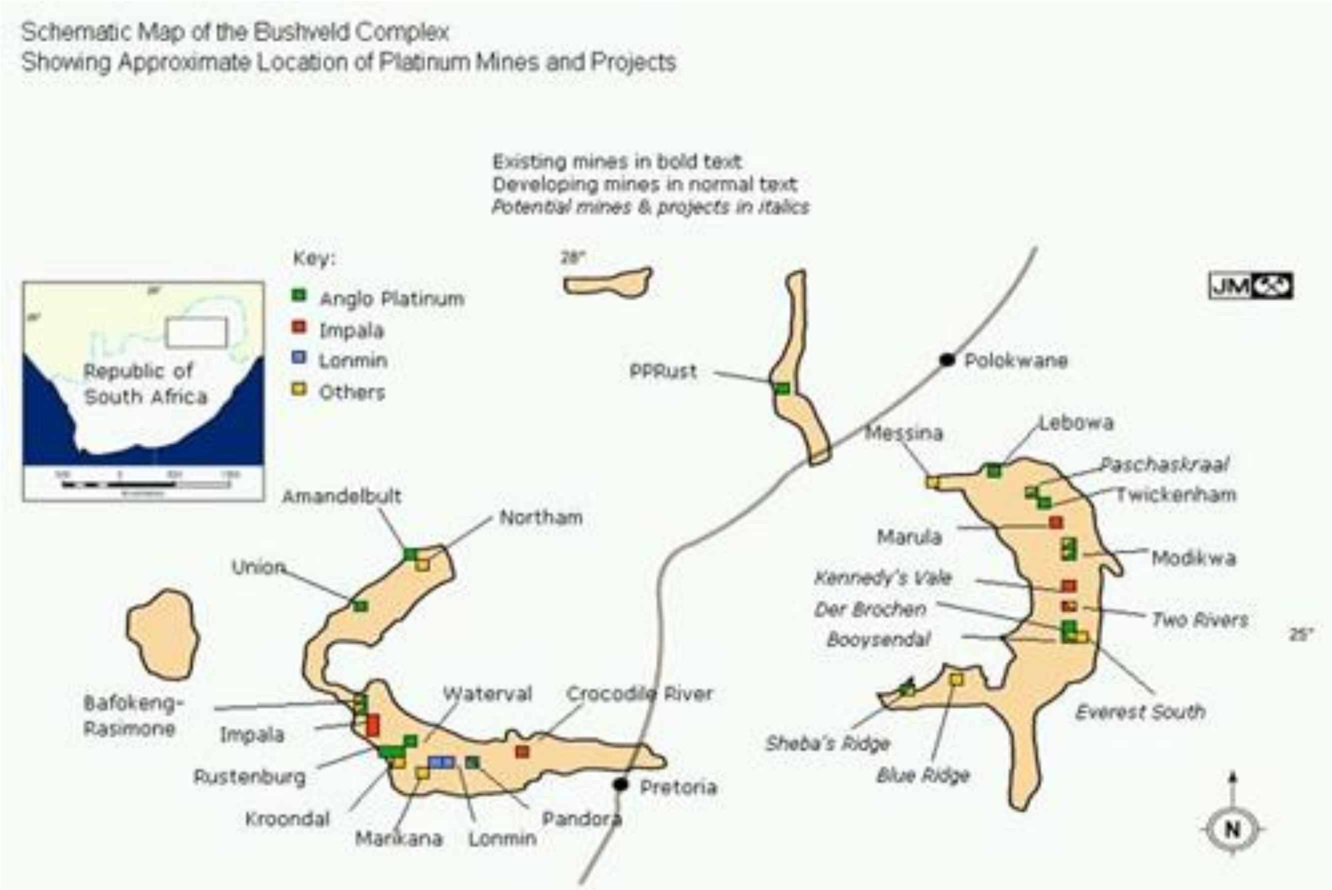

Figure C.4: South Africa – PGM Resource Map

Multi Use Case GH Pilot Plant (20 MW)

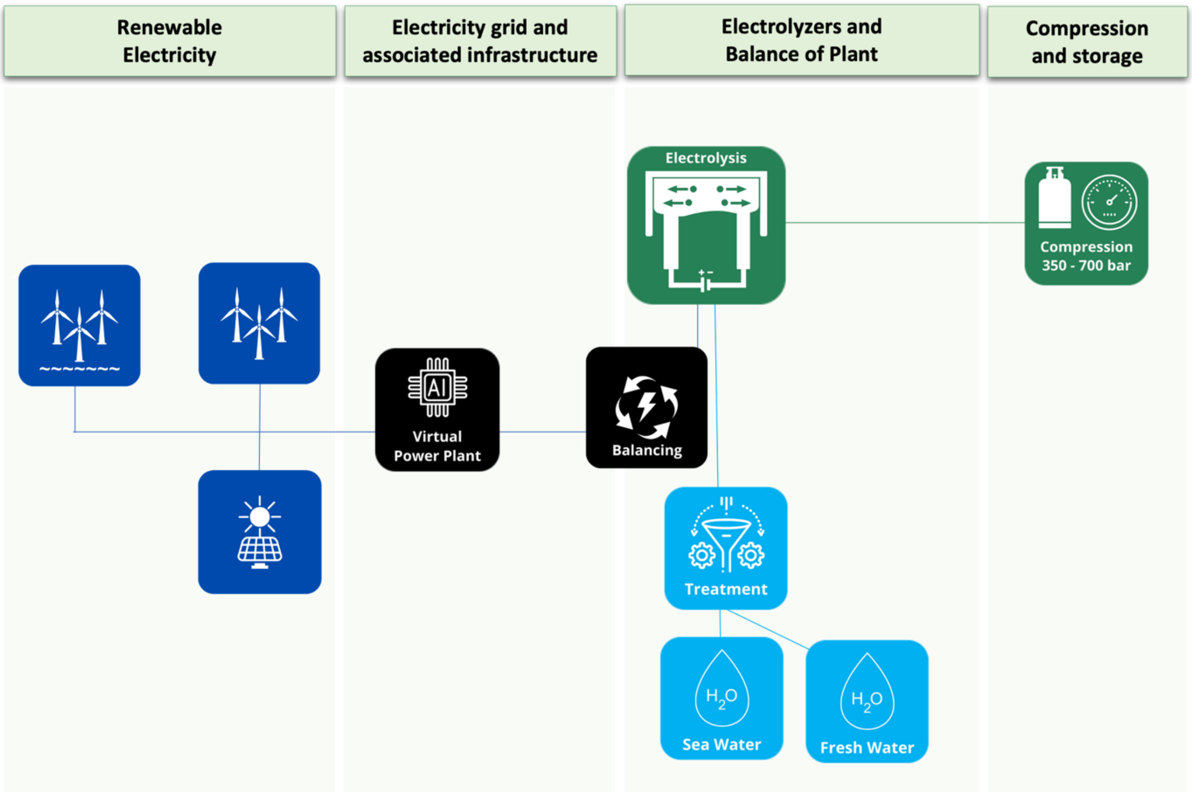

Figure C.5: Example of GH Pilot Plant

Noting the key requirements for project success, cross-sensitivities are provided for:

1. Renewable electricity prices.
2. Renewable electricity hours.
3. Electrolyser and Balance of Plant cost; and
4. Hydrogen price.

Table C.1: Cross Sensitivity – Operating Hours and Renewable Electricity Price

Red (IRR<15%), Orange (15%≥IRR≤20%), Green (IRR>21%)		Full Load Hours				Green Hydrogen Solutions, www.grennh2s.com				
		12	13	14	15	16	17	18	19	20
		4 453	4 818	5 183	5 548	5 913	6 278	6 643	7 008	7 300
	6.50	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.9%	5.8%
	6.25	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	6.6%	10.0%
	6.25	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	6.6%	10.0%
	5.75	0.0%	0.0%	0.0%	0.0%	0.7%	5.8%	10.1%	13.9%	16.8%
	5.50	0.0%	0.0%	0.0%	-0.1%	5.1%	9.5%	13.4%	17.0%	19.8%
	5.25	0.0%	0.0%	-1.3%	4.3%	8.8%	12.7%	16.4%	19.8%	22.5%
	5.00	0.0%	0.0%	3.2%	7.8%	11.9%	15.6%	19.1%	22.4%	24.9%
ELECTRICITY PRICE (USDc / kWh)	4.75	0.0%	1.8%	6.7%	10.9%	14.7%	18.2%	21.5%	24.7%	27.2%
	4.50	0.1%	5.4%	9.7%	13.6%	17.2%	20.6%	23.8%	26.9%	29.3%
	4.25	3.7%	8.3%	12.3%	16.0%	19.5%	22.7%	25.9%	28.9%	31.3%
	4.00	6.7%	10.9%	14.7%	18.2%	21.5%	24.7%	27.8%	30.8%	33.1%
	3.75	9.2%	13.1%	16.8%	20.2%	23.4%	26.6%	29.6%	32.5%	34.7%
	3.50	11.4%	15.2%	18.7%	22.0%	25.2%	28.2%	31.2%	34.0%	36.3%
	3.25	13.4%	17.0%	20.4%	23.7%	26.8%	29.8%	32.7%	35.5%	37.7%
	3.00	15.1%	18.6%	22.0%	25.2%	28.2%	31.2%	34.0%	36.8%	38.9%
	2.75	16.7%	20.1%	23.4%	26.5%	29.5%	32.4%	35.2%	38.0%	40.1%

Table C.1 demonstrates that the lowest renewable energy price for the longest hours increases returns and feasibility.

Table C.2: Cross Sensitivity – Operating Hours and Capex

Red (IRR<15%), Orange (15%≥IRR≤20%), Green (IRR>21%)		Full Load Hours				Green Hydrogen Solutions, www.grennh2s.com				
		12	13	14	15	16	17	18	19	20
		4 453	4 818	5 183	5 548	5 913	6 278	6 643	7 008	7 300
	7 028	0.0%	0.0%	2.1%	6.5%	10.3%	13.8%	17.0%	20.1%	22.4%
	6 708	0.0%	0.0%	2.6%	7.2%	11.1%	14.7%	18.0%	21.2%	23.6%
	6 389	0.0%	0.0%	3.2%	7.8%	11.9%	15.6%	19.1%	22.4%	24.9%
	6 069	0.0%	0.0%	3.8%	8.6%	12.8%	16.6%	20.3%	23.7%	26.4%
	5 750	0.0%	0.0%	4.4%	9.4%	13.8%	17.8%	21.6%	25.2%	28.0%
	5 431	0.0%	-1.4%	5.1%	10.3%	14.9%	19.1%	23.1%	26.9%	29.8%
	5 111	0.0%	-0.8%	5.9%	11.3%	16.1%	20.6%	24.8%	28.8%	31.8%
CAPITAL EXPENDITURE (USD N m3 H2 / h)	4 792	0.0%	-0.2%	6.7%	12.4%	17.5%	22.2%	26.7%	30.9%	34.1%
	4 472	0.0%	0.4%	7.7%	13.7%	19.1%	24.2%	28.9%	33.3%	36.6%
	4 153	0.0%	1.2%	8.8%	15.2%	21.0%	26.4%	31.4%	36.1%	39.6%
	3 833	0.0%	2.0%	10.1%	17.0%	23.3%	29.0%	34.4%	39.2%	42.9%
	3 514	0.0%	3.0%	11.7%	19.2%	26.0%	32.2%	37.8%	42.9%	46.6%
	3 194	0.0%	4.1%	13.6%	21.9%	29.3%	35.9%	41.8%	47.0%	50.8%
	2 875	0.0%	5.5%	16.0%	25.3%	33.4%	40.4%	46.4%	51.7%	55.5%
	2 556	0.0%	7.3%	19.3%	29.8%	38.4%	45.6%	51.7%	56.9%	60.7%
	2 236	0.0%	9.6%	23.9%	35.6%	44.5%	51.6%	57.6%	62.7%	66.3%

Table C.2 demonstrates that the higher the cost of the electrolyser, the more operating hours are required to increase returns and feasibility.

Table C.3: Cross Sensitivity – Hours and GH Price

Red (IRR<15%), Orange (15%≥IRR≤20%), Green (IRR>21%)		Full Load Hours				Green Hydrogen Solutions, www.grennh2s.com				
		12	13	14	15	16	17	18	19	20
		4 453	4 818	5 183	5 548	5 913	6 278	6 643	7 008	7 300
HYDROGEN PRICE (H2 USD / kg)	6.12	0.0%	0.0%	0.0%	0.0%	0.0%	3.2%	7.2%	10.7%	13.3%
	6.48	0.0%	0.0%	0.0%	-1.4%	3.7%	7.8%	11.5%	14.9%	17.4%
	6.84	0.0%	0.0%	0.0%	3.7%	8.0%	11.9%	15.4%	18.7%	21.3%
	7.20	0.0%	0.0%	3.2%	7.8%	11.9%	15.6%	19.1%	22.4%	24.9%
	7.34	0.0%	-0.6%	4.8%	9.3%	13.3%	17.0%	20.5%	23.8%	26.3%
	7.49	0.0%	1.2%	6.4%	10.8%	14.7%	18.4%	21.9%	25.2%	27.7%
	7.63	0.0%	3.0%	7.9%	12.2%	16.1%	19.8%	23.2%	26.5%	29.1%
	8.09	-1.4%	4.6%	9.3%	13.6%	17.4%	21.1%	24.6%	27.9%	30.4%
	8.24	0.4%	6.1%	10.7%	14.9%	18.7%	22.4%	25.9%	29.2%	31.8%
	8.39	2.1%	7.5%	12.0%	16.2%	20.0%	23.7%	27.2%	30.5%	33.1%
	8.54	3.7%	8.8%	13.3%	17.4%	21.3%	24.9%	28.4%	31.8%	34.4%
	8.69	5.1%	10.2%	14.6%	18.7%	22.5%	26.2%	29.7%	33.0%	35.6%
	8.84	6.5%	11.4%	15.8%	19.9%	23.7%	27.4%	30.9%	34.3%	36.9%
	8.99	7.8%	12.7%	17.0%	21.1%	24.9%	28.6%	32.1%	35.5%	38.1%
	9.14	9.1%	13.9%	18.2%	22.3%	26.1%	29.8%	33.3%	36.7%	39.3%
	9.29	10.3%	15.0%	19.4%	23.4%	27.3%	31.0%	34.5%	37.9%	40.5%

Table C.3 demonstrates that the lower the hours of operation, the higher the GH price to increase returns and feasibility.

Table C.4 Cross Sensitivity – Electricity Price and Capex

Red (IRR<15%), Orange (15%≥IRR≤20%), Green (IRR>21%)		ELECTRICITY PRICE (USDc / kWh)				Green Hydrogen Solutions, www.grennh2s.com				
		6.50	6.25	6.00	5.75	5.50	5.25	5.00	4.75	4.50
CAPITAL EXPENDITURE (USD N m3 H2 / h)	7 028	4.7%	8.6%	11.9%	14.9%	17.6%	20.1%	22.4%	24.5%	26.5%
	6 708	5.2%	9.3%	12.7%	15.8%	18.7%	21.2%	23.6%	25.8%	27.9%
	6 389	5.8%	10.0%	13.6%	16.8%	19.8%	22.5%	24.9%	27.2%	29.3%
	6 069	6.5%	10.8%	14.6%	17.9%	21.0%	23.8%	26.4%	28.8%	31.0%
	5 750	7.2%	11.7%	15.6%	19.1%	22.3%	25.3%	28.0%	30.5%	32.8%
	5 431	8.0%	12.7%	16.8%	20.5%	23.9%	27.0%	29.8%	32.4%	34.8%
	5 111	8.9%	13.8%	18.2%	22.0%	25.6%	28.8%	31.8%	34.5%	37.0%
	4 792	9.9%	15.1%	19.7%	23.8%	27.5%	31.0%	34.1%	36.9%	39.5%
	4 472	11.1%	16.6%	21.4%	25.8%	29.8%	33.4%	36.6%	39.6%	42.3%
	4 153	12.4%	18.3%	23.5%	28.2%	32.4%	36.2%	39.6%	42.6%	45.4%
	3 833	14.0%	20.3%	25.9%	30.9%	35.4%	39.3%	42.9%	46.1%	48.9%
	3 514	15.9%	22.8%	28.9%	34.2%	38.9%	43.0%	46.6%	49.9%	52.8%
	3 194	18.2%	25.8%	32.4%	38.0%	42.9%	47.1%	50.8%	54.1%	57.0%
	2 875	21.3%	29.6%	36.7%	42.6%	47.5%	51.8%	55.5%	58.8%	61.7%
	2 556	25.3%	34.5%	41.8%	47.8%	52.8%	57.0%	60.7%	63.9%	66.8%
	2 236	30.7%	40.5%	47.9%	53.8%	58.6%	62.8%	66.3%	69.4%	72.1%

Table C.4 demonstrates that the key focus of any project is to ensure the lowest possible renewable electricity price and lowest capex costs.

Islanded GH Pilot Plant (1.1 MW Base Load Power-to-Power)

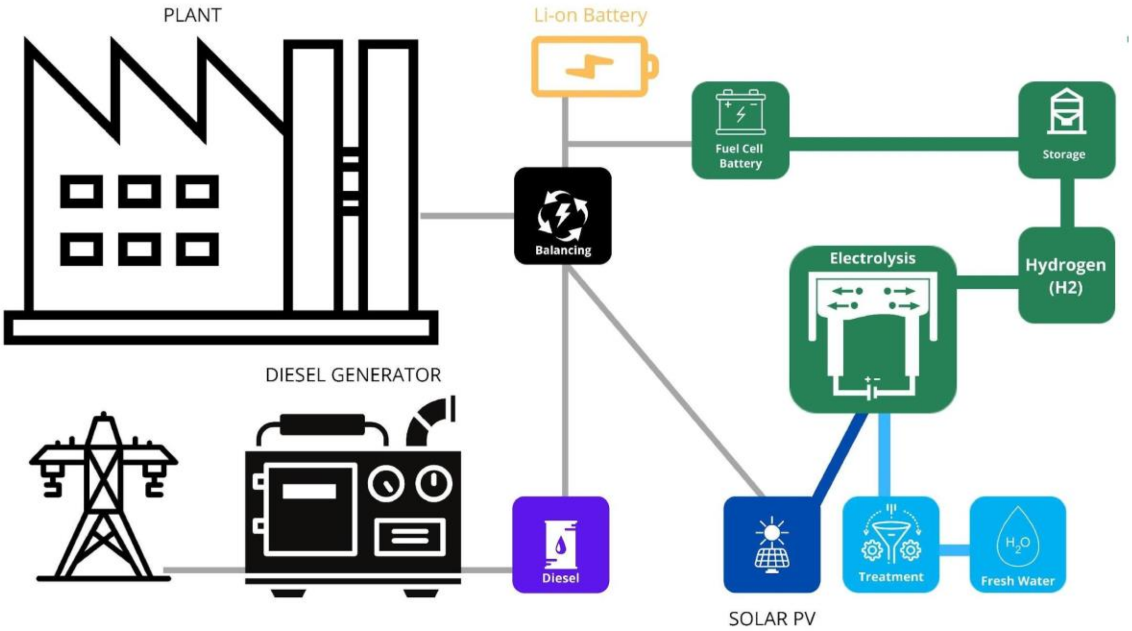

Figure C.6: Example of Islanded Power-to-Power system

GH is stored and deployed to displace diesel during non-solar hours always ensuring a supply of 1 100 kW to the plant for 12 hours per day. The plant, in a developing country is paying US$0.25/kWh for grid and diesel power, and with an islanded GH solution using Li-ion Batteries to supplement solar power could reduce its electricity price to US$0.21/kWh with carbon taxes and incentives. Essentially the plant could supply its own demand for electricity.

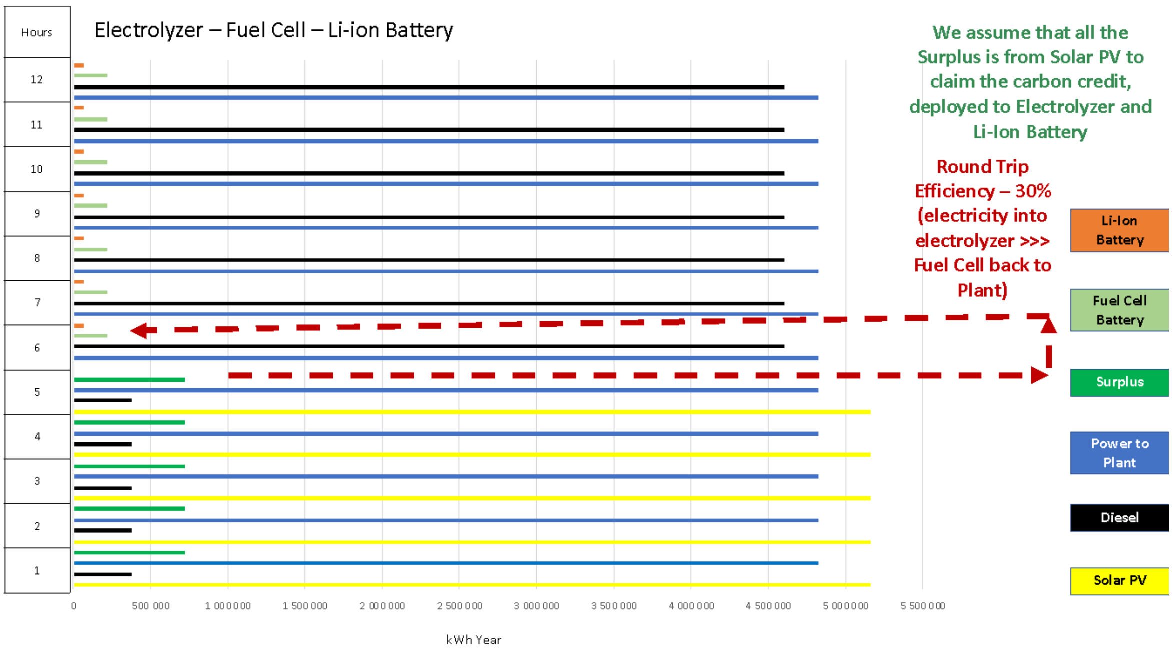

Figure C.7: Integration of Generation Options for Islanded Power-to-Power System

19. Appendix C: Current Projects in the country

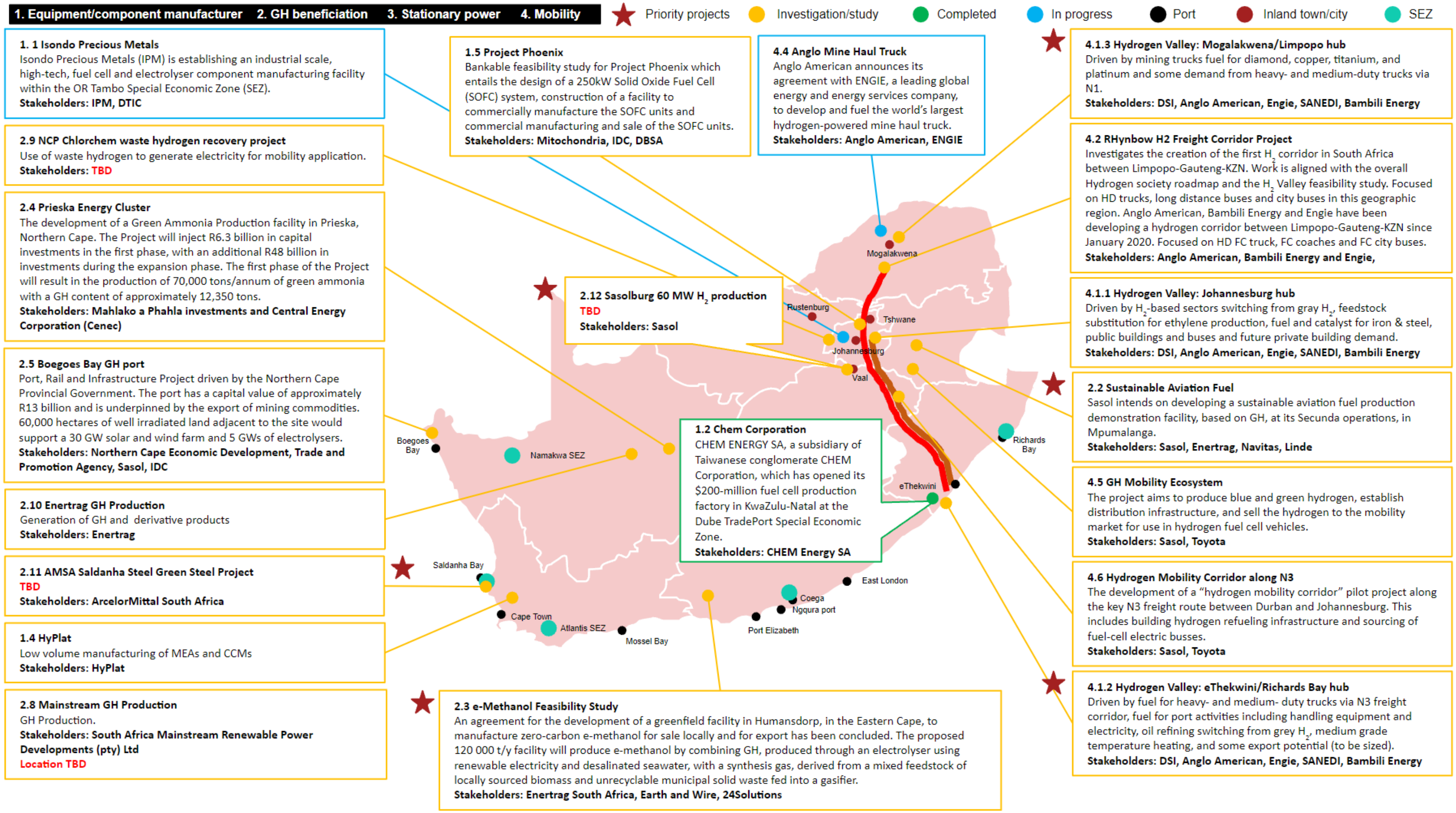

Figure 40. Prioritised summary of local GH activities

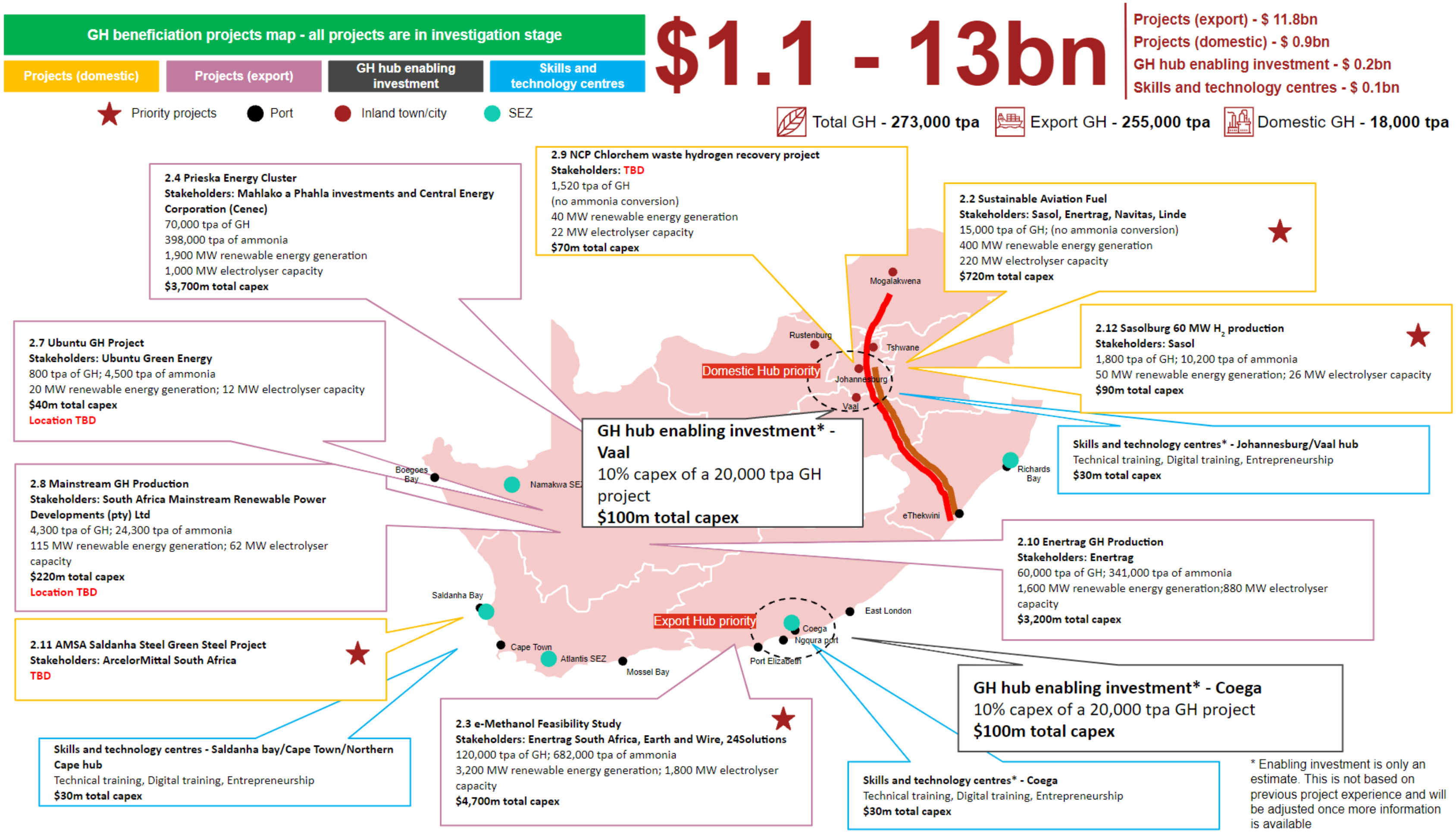

Figure 41. Capital invest support needed for GH production projects to be commissioned in 2025

The figure above shows the investment support needed for the GH production projects, including skills training centres and a GH hub enabling investment for Coega and Vaal.

The figure below shows the investment required to bring forward South Africa's 3.8 mtpa GH production scale from 2050 to 2040, and the additional demand uplift that can be unlocked through further funding' ~$133 bn in further funding

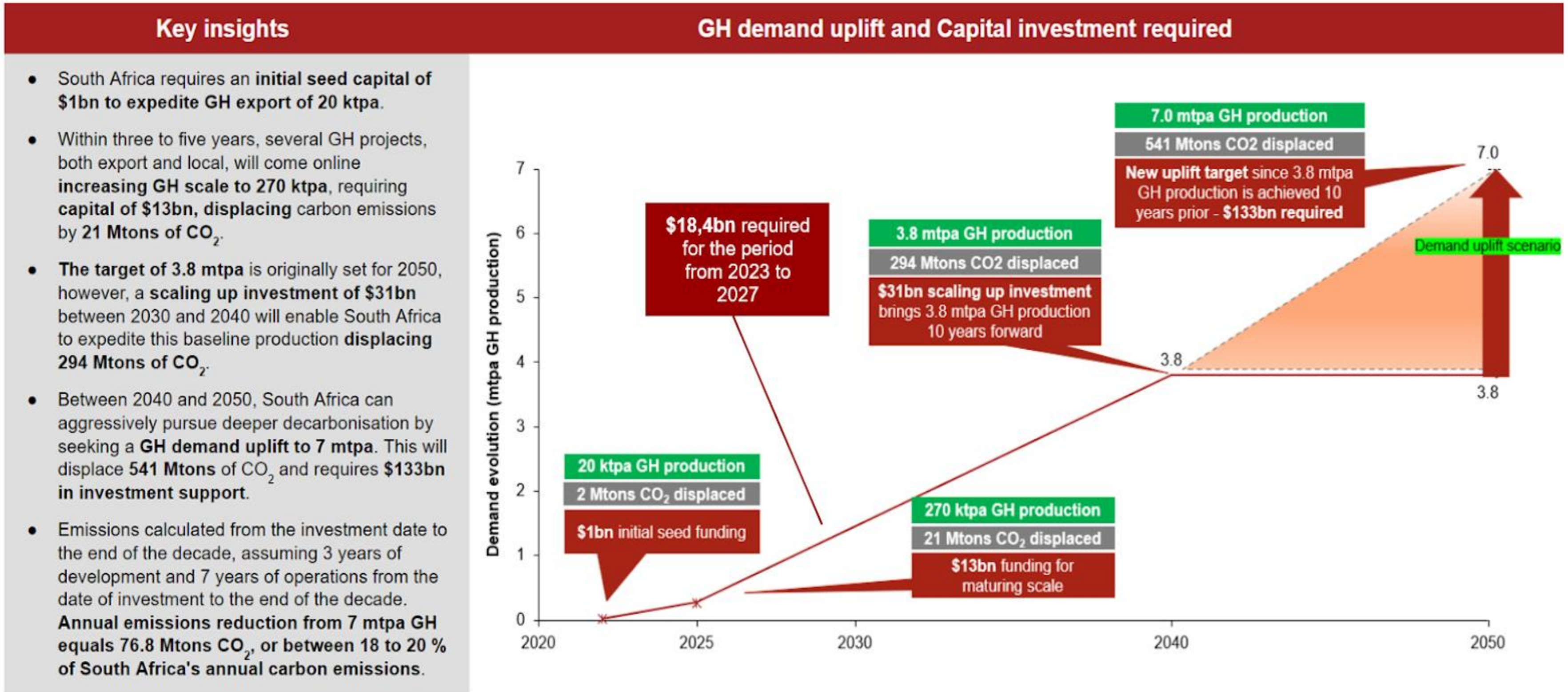

Figure 42. GH demand uplift and Capital investment required to scale up South Africa's GH production scale to 3.8 mtpa by 2040.

20. Appendix D: Equipment and Component Localisation

Table 8 provides the priority with high level description of criteria.

Table 8. Priority ranking of local manufacturing development.

Rank	Description
High priority	Low hanging fruit; Existing local capabilities and/or IP; Requires low initial or additional investment but current industry can pivot; Short term implementation; Competitive in a domestic market
Medium priority	Some components to be imported; Activity is based on fabrication and assembly; Medium investment needed or medium risk; Requires OEM license and/or offtake; Medium to short term implementation
Low priority	Invariably high value, high technology components will be imported in the short-medium term; Advanced manufacturing capability will be dependent on international OEM partnerships; Localisation will require substantial investment support and time development; Might not be globally cost or otherwise competitive

Table 9 gives the supply chain component priorities for potential localisation of PEM electrolyser-based equipment, components, stacks and systems.

Table 9. High and medium priority localisation potential for key PEM electrolysis components.

Component	Priority	Enablers and barriers
PGMs (Platinum, Iridium) catalyst	High	**Enabler** • Existing local industry. • SA leads global PGM supply with 90% of global resources. • PGM market will grow with H2 industry. • Cathode catalyst and anode catalyst contribute respectively 2% and 6% of electrolyser stack costs. **Barriers** • Reduced PGM loading. • Export of RAW material – requires beneficiation into higher value components locally.
CCM/MEA	High	**Enabler** • Established local manufacturing (small scale). • Existing local IP. • Still relatively small and new market.

Component	Priority	Enablers and barriers
		• MEA manufacturing contributes approximately 10% to the stack costs. **Barriers** • No local electrolysis stack manufacturers. • Requires scale up early-on to match future market growth. • Possible loss of current momentum if there is a lack of funding support. • Lack of high value-added Supported catalyst supplier.
End application (System integration/O&M)	High	**Enablers** • Strong local specialized services (environmental analysis, legal services, finance, engineering design, location assessment, etc.) **Barriers** • Establishment of local GH manufacturing.
PEM stack	Medium	**Enablers** • International OEMs eager to establish in SA due to the GH potential market and PGM supply dominance. • Potential for component export. • Beneficial ratio of expertise vs. labour cost. • Will enable the growth of non-PGM raw material supply chains. **Barriers** • Requires substantial local market (e.g., 1 GW). • Requires incentives to attract OEMs (tax, etc). • Export of RAW materials and import of high value-added materials and components.
BoP	Medium	**Enablers** • Majority of components can be sourced locally. • Expertise exists for engineering and after sales service. • **Barriers** • Many components are imported and only supported locally. • Detailed assessment is required to determine local content (%)of BoP subcomponents and suppliers.

PEM system	Medium	**Enablers**
		• Expertise exists for engineering and after sales service.
		• To attract international OEMs
		  ○ High ratio expertise vs. labour cost.
		  ○ High potential for local market based on SAs RE resources for GH production
		Barriers
		• To attract international OEMs
		  ○ Need for large domestic demonstration projects to build confidence for international OEMs to establish local facilities.
		  ○ Government policies and incentive

Recycling	Medium	**Enablers** • Bipolar plates, endplates and pressure components can be recycled. • Dependent on local GH industry - potential for import and recycle. • Supports local supply of high value add material (e.g., Ti, steel, PGM, etc). • Strong metal recycling industry **Barriers**

Component	Priority	Enablers and barriers
		• Will only be required in the medium to long term. • High energy intensive industry.

Table 10 gives the supply chain component priorities for potential localisation of PEM fuel cell electrolyser-based equipment, components, stacks and systems.

Table 10. High and medium priority localisation potential for key PEM fuel cell components

Component	Priority	Enablers and barriers
PGMs (Platinum) catalyst	High	**Enabler** • Existing local industry. • SA leads global PGM supply with 90% of global resources. • PGM market will grow with H2 industry. • Catalyst Ink and application contribute approximately 50% of PEM fuel cell stack costs. **Barriers** • Reduced PGM loading. • Export of RAW material – lack of local beneficiation into higher value components
MEA	High	**Enabler** • Established local manufacturing (small scale). • Existing local IP. • Still relatively small and new market. • MEA manufacturing contributes approximately 8% to the stack costs. **Barriers** • No local fuel cell stack manufacturers to prove concept. • Requires scale up to match future market growth – fine line • Possible loss of current momentum if there is a lack of funding support.
System integration/O&M	High	**Enablers** • Existing system assembly locally (Chem Energy SA.) • Existing local expertise in EPC and manufacturing. • The hydrogen industry globally is still in a development phase. Many technology (Electrolyser and fuel cell) manufacturers must still establish large-scale operations and retain flexibility in selecting where to deploy production facilities. • SAs comparative advantage in PGM supply. **Barriers** •
PEM stack	Medium	**Enablers** • International OEMs eager to establish in SA due to the GH potential market and PGM supply dominance. • Potential for component export. • Beneficial ratio of expertise vs. labour cost.

Component	Priority	Enablers and barriers
		Barriers ● Requires incentives to attract OEMs (tax, etc). ● Export of RAW materials and import of high value-added materials and components.
BoP	Medium	**Enablers** ● Majority of components can be sourced locally. ● Expertise exists for engineering and after sales service. ● **Barriers** ● Many components are imported and only supported locally. ● Detailed assessment is required to determine local content (%)of BoP subcomponents and suppliers.
PEM FC systems	Medium	**Enablers** ● Expertise exists for engineering and after sales service. ● High ratio expertise vs. labour cost. **Barriers** ● Requires policies and incentives to attract international OEMs
Manufacturing FCEVs	Medium	**Enablers** ● Growing automotive sector to transition from producing ICEVs to FCEVs or BEVs. Several major automotive OEMs are already present in South Africa. ● With a potentially growing demand for FCEVs globally and locally, the industry is well positioned to manufacture them locally for both the domestic and export markets.
Recycling	Medium	**Enablers** ● Bipolar plates, endplates and pressure components can be recycled. ● Dependent on local GH industry - potential for import and recycle. ● Supports local supply of high value add material (e.g., Ti, steel, PGM, etc). ● Strong metal recycling industry **Barriers** ● Will only be required in the medium to long term. ● High energy intensive industry.

The impact on PGM resource requirement for SA has not been considered due to lack of information of the potential hydrogen pathways (Source: GHP interim report of 13 August). Pathways identified are:

- Export (either GH, green ammonia, or other green products e.g., steel)
- Equipment localisation for local and export market
- Industry decarbonization
- Heavy duty mobility applications

A more detail analysis and prediction of the end-use demand for SA (export and domestic) applications are required to better determine the PGM resource requirement. The Typical PGM loadings for the various applications are provided in Table .

Table 11. PGM loading in different applications (source : US DOE)

Application	kW	Current Loading (g/kW)	Thrifted loading (g/kW)
PEM electrolysis (platinum)		0,6	0,13
PEM electrolysis (iridium)		1,2	0,4
Heavy duty trucks	200	0,9	0,3
Buses	100	0,8	0,3
Passenger vehicles (large & medium)	80	0,9	0,125
Passenger vehicles (small)	30	0,94	0,125

The global electrolysis low and high expected install base is provided in Figure B9 and Figure B.10 to be around 190 to 295 GW by 2050. Figure E.1 shows the expected main PGMs to benefit from the implementation of hydrogen technologies (Platinum and Iridium).

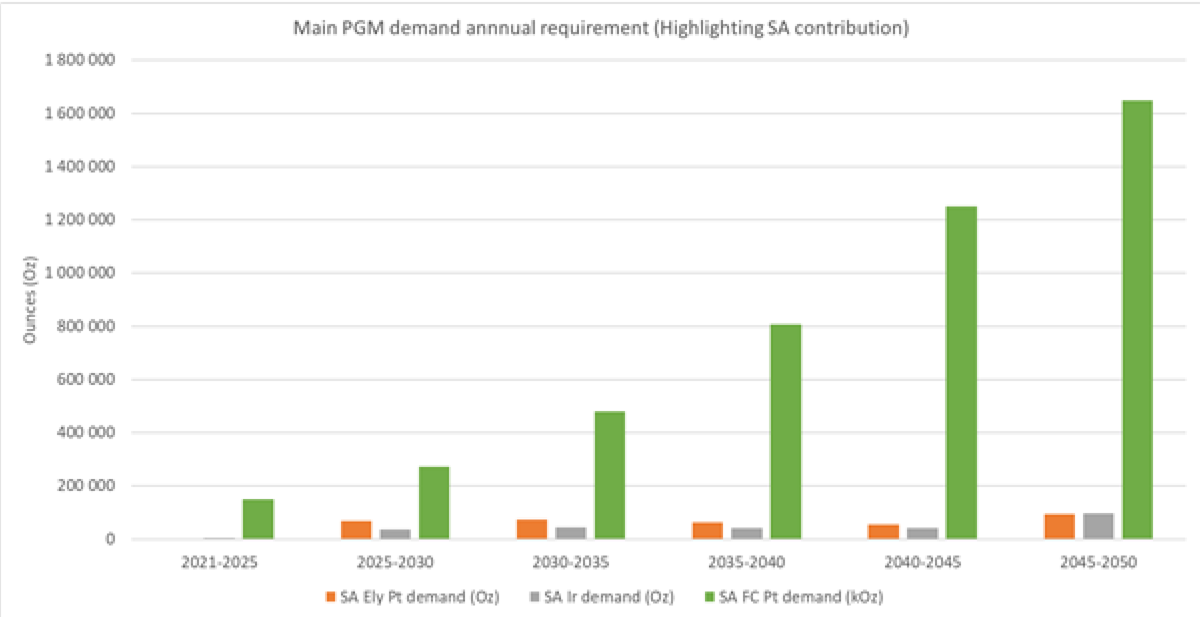

Figure 43. PGM demand for the hydrogen economy (PEM electrolysers and PEM fuel cells for mobility) for South Africa.

Assumptions used include:

- Electrolysis demand based on Figure B9 and Figure B.10.
- For PEM fuel cell for vehicle demand conservative values based on

- Reduction in PEM electrolyser and fuel cell PGM loadings are linearized between 2025 and 2050 based on Table E.4 current and thrifted values.
- SA global Pt contribution to global demand is approximately 75%.
- SA global Ir contribution to global demand is approximately 80%.
- PGM recycling increases from 30 to 40% between 2025 and 2050.
- Steady increase in PEM electrolyser efficiencies to 70% in 2050.
- Steady increase in PEM electrolyser contribution to global GH production from 1% in 2025 to 50% in 2050.

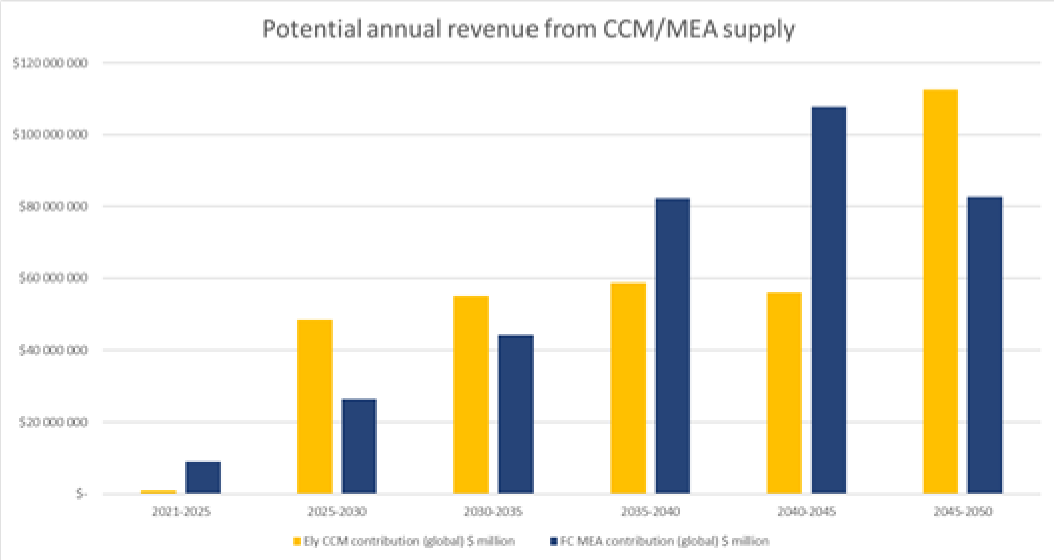

Figure 44. . Potential revenue from CCM/MEA supply into the global market for PEM electrolysers and fuel cells

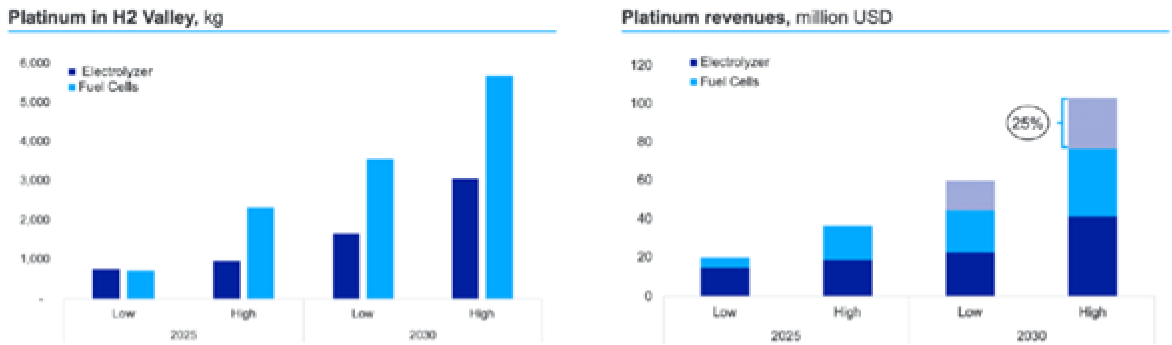

Figure 45. Potential PGM (Pt) demand from both electrolysers and fuel cells required in the H2 valley.

Existing local manufacturers of PEM electrolyser and fuel cell components and/or systems.

- Hydrox Holdings - Hydrox Holdings is a South Africa company that have developed IP for a membrane-less Alkaline electrolyser. They have in the past received funding from Shell to develop a scaled-up demonstration system.
- HyPlat – HyPlat is a UCT/HySA spinoff company to commercialised MEA IP developed. HyPlat supplies low numbers and sizes of PEM fuel cell MEAs into the international market and are currently in the process of quiring funding to scale up production to 1m units per year.
- Chem Energy SA – Chem's head office is based in Taiwan. They have established a local fuel cell system assembly plant in Durban, South Africa located in the Dube trade

Port.
HYENA Energy - Remote FC based power packs

- Isondo Precious Metals (IPM) – IPM have obtained equipment to localise MEA manufacturing under license. They have received funding from DTIC and are in the process of construction of their manufacturing facilities (Date announced: 16 July 2021).

Global major electrolyser manufacturers by type gives a list of current global major electrolyser OEMs for the three main electrolyser technologies: PEM, alkaline and high temperature (solid oxide) electrolysers.

Table 12. Global major electrolyser manufacturers by type.

PEM electrolysers	Alkaline Electrolysers	Solid Oxide Electrolysers
Framatome/Areave - France GH Systems - Denmark H-Tec Systems - Germany ITM Power - UK Siemens - Germany Nel Hydrogen/Proton Energy - USA PlugPower/Giner - USA Cummins/Hydrogenics Corporation - Canada	McPhy - France Nel Hydrogen - Norway ThyssenKrupp - Germany Elygrid - Spain De Nora (Chloralkali)- Italy Johncockerill Enapter (AEM) - Germany CHP (Membraneless) - UK	Sunfire - Germany Halder Topsoe - Denmark Ceres Power - UK Elcogen - Estonia Oxeon Energy - USA

Table 13. Global major fuel cell manufacturers by type.

PEM fuel cells (PEMFC)	Solid Oxide fuel cells (SOFC)	Phosphoric acid fuel cells (PAFC)
Cummins/Hydrogenics Ballard Plug Power Nuvera Altergy Power Cell Loop Energy Proton Motor Fuel Cell Energy Nedstack ElringKlinger Horizon Schaeffler Toshiba Intelligent Energy Advent (High Temp PEM)	Bloom Energy New Enerday Adaptive Energy Ceres Power Solid Power Mitshubishi Panasonic	Phosphoric acid fuel cells (PAFC) Doosan Fuji electric Alkaline fuel cells (AFC) GenCell AFC Energy Direct Methanol Fuel Cell SFC Energy

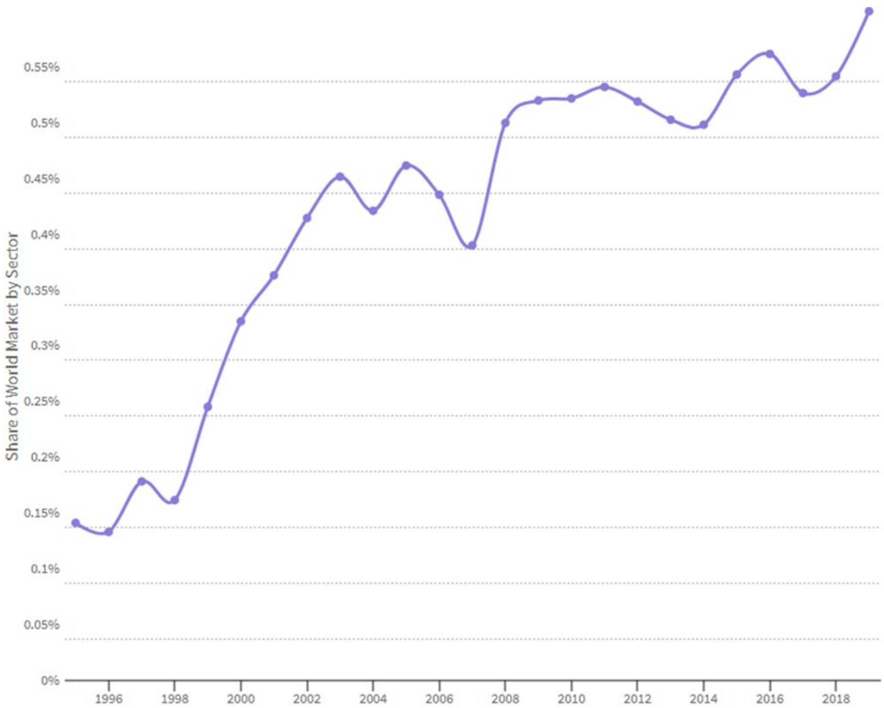

Figure 46. South Africa's global share of vehicle export.

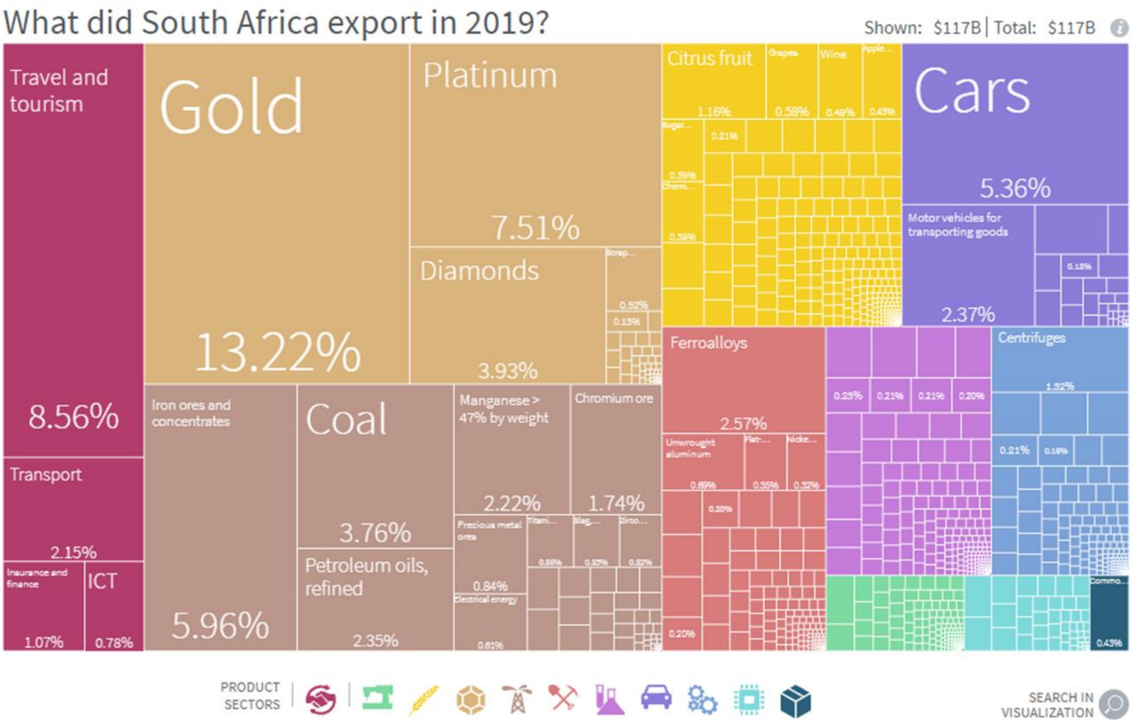

Figure 47. South Africa's export by Sector.

21. Appendix E: Initiatives and demonstration/catalysing projects in South Africa

Table E.1: Initiatives and demonstration/catalysing projects in South Africa

#	Project	Type/Status	Description	Stakeholders
1.1	Isondo Precious Metals	Local component manufacture/IP procured. facility being constructed	Isondo Precious Metals (IPM) is establishing an industrial scale, high-tech, fuel cell and electrolyser component manufacturing facility within the OR Tambo Special Economic Zone (SEZ)	IPM. DTIC
1.2	Chem Corporation	Local assembly/Facilities established	CHEM ENERGY SA, a subsidiary of Taiwanese conglomerate CHEM Corporation, which has opened its $200-million fuel cell production factory in KwaZulu-Natal at the Dube TradePort Special Economic Zone.	CHEM Energy SA
1.3	Hydrox Holdings	Local IP development/R&D	Hydrox Holdings Ltd. AAE technology has been demonstrated with integration in a full balance of plant with production capacities noted as small scale.	Hydrox Holdings
1.4	HyPlat	Local IP development and component manufacture/Operating	Low volume manufacturing of MEAs and CCMs	HyPlat

#	Project	Type/Status	Description	Stakeholders
1.5	Mitochondria	Feasibility study in progress	Bankable feasibility study for Project Phoenix which entails the design of a 250kW Solid Oxide Fuel Cell (SOFC) system, construction of a facility to commercially manufacture the SOFC units and commercial manufacturing and sale of the SOFC units.	Mitochondria, IDC, DBSA
2.1	Air products	GH beneficiation cooperation agreement/Signed	Air Products and ThyssenKrupp sign exclusive strategic cooperation agreement for world-scale electrolysis plants to generate GH.	Air Products, ThyssenKrupp
2.2	Sustainable Aviation Fuel	GH beneficiation cooperation agreement/Announced	SASOL intends on developing a sustainable aviation fuel production demonstration facility, based on GH, at its Secunda operations, in Mpumalanga to be bid in the first round of the H2Global auction programme.	Sasol, Enertrag, Navitas, Linde
2.3	e-methanol feasibility study	GH beneficiation feasibility study/Unknown (requires more detail)	An agreement for the development of a greenfield facility in Humansdorp, in the Eastern Cape, to manufacture zero-carbon e-methanol for sale locally and for export has been concluded by a consortium comprising Earth and Wire, ENERTRAG South Africa and 24Solutions. The proposed 120 000 t/y facility will produce e-methanol by combining GH, produced through an electrolyser using renewable	Enertrag South Africa, Earth and Wire, 24Solutions

#	Project	Type/Status	Description	Stakeholders
			electricity and desalinated seawater, with a synthesis gas, derived from a mixed feedstock of locally sourced biomass and unrecyclable municipal solid waste fed into a gasifier.	
2.4	Prieska Energy Cluster	GH beneficiation feasibility study/Scoping	The project entails the development of Green Ammonia Production facility in Prieska, Northern Cape. The Project will inject R6.3 billion in capital investments in the first phase, with an additional R48 billion in investments during the expansion phase. The first phase of the Project, which will be located 10km outside Prieska in the Northern Cape, South Africa, will result in the production of 70,000 tons/annum of green ammonia with a GH content of approximately 12,350 tons.	Mahlako a Phahla investments and Central Energy Corporation (Cenec).
2.5	Boegoe Bay GH Port	GH beneficiation feasibility study (memorandum of agreement signed)	Port, Rail and Infrastructure Project driven by the Northern Cape Provincial Government. The port has a capital value of approximately R13 billion and is underpinned by the export of mining commodities. 60,000 hectares of well irradiated land adjacent to the site would support a 30 GW solar and wind farm (6 times SA's current installed renewable energy capacity) and support 5 GWs of electrolysers	Northern Cape Economic Development, Trade and Promotion Agency, Sasol, IDC

#	Project	Type/Status	Description	Stakeholders
2.6	Green H2 & NH3 zero emission marine fuel for export	GH beneficiation feasibility study/Pre-feasibility	GH & green ammonia production and storage at Richards Bay port or alternatively suitable port	African Renewable Development
2.7	Ubuntu GH Project	GH beneficiation feasibility study/Unknown	20MW GH production project in the Northern Cape	Ubuntu Green Energy
2.8	Mainstream GH production	GH beneficiation feasibility study/In progress	GH production.	South Africa Mainstream Renewable Power Developments (pty) Ltd
2.9	Renew e waste hydrogen power generation	GH beneficiation feasibility study/Pre-feasibility	Use of waste hydrogen to generate electricity for mobility application.	Renew e
2.10	Enertrag GH Production	GH beneficiation feasibility study/Completed	Generation of GH; green-hydrogen based products (green ammonia production).	ENERTRAG AG
3.1	Telecoms Towers	Stationary power demonstration/Various stages (Detail unknow)	As early as 2010, Vodacom South Africa deployed 89 fuel cell systems at base stations in South Africa to confirm the value proposition of fuel cells and demonstrate the growing trend of telecom service providers to	Vodacom, MTN

#	Project	Type/Status	Description	Stakeholders
			support and promote more eco-friendly initiatives. MTN also has various towers powered with fuel cell solutions.	
3.2	Military One Hospital Fuel cell field deployment	Stationary power demonstration/Operating	PPP for seven fuel cell systems to power a field facility at 1 Military Hospital in Pretoria. Bambili Energy focuses on the hydrogen economy, providing solutions to complement various forms of alternative energy, and is committed to commercialising intellectual property developed through the Hydrogen South Africa (HySA) programme.	DSI, DPWI, DoD, HyPlat, Bambili Energy, PowerCell, Horizon Fuel Cell Technologies, Element 1 Corporation
3.3	Mitochondria	Stationary power demonstration/Operating	In 2015, the IDC and Mitochondria successfully launched a 100 kW Combined heat and Power Phosphoric acid Fuel Cell at the Chamber of Mines offices in Johannesburg.	Mitochondria, DTI, Chamber of Mines
3.4	Naledi Trust Project Anglo American	Stationary power demonstration/Completed (decommissioned)	In 2014, Amplats started a rural electrification pilot project in Kroonstad to power 34 homes in a remote community in the Free State province in a 12-month trial period. Amplats invested around $20 million in the “mini-grid”, which functioned independently from the national grid. The pilot system generated 15	Amplats, Ballard Power Systems

#	Project	Type/Status	Description	Stakeholders
			kilowatts (kW) and a maximum of 60 kW with battery storage.	
3.5	Poelano school RE H2 energy system	Stationary power demonstration/Completed (decommissioned)	An off-grid energy system was installed and operated at Poelano High School. The energy system consisted of PV, Batteries, a PEM electrolyser unit, hydrogen low pressure storage and a fuel cell. The system operated from March 2018 until the electrolyser and fuel cell were removed at the end of 2020. The PV system and batteries are still supplying the school with energy, along with an Eskom connection.	DSI, HySA Infrastructure/NWU, HySA Systems/UWC, HySA Catalysis/UCT/HyPlat
3.6	Cofimvaba Rural Schools fuel cells	Stationary power demonstration/Completed (decommissioned)	Three schools in the Cofimvaba district (Arthur Mfebe Senior Secondary School, St Marks Junior Secondary School, Mvuzo Junior Secondary School) were supplied with fuels cells as back-up power. Hydrogen was supplied by Air Products to the school in cylinders.	DSI, Amplats, Air Products, Clean Energy Investments.

#	Project	Type/Status	Description	Stakeholders
3.7	Windsor Clinic Fuel cell	Stationary power demonstration/Completed (decommissioned)	The Windsor Clinic in Randburg was supplied with a fuels cell as back-up power for their vaccine refrigerators and pharmacy air-con to prevent regular power cuts from causing unused vaccines and medicines to be discarded. Hydrogen was supplied by Air Products to the school in cylinders.	DSI, Amplats, Air Products, Clean Energy Investments.
3.8	Cofimvaba Science centre RE H2 energy system	Stationary power demonstration/Operating	An off-grid energy system is installed and operated at Cofimvaba Science Centre in the Eastern Cape. The energy system consisted of a small wind turbine, PV, Batteries, a PEM electrolyser unit, hydrogen low pressure storage and a fuel cell. The system started operating early 2021.	DSI, Hysa Infrastructure/NWU, Western Cape
4.1.1	Hydrogen Valley Feasibility Investigation - Johannesburg hub	Mobility feasibility study started	Driven by H2-based sectors switching from grey H2, feedstock substitution for ethylene production, fuel and catalyst for iron & steel, public buildings and buses and future private building demand.	DSI, Anglo American, Engie, SANEDI, Bambili Energy
4.1.2	Hydrogen Valley Feasibility Investigation - eThekwini/Richards Bay hub	Mobility feasibility study started	Driven by fuel for heavy- and medium- duty trucks via N3 freight corridor, fuel for port activities including handling equipment and electricity, oil refining switching from grey H2, medium grade temperature	DSI, Anglo American, Engie, SANEDI, Bambili Energy

#	Project	Type/Status	Description	Stakeholders
			heating, and some export potential (to be sized).	
4.1.3	Hydrogen Valley Feasibility Investigation - Mogalakwena/Limpopo hub	Feasibility study started	Driven by mining trucks fuel for diamond, copper, titanium, and platinum and some demand from heavy- and medium-duty trucks via N1.	DSI, Anglo American, Engie, SANEDI, Bambili Energy
4.2	RHynbow H2 freight corridor project	Mobility feasibility study/Started	Investigates the creation of the first H2 corridor in South Africa between Limpopo-Gauteng-KZN. Work is aligned with the overall Hydrogen society roadmap and the H2 Valley feasibility study. Focused on HD trucks, long distance buses and city buses in this geographic region Anglo American, Bambili Energy and Engie have been developing a GH corridor between Limpopo-Gauteng-KZN since January 2020. Focused on HD FC truck, FC coaches and FC city buses	Anglo American, Bambili Energy and Engie
4.3	Impala Platinum	Mobility demonstration project/Operating (Unknown)	Hydrogen fuel cell forklift and refuelling station at the Impala Platinum Refineries in Springs	Impala Platinum, HySA Systems

#	Project	Type/Status	Description	Stakeholders
4.4	Anglo Platinum	Mobility demonstration/Being implemented	Anglo American announces its agreement with ENGIE, a leading global energy and energy services company, to develop and fuel the world's largest hydrogen-powered mine haul truck.	Anglo American, ENGIE
4.5	GH Mobility Ecosystem	Mobility demonstration/Concept phase	The project aims to produce blue and GH, establish distribution infrastructure, and sell the hydrogen to the mobility market for use in hydrogen fuel cell vehicles	Sasol, Toyota
4.6	Hydrogen Mobility Corridor along N3	Mobility demonstration/Concept phase	The development of a "hydrogen mobility corridor" pilot project along the key N3 freight route between Durban and Johannesburg. This includes building hydrogen refuelling infrastructure and sourcing of fuel-cell electric busses.	Sasol, Toyota
4.7	SAPO fuel cell scooters	Mobility demonstration/Operating	Three fuel cell scooters have been developed and are being tested by the South African Post Office in Cape Town.	DSI, HySA Systems/UWC, SAPO

#	Project	Type/Status	Description	Stakeholders
5.1	Containerised hydrogen dispensing unit	Remote hydrogen production pilot/Operating	HySA Infrastructure have developed a containerised hydrogen production unit capable of producing 13kg hydrogen per day. They can be transported anywhere and requires any suitable 3 phase supply and potable water. Purification, cooling, compression to 350 bar, and composite storage is included. A 350-bar vehicle dispenser capable of slow filling is included. The unit is coupled to a 65-kW grid connected PV system and is used to produce H2 for hydrogen safety experiments and commercial fuel cell demonstrations.	DSI, HySA Infrastructure/NWU
6.1	BMU	Funding program/in progress	Germany's National Hydrogen Strategy provides 600 million euros which the BMU will use to fund the PtX Pathways project developing the PtX market in Morocco, Argentina and South Africa	Germany
6.2	BMWi	Funding program/in progress	Funding the 200-million-euro concessional financing for hydrogen projects in South Africa by KfW	Germany
6.3	BMBF	Funding program/in progress	Funding the Hydrogen Atlas for sub-Saharan Africa	Germany, SADC, ECOWAS

#	Project	Type/Status	Description	Stakeholders
6.4	BMZ	Funding program/in progress	Funding H2Global, which subsidises the import of green H2 into Germany	Germany

22. Appendix F : Proposed responsibilities of the different government departments

The Presidency	• Prioritise an in-depth analysis of required GH2 regulatory framework. • Develop a programme to implement the required regulatory changes i) Prepare a Regulatory Development Timeline; ii) Develop regulatory objectives for how the GH2 industry should be regulated. iii) Develop a set of Regulations specifically aimed at creating enabling environment for GH_2 • Fast track project regulatory approvals with support from the ISA office • Prioritise support of project applications to the H2 Global organization
The dtic	• Attract investment into establishing equipment manufacturing facilities specifically for electrolysers, fuel cells, ammonia crackers and balance of plant components along the hydrogen value chain in the country for both internal demand and export, with significant incentives (tax breaks, infrastructure support) • Develop and introduce GH2 Standards and specifications. • Design and introduce a Guarantees of Origin system to install investor confidence in key import nodes.
DIRCO	Advocate for policies at EU level to support GH2 development in RSA namely: a) Extension of the time allowed to use hard to abate CO2 for the production of Sustainable fuels with GH_2. The current EU directives allow use of CO2 only to 2036 b) Modify the current rules for emission allocation to allow for flexibility and use of existing facilities c) Lobby to allow for a longer transition period to sustainable carbon use in the production of hydrocarbon fuels.Facilitate bilateral government to government agreements relating to off take of GH2 derivatives
The DMRE	• Clarify the power planning regime for GH2 power requirements and specifically differentiate between GH2 grid tied projects and non-grid tied projects. With regards to specifically GH2 grid tied projects, the IRP should align to the GHCS and make the necessary allocation for both wind and PV technology to enable the development of the new GH2 industry. • Consider the role of the section 19(1)(f) of the National Energy Act in respect of incentives to promote the production, consumption, investment, research and development of renewable energy and green hydrogen
The DFFE	• Advocacy for policies and support at global level, especially UNFCCC, to support GH2 development in RSA • Critical enablement of projects through timely environmental approvals. • Monitoring of carbon emissions within hard-to-abate sectors and oversight of outcomes from GH development to support achievement of NDC commitments • Waste management regulation
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The DoT	• Create an enabling environment for the deployment of GH2 mobility technologies and related infrastructure • Leverage the green transport strategy to drive the development of the GH2 sector
National Treasury	• Evaluate allocations for future budget support • Manage JET-IP funding requests and enablement
The DSI	• Drive innovation, RD&I and skills development • Together with dtic, support commercialisation of innovative products, processes and services that will reduce costs and enhance competitiveness of SA component production • Assist with management of patents and licenses, both local and foreign

	• Co-ordinate research on critical mineral value chains • Research and insights into chemical value chains to support sustainability and global competitiveness
The DHET	• Align to the identified skills and action plan in this commercialisation strategy • Co-create technical training courses to develop future skills requirement to support GH2 and associated value chains • Focus on systems and design thinking to under-pin inter-related nature of GH2 development • Co-ordinate funding and support for university programmes • Support and coordinate skills development in industry • Bring SETA funding at industry level • Funding support for GH2 PhD projects, programmes and scholarships
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