

HYDROGEN SOCIETY ROADMAP FOR SOUTH AFRICA 2021

DEPARTMENT OF SCIENCE AND INNOVATION



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Department:
Science and Innovation
REPUBLIC OF SOUTH AFRICA



SECURING A CLEAN, AFFORDABLE
AND SUSTAINABLE ENERGY
FUTURE FOR SOUTH AFRICA



FOREWORD BY THE MINISTER OF HIGHER EDUCATION, SCIENCE AND INNOVATION

We are holding this important launch of the Hydrogen Society Roadmap (HSRM) at a time when the world and our country are faced with four major challenges

- The Covid 19 pandemic
- Persisting and stubborn economic crises, and its associated challenges of poverty, inequality and unemployment
- The crises facing poor families, households and communities to make ends meet - the struggle to sustain life and livelihoods
- Climate Change


The role of science, technology and innovation (STI) in confronting the above challenges has perhaps never been this relevant and important. It is also for this reason that STI remains one of the key drivers in the implementation of our Economic Reconstruction and Recovery Plan to embark on sustainable economic growth and development, job creation and socio-economic transformation. For instance, transitioning towards a just and inclusive net zero carbon economy will require scaled up collaboration, investment and innovation in order to address the four major challenges.

There is an African proverb that states that "If you want to sit under a shade in your old age, plant a tree now". In 2007, when Cabinet approved the Hydrogen South Africa Strategy (HySA), the first seeds were planted, and that is why South Africa today is well placed and poised to leverage the hydrogen opportunity to be at the centre of our economic growth and development strategies, as well as part of our mitigation strategy for climate change through greening our economy and society. Transitioning through the hydrogen development trajectory must also form a strong platform to address the needs of the overwhelming majority of our people, especially blacks, women, youth and the poor, both urban and rural.

The Hydrogen Society Roadmap is one of government's strategies and policy direction aimed at bringing together a variety of stakeholders and institutions (both public and private) around a common vision on how to use and deploy hydrogen and hydrogen related technologies as part of our economic development and greening objectives. As a country we have demonstrated our scientific capacity and capabilities in confronting the Covid 19 pandemic. Similarly this roadmap is also important and has the potential of placing South Africa as an important player, participant and scientific thought leader in the emerging global hydrogen system.



I am confident that through the effective implementation of this hydrogen society roadmap, hydrogen will become an important energy source and catalyser that will, amongst other things, enable decarbonisation of crucial carbon intensive sectors of our economy, like heavy duty transport and other energy intensive industries. Successful implementation of this roadmap must lead to the rapid development of a green power sector, a domestic manufacturing sector for hydrogen products, fuel cell components, and the creation of an export market for South Africa's green hydrogen.


Dr BE Nzimande
Minister of Higher Education, Science and Innovation



Cofimvaba Science Centre, launched by the Minister on 6 October 2021, is powered by a combination of renewable energy and fuel cell with on-site hydrogen production

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EXECUTIVE SUMMARY

South Africa faces the challenge of securing clean, affordable and sustainable energy to power its economy and transition into a carbon-neutral society. The country's overarching National Development Plan (NDP) 2030 advocates for increased investment in an energy sector that is both economically inclusive and environmentally sustainable. The NDP identifies, as a priority, the production of sufficient energy to ensure availability, accessibility and affordability while reducing the carbon intensity of the economy. In its quest to reduce emissions in the energy mix, South Africa has developed a highly respected Renewable Energy Independent Power Producer Procurement Programme (REIPPPP). The country has made further significant commitments to integrating renewable energy (RE) sources through the Integrated Resource Plan 2019, while also pursuing its emissions-reduction targets based on commitments made in response to the 2015 Paris Climate Agreement (PA). With a sound foundation, hydrogen is well positioned to become a game changer in South Africa's aspirations to move towards a net-zero carbon economy.

South Africa should leverage the hydrogen opportunity as part of its Economic Reconstruction and Recovery Plan

The Hydrogen Society Roadmap (HSRM) will serve as a national coordinating framework to facilitate the integration of hydrogen-related technologies in various sectors of the South African economy and stimulate economic recovery, in line with the Economic Reconstruction and Recovery Plan. In its pursuit of a hydrogen society, South Africa will leverage its significant natural renewable resources, mineral endowment and capabilities to stimulate local demand for renewable hydrogen and build a viable green-hydrogen export market. This will contribute to the growth and development of the South African economy and the creation of sustainable green jobs, while moving the country towards secure and low-cost sustainable energy, promoting broader national competitiveness. In parallel, South Africa will be a catalyst in the transition of its Southern African neighbours from fossil fuels to renewable

energy (RE) systems through increased intra-Africa trade. Significant local value creation and wealth will therefore be realised from the production, distribution, storage and utilisation of the green-hydrogen value chain in South Africa and across the world.

Ensure that Gender, Equality and Social Inclusion (GESI) are at the core of the transition to a low carbon economy to tackle the triple challenges of poverty, inequality and unemployment

The implementation of the HSRM is expected to contribute to the goal of a just and inclusive net-zero carbon economic growth for societal wellbeing by 2050 through the following high-level outcomes:

- Decarbonisation of heavy-duty transport;
- Decarbonisation of energy-intensive industry (cement, steel, mining, refineries);
- Enhanced and green power sector (main and micro-grids);
- Centre of Excellence in Manufacturing for hydrogen products and fuel cell components;
- Creating an export market for South African green hydrogen; and
- Increase the role of hydrogen (grey, blue, turquoise and green) in the South African energy system in line with the move towards a net-zero economy.

A total of 70 priority actions have been identified and classified according to the high-level outcomes (Figure ES-1). The role of GESI was analysed for each of the key actions with a view to embed GESI indicators into the monitoring, evaluation and learning framework of the HSRM.



Figure ES-1: Priority actions based on the HSRM outcomes

The implementation of the HSRM is expected to set the pace for the country's creation of a sustainable workforce that is inclusive and green-growth oriented. The importance of aligning the country's TVET college system with real industry needs and opportunities to improve labour absorption is therefore critical. A sectoral alignment with industry-specific requirements will facilitate a just labour transition, where potential job losses in the traditional coal-mining industry, for example, are mitigated through the upskilling, retraining and on-boarding of workers.

Rebrand South Africa as a destination for sustainable investment that incorporates environmental, societal and good governance principles

To kickstart the hydrogen economy in South Africa, four catalytic projects have been identified through engagements with stakeholders in the private sector. These include the Platinum Valley Initiative (South African Hydrogen Valley), the CoalCO₂-X Project, Boegoebaai Special Economic Zone (SEZ) and the Sustainable Aviation Fuels (SAF) project. Through their implementation, the flagship projects are expected to produce approximately 500kt of hydrogen and create at least 20 000 jobs annually by 2030 and a Gross Domestic Product (GDP) contribution of at least USD5 billion to the economy by 2050. The projects will contribute to a growth of sustainable green industries that are resource- and energy-efficient, low-carbon and low-waste, non-polluting and safe. The private sector is expected to co-fund and lead the execution of large-scale deployment projects to demonstrate commercial viability. Providing tailor-made support to shovel ready flagship projects can enable innovation in the policymaking process while de-risking the financial

and technical components of a project. Furthermore, such industries have great potential to act as a catalyst for enhanced gender equality and the empowerment of women in wider society.

Build a stronger partnership between government, the private sector and civil society by putting in place an enabling policy environment as quickly as possible

To ensure that the development of the roadmap was inclusive, the Department of Science and Innovation (DSI) consulted widely across various stakeholder groups. This consultation process was commenced in September 2020, with more than 50 stakeholder organisations participating, followed by smaller engagements with key stakeholders on the Theory of Change, the Hydrogen Valley Report and the Green Hydrogen Economy Technical and Vocational Education and Training college study, including high-level bilateral discussions with other Government departments. The HSRM consultative process culminated in the Collaboration Workshop, in which close to 100 stakeholders participated. The purpose of the Workshop was to synthesise the proposed draft action plan with stakeholder roles and identify gaps emanating from the earlier consultations. Government has an important role to play in supporting the transition towards a low-carbon economy that is driven through the coordination of efforts across industry, science councils and academia to transform commitments into action. Using the International Energy Agency (IEA) Policy Framework nomenclature, the 70 priority actions were classified and the summary is included in Figure ES-2.



Figure ES-2: Priority actions based on IEA Policy Framework

Some of the priority actions to be pursued in the short term (2021-2024) include:

- The alignment and integration of the HSRM with relevant national priorities and plans pertaining to energy, industry, decarbonisation and just transition in order to provide investor confidence and support scale-up;
- The support of catalytic projects that demonstrate commercial viability, with a focus on industrial clusters to support wider adoption;
- The review of regulatory, fiscal and other policy measures to support the development of a hydrogen economy;
- Identification of skills required for a hydrogen workforce, and developing a plan to build these skills while recognising the objectives of GESI;
- Continuing the building of the research ecosystem to support innovation, which will be essential to ensure that costs are reduced and hydrogen and hydrogen fuel-cell technologies (HFCT) move from a niche technology to market adoption;
- Mapping international financial programmes and partnerships that are instrumental in supporting the hydrogen economy; and
- Establishing realistic targets, and implementing a monitoring, evaluation and learning framework, in order to support the successful implementation of the HSRM in the short, medium and long term.

Build upon the momentum created by the Hydrogen South Africa Programme to position South Africa as a global player in the green hydrogen and green ammonia markets

Building on the successful implementation of the Cabinet-approved Hydrogen South Africa (HySA) Strategy, DSI, together with other government departments, initiated the development of the HSRM in March 2020. To support the development of a sustainable hydrogen society in South Africa, it is critical to build on the achievements and technical expertise of the HySA Programme, and continue to support research, development and innovation (RDI) beyond the initial 15-year period, which ends on 31 March 2023. In this regard, on 14 September 2021, Cabinet approved the extension of support for the HySA Programme for an additional 10 years, in order for the programme to provide the technical expertise required for the implementation of the HSRM.

International partnerships are key to the realisation of the hydrogen economy however, national interest needs to be protected

In order for South Africa to realise the full benefits of the hydrogen economy international partnerships are critical. Internationalisation and partnerships are embedded within each of the focus areas of the IEA Policy Framework. For instance, under harmonisation of standards and removing barriers, the participation of South Africa in international forums such as the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE) task teams on hydrogen certification, hydrogen trade rules and hydrogen carriers, will be critical to ensure that South African green hydrogen conforms to international standards. International partnerships will also be critical to support the scale-up of training of a future workforce in the hydrogen economy as well as RDI programmes that seek to reduce the cost of hydrogen-related technologies in various applications.

SECTION

A

H₂
Hydrogen

UNDERSTANDING SOUTH
AFRICA'S HYDROGEN
OPPORTUNITY



I. SOUTH AFRICA'S CURRENT ENERGY LANDSCAPE



South Africa is facing the challenge of securing clean, affordable and sustainable energy to power its economy and to contribute to the transition to a climate-neutral society. A clean energy future is seen as a critical enabler of inclusive and transformational economic growth and development.

South Africa's NDP 2030¹ advocates for increased investment in an energy sector that is both economically inclusive and environmentally sustainable. The plan identifies, as a priority, the production of sufficient energy to support industry at competitive prices, ensuring access for poor households, while reducing the carbon intensity of the economy.

In its quest to reduce emissions from the energy mix, South Africa developed the REIPPPP. This programme has, to date, supported the implementation of 5 GW of operational renewable electricity-generation capacity, which in 2020 accounted for 5.6% of South Africa's domestic electricity demand.² Although coal remains the country's primary source of energy, the REIPPPP heralds an important shift to clean energy production. Further significant commitments towards integrating RE in the power sector have been outlined in the IRP 2019.³ The transition from a carbon-based energy system with substantial dependence on coal to a sustainable, clean and affordable energy system based on RE resources is a priority for South Africa as it pursues both economic prosperity and its international climate commitments.

I.1 SOUTH AFRICA'S ENERGY SUPPLY AND DEMAND

Figure I.1 depicts a Sankey representation of energy supply and demand for the South African economy. The figure highlights the dependency on coal and oil products as primary sources of energy: these comprised approximately 90% of primary energy supply in 2017, with coal accounting for 75%. The interdependency of coal exports and crude-oil imports is also illustrated.

Revenue from coal exports essentially balances expenditure on imported oil products: historically, crude and refined petroleum product represents South Africa's largest import burden, accounting for 15-20% of total merchandise imports.⁴

1. Government of South Africa, National Planning Commission, *National Development Plan 2030*, gov.za/issues/national-development-plan-2030.

2. Council for Scientific and Industrial Research (CSIR), *Statistics of utility-scale power generation in South Africa in 2020, 2021*, researchspace.csir.co.za/dspace/handle/10204/11865.

3. DMRE, *Integrated Resource Plan (IRP2019)*, <http://www.energy.gov.za/IRP/2019/IRP-2019>.

4. Industrial Development Corporation (IDC), 2021, "Economic Trends: Key trends in the South African economy", <https://www.idc.co.za/wp-content/uploads/2021/04/IDC-RI-publication-Key-Trends-in-the-South-African-Economy-31-March-2021-FINAL.pdf>

I. SOUTH AFRICA'S CURRENT ENERGY LANDSCAPE (CONTINUED)

SOUTH AFRICA'S ENERGY BALANCE (2017)

Units: Petajoules

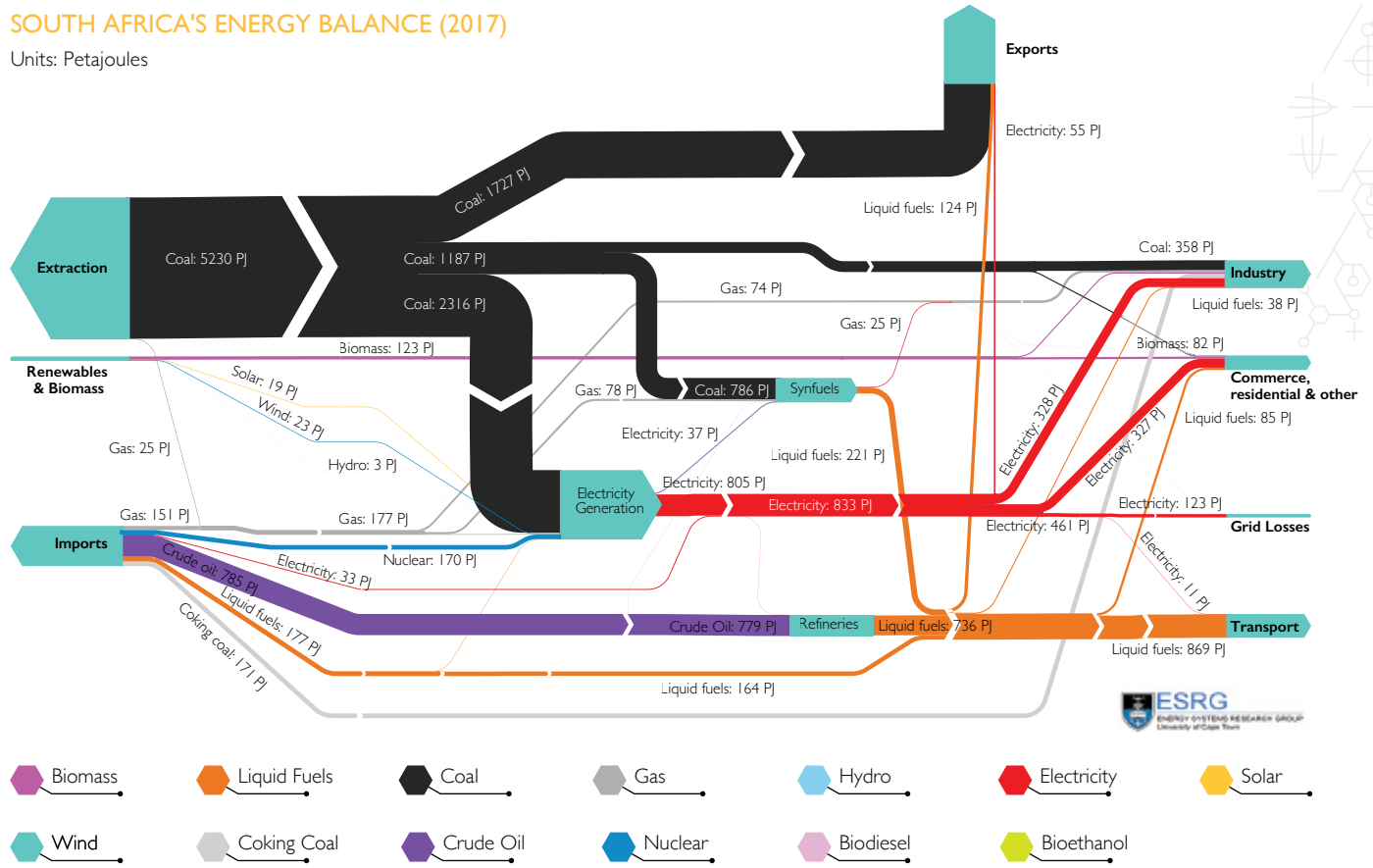


Figure 1.1: South African energy flow in 2017
Source: UCT 2020⁵

I.2 SOUTH AFRICA'S ENERGY INFRASTRUCTURE

The dominant role of coal and oil in South Africa's energy supply is reflected in the supply and distribution infrastructure. Electricity generation, for which coal accounted for 79% in 2020, is dominated by the state utility, Eskom (Figure 1.2). Eskom's nominal generation capacity comprises around 38 GW of coal, 1.9 GW of nuclear, 3.3 GW of hydro/pumped storage, 3.4 GW of open-cycle gas turbines⁶ and less than 1 GW of non-dispatchable RE.

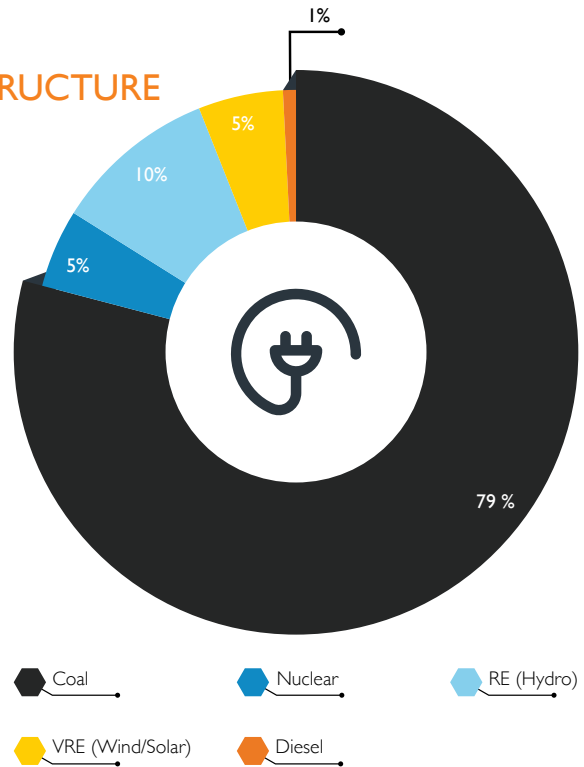


Figure 1.2: South Africa's electricity supply mix by key technology
Source: CSIR 2020

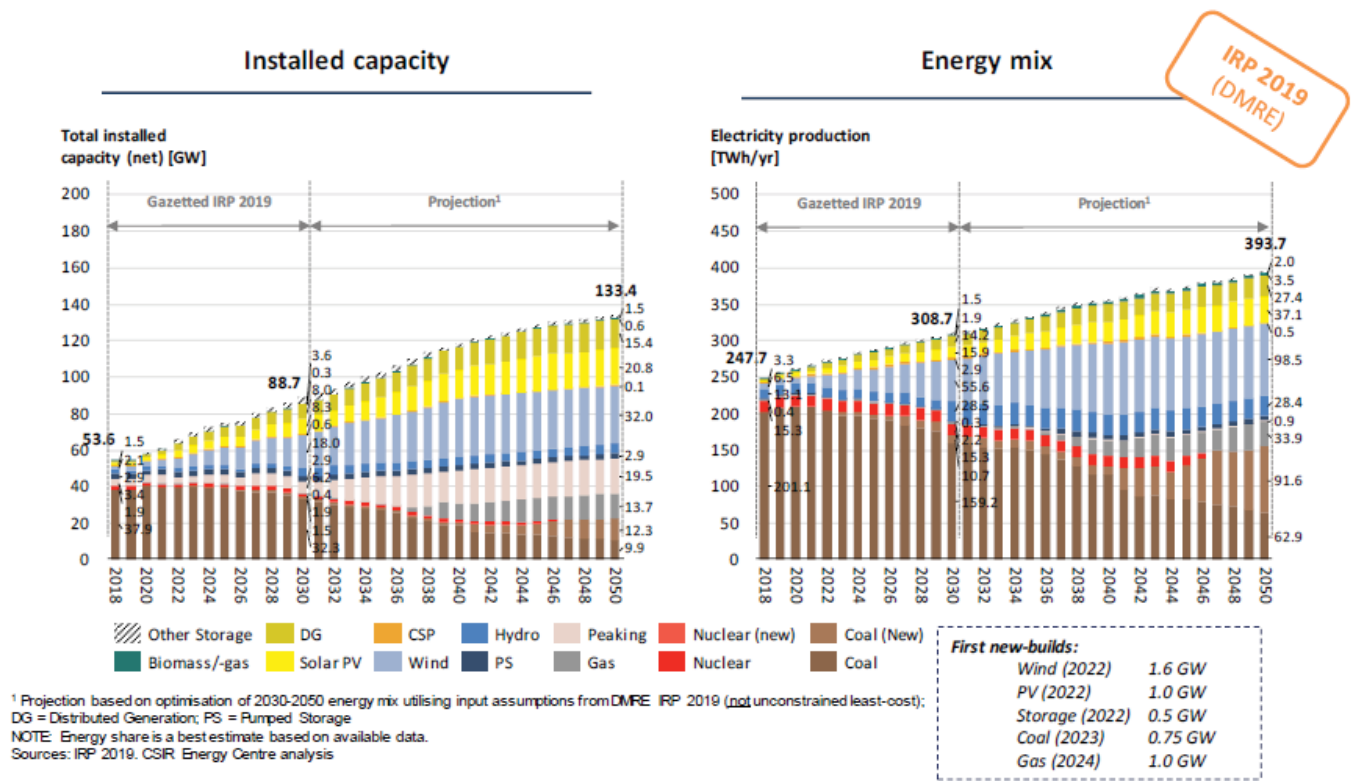
5. University of Cape Town, Technical analysis to support the update of South Africa's first NDC's mitigation target ranges, 2021, doi.org/10.25375/uct.16691950.
6. Open-cycle gas turbines that consume diesel and kerosene.

I. SOUTH AFRICA'S CURRENT ENERGY LANDSCAPE (CONTINUED)

In addition to Eskom's portfolio, the REIPPPP has added another 5 GW of variable RE to the national portfolio, largely wind (2.5 GW) and solar PV (2.5 GW). The REIPPPP has to date contracted a total of 6.4 GW of capacity, with a further allocation of 1 GW of solar PV and 1.6 GW of wind having been recently promulgated.⁷

In 2012, the average age of the South African coal-powered stations was placed at 30 years, and some plants were reported to have already reached 300% of their design life.⁸ Many power stations will thus need to be decommissioned over the next three decades. Based on information from Eskom, the Department of Mineral Resources and Energy (DMRE) reports that by 2030, 9.6 GW of existing capacity will be decommissioned, with less than 10 GW of existing capacity still in operation by 2050.

The IRP 2019 maps the future expansion of the electricity system. RE generation is expected to comprise a significant and competitive share of the generation portfolio by 2030, and potentially be the primary electricity source by 2050, mirroring the present-day dominance of coal. Figure 1.3 reflects the planned energy mix of the country as set forth in the IRP 2019 to 2030, and extended to 2050 by the CSIR.⁹ The IRP 2019 indicates that coal will continue to play a significant role in electricity generation in South Africa in the near future, as it is the largest base of installed generation capacity. However, coal generation decreases to 43% of the energy mix due to the planned decommissioning of coal plants from 2019 to 2023 and from 2026 to 2030. Notable is the increase in solar and wind, making up a combined share of 34% of the energy mix by 2030.



Installed capacity and energy mix for IRP 2019 (extended to 2050 by CSIR) revealing intentions for an increasingly diversified energy mix

Figure 1.3: Planned South African energy mix extended to 2050
Source: CSIR 2020

Two key technical aspects of a transition to an electricity supply system characterised by variable or intermittent generation are the geographical shift in production zones, and the requirement for network balancing to maintain the stability of the transmission and distribution system. Eskom Currently functions as the system operator, and owns and operates the transmission

and distribution networks outside those owned and managed by large municipalities. The growth of RE will require further enhancement of the transmission system, as shown in Figure 1.4, to accommodate the increasingly distributed footprint of the electricity supply system.

7. Dept. Mineral Resources and Energy (DMRE), Renewable Energy Data and Information Service: Location and Contracted Capacities, 2021, redis.energy.gov.za/power-producers/; DMRE, Independent Power Producer Procurement Programme: Bid Window, 2021, https://www.ipp-renewables.co.za.
8. Eskom, Opportunities and considerations for power plant refurbishment and upgrades, 2012, energy.gov.za/files/4thEUSouthAfricaCleanCoalWorkingGroup/Eskom%20Refurbishment%20N%20Volk.pdf.
9. Council for Scientific and Industrial Research (CSIR), Systems analysis to support increasingly ambitious CO₂ emissions scenarios in the South African electricity system, 2020, researchspace.csir.co.za/dspace/bitstream/handle/10204/11483/Wright_2020_edited.pdf.

I. SOUTH AFRICA'S CURRENT ENERGY LANDSCAPE (CONTINUED)

As shown in Figure 1.4, over 2 GW of battery storage is planned by 2030, in combination with natural-gas-fuelled turbines to provide network stability.¹⁰ Natural gas is primarily imported from Mozambique. Domestic production, offshore in the Eastern Cape, is estimated at 17% of domestic demand (26 PJ), with the remainder sourced from the ROMPCO pipeline via Sasol, the country's largest integrated fuels-and-chemicals producer.

Figure 1.5 highlights the current reliance of the existing fuels-and-chemicals complex on imported natural gas, with a third of the gas retained externally to commercial and industrial users.

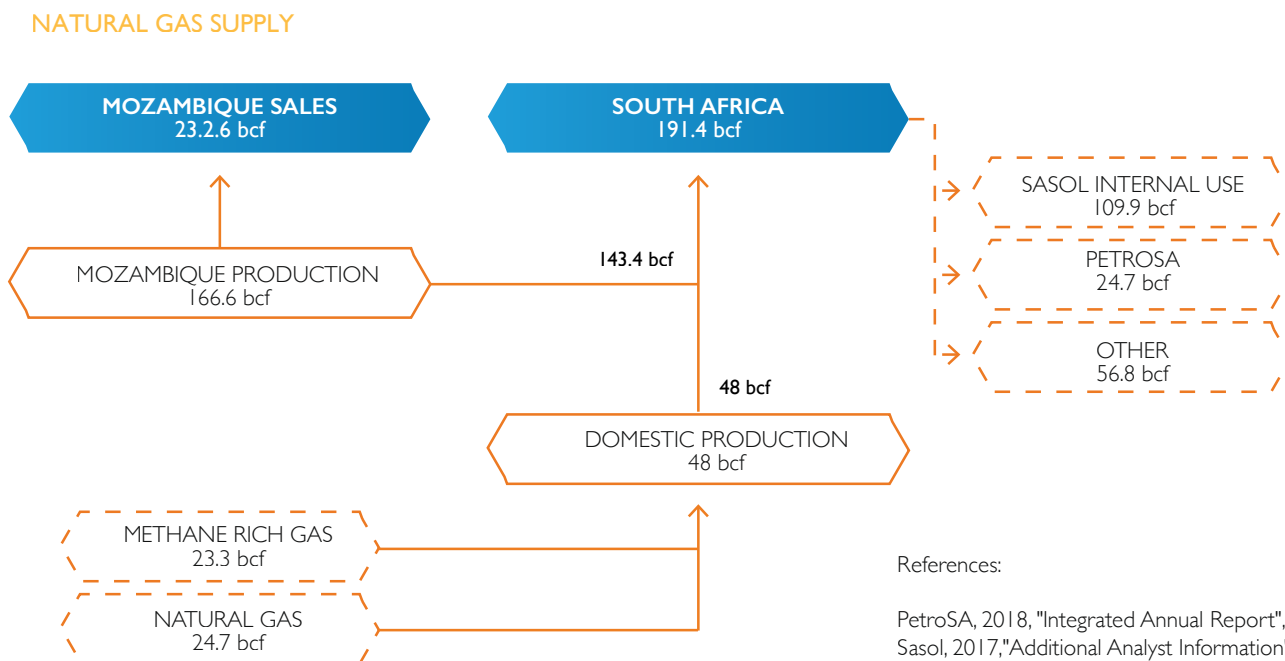


Figure 1.5: Natural gas supply from Mozambique
Source: Sasol 2017

Sasol operates both gas-to-liquids (GTL) and coal-to-liquids (CTL) synfuel facilities, with coal representing the majority share of feedstock (Figure 1.1). Excluding the electricity sector, the CTL facility is responsible for 60% of total domestic coal consumption (approximately 40 Mt per annum), with almost two-thirds consumed as feedstock in the synfuel process to produce fuels and chemicals, and the remainder utilised for captive power. The CTL process also produces nature-identical methane-rich gas, complementing the gas sourced from Mozambique. Prior to the recent closure of one of South Africa's major crude-oil refineries, the CTL facility was responsible for approximately 25% of locally-produced refined liquid oil product (diesel, petrol and jet fuel).

Approximately 95% of liquid fuel demand is consumed by the transport sector. In 2017, 12.1 billion litres of diesel were consumed, followed by petrol and jet fuel at 11.2 and 2.7 billion litres respectively.¹¹ Although in 2017 the requirement for diesel for the power sector amounted to approximately 10 million litres, historically, electricity generation has consumed in excess

of 1 billion litres per annum to alleviate the power outages that continue to plague the country and exacerbate the need for diesel.¹² Demand for liquid fuels is met by both imported refined product and crude oil via domestic refineries. Regional exports of petrol, diesel and jet fuel each amount to approximately 10% of the total product inventory. Demand for petrol and jet fuel is mostly met by domestic production (more than 90%), while a third of diesel demand requires importation.

Liquid fuels infrastructure in South Africa currently consists of five refineries. There are three crude-oil refineries with a combined nominal capacity of 388 000 barrels per day (bpd), the CTL refinery (Secunda) with an oil-equivalent nominal capacity of 150 000 bpd, and a GTL refinery (Mossel Bay) operated by the Petroleum Oil and Gas Corporation of South Africa (PetroSA) with a nominal capacity of 45 000 bpd.¹³ Figure 1.6 shows these in relation to the major liquid fuel and gas pipelines.¹⁴

10. Eskom, *Eskom Transmission Development Plan (TDP) 2021-2030*, 2020, eskom.co.za/wp-content/uploads/2021/08/TDP_2020_-_Public_Forum_Presentation_20_Oct2020_Final_Rev1.pdf.

11. South African Petroleum Industry Association, *Annual Report*, 2018.

12. Eskom, *Fuel consumption*, eskom.co.za/OurCompany/SustainableDevelopment/Pages/CDM_Calculations.aspx.

13. The Engen refinery located in eThekweni (Durban) with a nominal capacity of 135 000 bpd was retired in early 2021 with the intention to convert to an import terminal; engineeringnews.co.za/article/engen-to-shut-refinery-and-repurpose-kzn-site-as-an-import-terminal-2021-04-23; the National Petroleum Company of South Africa was recently inaugurated following the merger of PetroSA with other Central Energy Fund subsidiaries.

14. Transnet, *Transnet Long Term Planning Framework: Pipeline Development Plan*, 2017, transnet.net/BusinessWithUs/Pages/LTPF.aspx.

I. SOUTH AFRICA'S CURRENT ENERGY LANDSCAPE (CONTINUED)

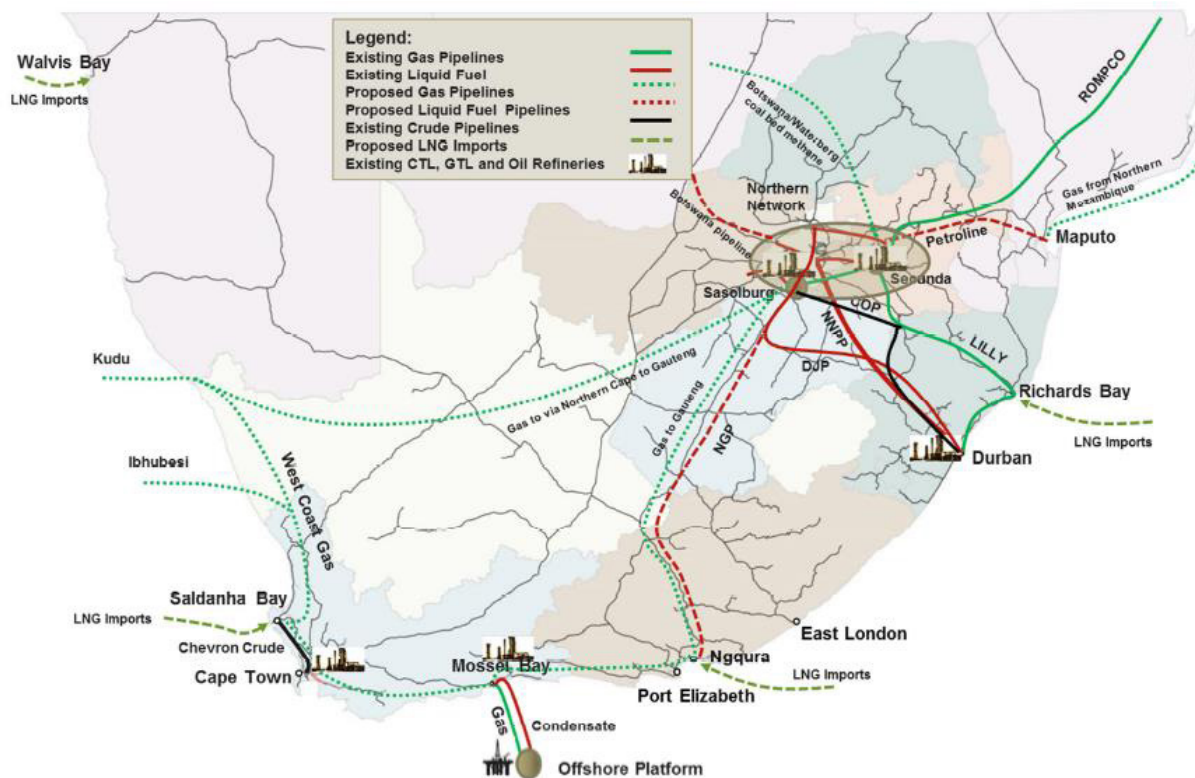


Figure 1.6: Refineries and major existing and planned oil and gas pipelines

Source: Transnet 2017

Regarding the future supply of liquid fuels, the country is at a crossroads. The crude-oil refineries produce Euro-2 standard fuel; however, the DMRE recently gazetted regulations enforcing improved fuel-quality standards, known as “Cleaner Fuels Phase 2”, which aim to raise the fuel standard to Euro-5 to improve air quality and permit more fuel-efficient vehicles to operate domestically.¹⁵ Key strategic decisions are required in the near term: to invest in refurbishing the existing refineries, which are uncompetitive at global scale; to retire domestic production and switch to imports; or to invest in a new, larger refinery (400 000 bpd) in the Richards Bay area.

Figure 1.6 highlights future import terminals and pipelines that would increase the share of natural gas as a primary energy source. Recent offshore discoveries of indigenous gas fields (Brulpadda and Luiperd), near the existing Mossel Bay complex, present additional prospects for expanding the existing power-sector infrastructure. Open-cycle gas turbines at Ankerlig (Saldanha Bay), Gourikwa (Mossel Bay), Avon (Durban) and Dedisa (Coega IDZ), currently consuming diesel, could switch to gas and be converted to more energy-efficient combined-cycle gas turbines.¹⁶

The IRP 2019 states that gas-to-power technologies will provide the flexibility required to complement RE. It also notes that new gas resources – such as the Brulpadda field, Rovuma basin in Mozambique, and indigenous gas-like coal-bed methane – could form a central part of South Africa’s strategy for regional economic integration in the Southern African Development Community (SADC).¹⁷

The National Planning Commission’s Energy Paper notes that natural gas currently plays a relatively small role in the South African energy mix as a result of limited domestic availability, with a fraction (less than 20%) originating from domestic offshore production.¹⁸ South Africa is considering cooperation with neighbouring countries in this regard, and partnerships are being put in place for joint exploitation and beneficiation of natural gas within the SADC region. The SADC is developing a Gas Master Plan to identify short- and long-term infrastructure requirements to enable the uptake of a natural-gas market. This additional infrastructure may also potentially cater for an increasing role for hydrogen in the SADC region, in both export and domestic contexts.

15. Department of Mineral Resources and Energy (DMRE), *Regulations regarding petroleum products specifications and standards for implementation*, Government Gazette 45068, 2021, energy.gov.za/files/policies/petroleum/Gazette45068-Regulations-Regarding-Petroleum-Products-Spec-Stds-for-Implementation.pdf.

16. *Ibid.*

17. *Ibid.*

18. National Planning Commission, *Economy Series Energy*, 2018, gov.za/sites/default/files/gcis_document/201802/npc-energy-paper.

1.3 SOUTH AFRICA'S EXISTING ENERGY POLICIES AND STRATEGIES

The South African energy landscape is governed by a range of policies and strategies. The 1998 White Paper on Energy Policy provides the framework for regulating energy supply and demand, with the objectives of ensuring energy access, energy governance, stimulating economic development, managing energy-related environmental impacts, and securing supply through diversity.¹⁹ It recognises the role of RE in addressing environmental challenges, and in meeting supply in areas not connected to the grid, alongside the ongoing use of fossil fuels in the energy mix. Hydrogen commands one brief mention in this document, developed at a time when hydrogen was not at the forefront of energy planning. The 2003 White Paper on Renewable Energy Policy built on the high-level intentions regarding RE in the 1998 White Paper, setting a 2013 target for RE in power generation and non-electric applications.²⁰ Hydrogen is again briefly mentioned as a potential future technology. Neither of these documents has been updated subsequently. The 2008 National Energy Act provides a legal framework for governing various aspects of the energy landscape in South Africa, including those related to supply and demand.²¹

The instrument that provides detailed information to guide planning of the overall energy mix for the country is the IEP.²² The requirement for the preparation of the IEP was identified in the White Paper on Energy Policy, with the National Energy Act of 2008 further defining its objectives. In the development of the IEP, current energy supply-and-demand trends in different sectors of the economy and across all energy carriers, along with assumptions about future demand and technology evolution, was used to project future energy requirements in a variety of scenarios. These included scenarios with emissions caps and different carbon prices. A draft IEP was issued in 2016 as part of the process to update 2003 IEP version. The IEP update is critical to guiding overall energy planning for the country, including the development of hydrogen.

The IRP 2019 specifies the build plan for the electricity sector specifically, providing a mechanism for Government to drive diversification of the electricity-generation mix and to promote RE and other low-carbon

technologies.²³ Developed using a least-cost optimisation model with carbon constraints, among others, the IRP details the contribution of RE and non-RE technologies up to 2030, as well as forecasts of demand to 2050. The IRP 2019 therefore includes a schedule for decommissioning Eskom's power stations. The electricity supply involving hydrogen does not feature explicitly in the IRP, although mention is made of its potential role in energy storage, and the need to support ongoing hydrogen research and development (R&D) in South Africa.

In addition to instruments that have energy as their primary focus, other national instruments have implications for the energy sector, and thus for implementation of the HSRM. Policy and legislation that seek to address the climate challenge is discussed in Section 1.5 below. The NDP's overall objective is to eliminate poverty and reduce inequality by 2030.²⁴ Chapter 4 of the NDP focuses on infrastructure, including energy infrastructure, noting the need for diversification of energy supply. The NDP also highlights climate-change impacts and mitigation as critical issues to be addressed. The Department of Transport's (DoT) Green Transport Strategy (GTS 2018) explores in detail the potential future role of hydrogen fuel cells in various applications in the transport sector.²⁵

The Minerals Beneficiation Strategy focuses on the need for downstream beneficiation of South Africa's mineral resources, noting the potential for fuel-cell production.²⁶ The National Industrial Policy Framework (NIPF), adopted as a broad framework governing industrial policy, articulates the approach to industrial development. The Industrial Policy Action Plan (IPAP) represents the implementation plan for the NIPF. The most recent revision of the IPAP, which covers the period 2018/2019 to 2020/2021, provides updates on key focus areas in the industrial sector, including green-industry investment. Particularly relevant are the focus areas of developing a policy roadmap for climate-compatible industrial development, and support for fuel-cell industry development. Finally, the HySA Strategy, approved by Cabinet in 2007, and the associated 15-year HySA Programme, focus on beneficiation of PGM through the development of HFCT.²⁷

19. DMRE, *White Paper on the Energy Policy of the Republic of South Africa*, 1998, energy.gov.za/files/policies/whitepaper_energypolicy_1998.

20. *Ibid.*

21. Republic of South Africa, *National Energy Act*, 2008, gov.za/sites/default/files/gcis_document/201409/316381263.pdf.

22. Department of Energy, *Integrated Energy Plan*, 2016, energy.gov.za/files/IEP/2016/Integrated-Energy-Plan-Report.

23. DMRE, *Integrated Resource Plan (IRP2019)*.

24. National Planning Commission, *National Development Plan 2030*, nationalplanningcommission.org.za/assets/Documents/ndp-2030-our-future-make-it-work.pdf.

25. DoT, *GTS for South Africa: (2018-2050)*, transport.gov.za/documents/11623/89294/Green_Transport_Strategy_2018-2050_onlineversion.pdf/71e19f1d-259e-4c55-9b27-30db418f105a.

26. Department of Mineral Resources, *A Beneficiation Strategy for the Minerals Industry of South Africa*, 2011, gov.za/sites/default/files/gcis_document/201409/beneficiation-strategy-june-2011-final-30.pdf.

27. Department of Science and Technology, *Hydrogen South Africa (HySA) Strategy*, 2007.

I. SOUTH AFRICA'S CURRENT ENERGY LANDSCAPE (CONTINUED)

I.4 THE ENERGY-SECTOR STAKEHOLDERS

Table 1.1 presents an overview of the Government departments, state-owned entities and private companies that play a role in the energy sector in South Africa, and that may be impacted by the implementation of the HSRM.

Table 1.1: Key roleplayers and their mandates

ROLE PLAYER	MANDATE RELEVANT TO THE HSRM
GOVERNMENT DEPARTMENTS AND REGULATORS	
Department of Mineral Resources and Energy (DMRE)	Custodian of policy and planning for the energy sector; focusing on energy security through diversifying the country's energy mix to include RE sources.
National Energy Regulator of South Africa (NERSA)	Regulates the energy sector in the context of national policy and planning, licenses new energy infrastructure and regulates electricity and hydrocarbons-infrastructure tariffs.
National Treasury	Governs fiscal and procurement policies.
Department of Transport (DoT)	Leads the implementation of the Green Transport Strategy 2018.
Department of Trade, Industry and Competition (DTIC)	Develops local industries and trade with particular focus on green industries and job creation; works to attract foreign investment.
Department of Public Enterprises (DPE)	As the main shareholder, the DPE provides oversight to Eskom, the sole power off-taker
Department of Public Works and Infrastructure (DPWI)	With a portfolio of more than 500 000 buildings in the public sector, has developed the Public Works and Infrastructure Green Building Policy with a focus on deploying green technologies in public buildings.
Department of Forestry, Fisheries and the Environment (DFFE)	Sustainable development and environmental integrity; grants environmental authorisations in terms of the National Environmental Management Act (NEMA).
Department of Science and Innovation (DSI)	Custodian of national research, development and innovation focused on new energy technologies; has implemented the Hydrogen South Africa Strategy since 2008.
Provincial departments and municipalities	Regulates private RE generation (embedded generation) through by-laws and policies. Responsible for procurement of energy services.

I. SOUTH AFRICA'S CURRENT ENERGY LANDSCAPE (CONTINUED)

ROLE PLAYER	MANDATE RELEVANT TO THE HSRM
STATE-OWNED ENTITIES	
Eskom	National electricity-supply utility and single buyer for renewables from the REIPPPP.
Central Energy Fund (CEF)	Contributes to the security of energy supply of South Africa through exploration, acquisition, development, marketing and strategic partnership.
South African National Energy Development Institute (SANEDI)	Promotes energy research and technology innovation, supports green energy and energy-efficiency uptake.
Industrial Development Corporation (IDC)	Development finance institution (DFI) providing finance for industrialisation projects.
PetroSA (now incorporated into the South African National Petroleum Company)	National oil company with interests along the oil and gas value chain. Activities include exploration, production of liquid fuels from gas through the gas-to-liquids process, development of logistical infrastructure, and marketing and trading of products.
PRIVATE COMPANIES	
Sasol	Producer of liquid fuels and chemicals via coal-to-liquids and gas-to-liquids processes. Has signalled an intention to develop hydrogen-based infrastructure.
Engen, BP, Shell, Astron Energy	Owners of crude-oil refineries and distribution channels for refined product.
OTHER	
Academic institutions and science councils	RDI linked to all stages of the hydrogen value chain.

I. SOUTH AFRICA'S CURRENT ENERGY LANDSCAPE (CONTINUED)

I.5 THE GREENHOUSE GAS (GHG) LANDSCAPE

The 2015 PA emphasised the urgency of “holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels”.²⁸ In 2018, the Intergovernmental Panel on Climate Change (IPCC) produced the Special Report on Global Warming of 1.5°C. The report states that the planet is already experiencing climate impacts, and that these will be significantly worse at 2°C than at 1.5°C. It further emphasises that global carbon dioxide (CO₂) emission pathways consistent with keeping global temperature within the 1.5°C limit require rapid global emissions reductions of 45% by 2030 (in relation to 2010 levels), and reaching net-zero CO₂ emissions by 2050.²⁹

South Africa is the world's 14th largest emitter of GHGs, particularly CO₂ emissions, due to its heavy reliance on coal. As a signatory to the PA, South Africa signalled its intent to decarbonise its coal-centric economy, ratifying its first Intended Nationally Determined Contribution (INDC) in 2016.³⁰ In accordance with Article 4.9 of the PA, which requires a Nationally Determined Contribution (NDC) submission every five years to monitor the progress of implementation, South Africa submitted its updated NDC to the United Nations Framework Convention on Climate Change (UNFCCC) in 2021.³¹

The NDC provides the basis for monitoring the progress of emissions reductions and establishing equitable carbon budgets for the medium term (to 2030).

The National Climate Change Response White Paper (NCCRP), Carbon Tax Act and Climate Change Bill recently tabled before Cabinet are three key legislative documents that outline South Africa's response to climate change (Table I.2).³² The NCCRP serves as a foundation for the Climate Change Bill, which underpins the regulatory landscape for managing emissions. The Bill will place emissions caps on sectors and companies, and thus provide a further driver for the adoption of RE alternatives. The Carbon Tax Act institutes taxes on emissions from certain activities, including electricity generation.

Additional fiscal instruments in the form of environmental levies for electricity generation and vehicles also exist. Eskom charges an environmental levy for electricity generation from fossil fuels, which funds its demand-side management programme. The vehicle emissions or environmental levy is designed to promote the sale of low-carbon-emission vehicles. It applies to new-vehicle purchases and is based on the manufacturer's advertised CO₂ intensity.

Table I.2: Key climate change policy documents

POLICY/PLAN	KEY ASPECTS
White Paper on National Climate Change Response 2011	<ul style="list-style-type: none"> Addresses both mitigation and adaptation in the short, medium and long term (up to 2050). Manages inevitable climate-change impacts through interventions that build and sustain social, economic and environmental resilience. Makes a fair contribution to the global effort to stabilise GHG concentrations in the atmosphere.
Carbon Tax Act, 2019	<ul style="list-style-type: none"> Taxes a wide range of activities across the economy. Allocates various allowances to reduce the tax burden, although these will fall away over time.
Nationally Determined Contribution 2020	<ul style="list-style-type: none"> Revision of original submission for a 2030 mitigation target range, from 398-614 Mt CO₂e to a range of 350-420 Mt CO₂e (reviewed every five years).
Climate Change Bill 2021	<ul style="list-style-type: none"> Uses the best available science to decarbonise the economy in a manner that reduces the socioeconomic vulnerability of the population. Enhances the capacity of society, the environment and the economy to adapt to the impacts of climate change. Allocates carbon budgets (at five-yearly periods) to activities that generate GHG emissions.
Electricity environmental levy	<ul style="list-style-type: none"> Levy administered by Eskom for electricity generated from fossil fuels. Currently an offset against the carbon-tax liability is applicable.³³
New-vehicle emissions levy	<ul style="list-style-type: none"> Levy administered by the South African Revenue Service on new-vehicle purchases; based on the CO₂ emissions intensity of the vehicle.

28. United Nations Framework Convention on Climate Change (UNFCCC), *The Paris Agreement*, unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement.

29. Intergovernmental Panel on Climate Change (IPCC), *Global Warming of 1.5°C: An IPCC Special Report*, 2018, ipcc.ch/sr15.

30. Intended Nationally Determined Contribution (INDC) were subsequently rephrased to Nationally Determined Contribution (NDC).

31. Department of Forestry, Fisheries and Environment (DFFE), *South Africa's updated Nationally Determined Contribution (NDC)*, 2021, nfccc.int/sites/ndcstaging/PublishedDocuments/South%20Africa%20First%20South%20Africa%20updated%20first%20NDC%20September%202021.pdf.

32. Department of Environmental Affairs (DEA), *South Africa's National Climate Change Response Policy*, 2011, environment.gov.za/sites/default/files/legislations/national_climatechange_response_whitepaper.

33. National Treasury, *Explanatory memorandum on the carbon tax bill*, 2018.

I. SOUTH AFRICA'S CURRENT ENERGY LANDSCAPE (CONTINUED)

South Africa's INDC articulated South Africa's commitment to reducing GHG emissions as the "peak, plateau and decline (PPD) trajectory", as did the NCCRP. The PPD currently represents the benchmark against which South Africa's mitigation efforts are measured. The revised NDC submission, however, expresses the updated commitment against two points in time rather than a trajectory; it suggests that national emissions in 2025 will be in the range of 398-510 Mt CO₂e, and between 350-420 Mt CO₂e in 2030.

South Africa's commitment to the PA on climate change will require collaboration between Government and business to achieve its stated carbon-reduction goals. The country's GHG emissions are currently dominated by energy industries that emit 410.7 Mt CO₂e, or 80% of the official GHG inventory of 512.7 Mt CO₂e (excluding natural land sinks).³⁴ Within the energy sector, power generation constitutes the major share at 216.5 Mt CO₂e (42%), followed by transport at 54.7 Mt CO₂e (11%).³⁵ The two sectors represent the two major emissions sources in the country. Within the transport sector, road transport is responsible for 96% of transport emissions, with heavy-duty road freight comprising approximately

20% of road-transport emissions.³⁶ Notably, coal liquefaction, primarily for the production of transportation fuels, is another key source of emissions in the energy sector (10%).

Industrial processes further contributed an additional 32.1 Mt CO₂e in 2017 (6.3%), with ferroalloys and iron and steel, the predominant sectors, emitting 11.3 Mt CO₂e and 7.7 Mt CO₂e respectively.

The continued reliance on fossil fuels, and the domestic coal endowment in particular, has resulted in a GHG-emissions-intensive economy that, at 1.4 kt CO₂e per USD GDP, is currently more than double the G20 and global average³⁷, which has also surpassed the BRICS economic group in recent years.³⁸ As shown in Figure 1.7, the carbon intensity of South Africa's economy has exhibited a general decline for the period 2000 to 2017. However, to meet international obligations to mitigate the environmental and socioeconomic costs arising from climate change, dramatic reductions in GHG emissions are required.

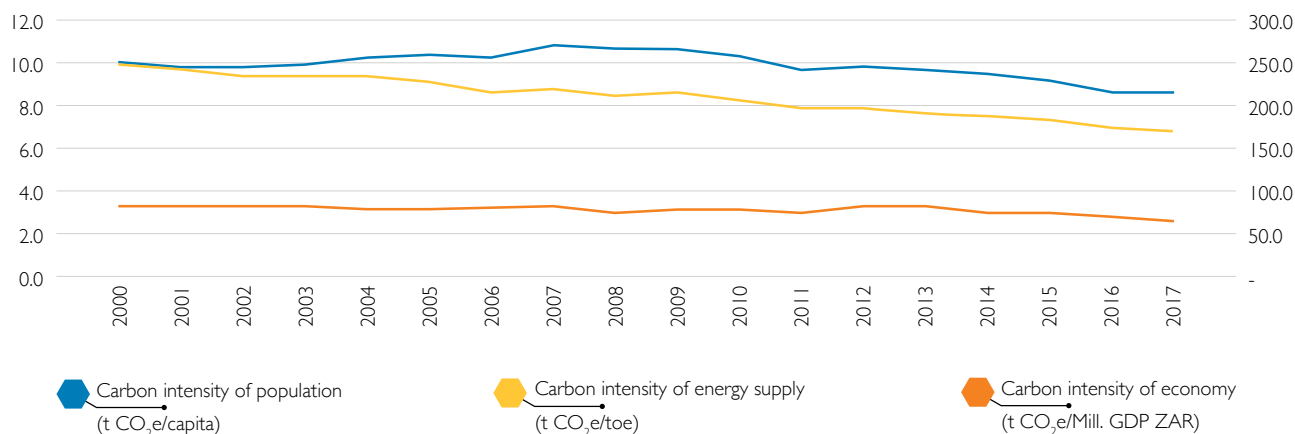


Figure 1.7: Trends in carbon-intensity indicators for South Africa between 2000 and 2017

Source: National Inventory Report 2017, DFFE

34. The national inventory for 2017 amounts to 482,016 GgCO₂e when land sinks are included.

35. DFFE, *National GHG Inventory Report South Africa 2017*, 2021, environment.gov.za/mediarelease/creecy_greenhouse-gas-inventory_report.

36. University of Cape Town, *Technical analysis to support the update of South Africa's first NDC's mitigation target ranges*, 2021, doi.org/10.25375/uct.16691950.

37. ClimateWatch, *Historical GHG Emissions*, 2018. <https://www.climatewatchdata.org>.

38. BRICS is the term to describe the group of major emerging markets comprising Brazil, Russia, India, China and South Africa.

I.6 AIR QUALITY

According to the World Health Organisation (WHO)³⁹, air pollution is one of the biggest environmental threats to human health, alongside climate change, and causes seven-million premature deaths each year. The main constituents of poor air quality include particulate matter, ozone, nitrogen dioxide, sulphur dioxide and carbon monoxide. The WHO notes that through the reduction of air pollution levels, countries can reduce the burden of disease from stroke, heart disease, lung cancer and both chronic and acute respiratory diseases, including asthma. In this regard, WHO has revised the guideline for annual average exposure to PM_{2.5} (particles smaller than 2.5 micron in diameter) from 10 to 5 micrograms per cubic metre, while the annual limit has been reduced from 40 to 10 micrograms per cubic metre for nitrogen dioxide.

As part of monitoring the extent of pollution in the country, the DFFE monitors the air quality in terms of Section 18(1) of the National Environmental Management: Air Quality Act No 39 of 2004 (NEM: AQA). Studies show that industrial activity, domestic fuel burning, waste burning and mining activities are some of the main contributors to poor air quality. Following the assessment of national air quality data, DFFE classified some highly polluted areas as National Priority Areas. The three priority areas, which are located in Gauteng, Mpumalanga and North West provinces, respectively, are:

- Vaal Triangle-Air shed Priority Area in 2006;
- Highveld Priority Area in 2007; and
- Waterberg-Bojanala Priority Area in 2012.

The air quality in Mpumalanga is of particular concern as the province is home to 12 Eskom coal-fired power stations, a Sasol plant and a NatRef refinery.

39. <https://mg.co.za/tag/world-health-organisation/>.

2. SOUTH AFRICA'S OPPORTUNITY TO BECOME A SIGNIFICANT PLAYER IN THE HYDROGEN MARKET



Adhering to the PA requires a variety of solutions to reduce GHG emissions, particularly for sectors in which emissions have traditionally been hard to abate, such as transport and industry. Hydrogen has emerged as one of these solutions, due to its zero-emission output at the point of application and its flexible production pathways, which include production from RE with virtually zero-carbon emissions. The potential for hydrogen to make a significant impact on the global economy has been articulated previously, although a large-scale hydrogen economy is yet to materialise at the envisaged pace and scale. However, recent reports suggest that the opportunity presented by hydrogen is starting to become a reality.⁴⁰

2.1 GLOBAL TRENDS IN HYDROGEN

Hydrogen is currently produced and consumed widely in industrial processes, such as in ammonia production and oil refining. Hydrogen is also a versatile energy carrier and can be produced from carbon-emitting fossil fuels such as coal and natural gas, as well as from clean, renewable resources such as solar and wind (Table 2.1).

Table 2.1: Hydrogen production methods and associated carbon footprints

CATEGORIES	DESCRIPTION
Grey hydrogen	<ul style="list-style-type: none"> Produced from fossil fuels (coal, natural gas). Emits carbon through coal gasification with a carbon-capture system or via electrolysis. Considered dirty, even though this hydrogen produces zero emissions at point of use.
Blue hydrogen	<ul style="list-style-type: none"> Produced from fossil fuels, with carbon emissions reduced by the use of Carbon Capture Utilisation and Storage (CCUS). Includes hydrogen produced as a by-product through processes such as chlor-alkali. Lower greenhouse gas emissions than grey hydrogen.
Pink/Purple hydrogen	<ul style="list-style-type: none"> Produced using nuclear energy. Lower emissions than both grey and blue hydrogen.
Turquoise hydrogen	<ul style="list-style-type: none"> Produced from thermal splitting of methane, which produces solid carbon rather than carbon dioxide. The heat for the high temperature reactor is produced from renewable or carbon-neutral energy sources.
Green hydrogen	<ul style="list-style-type: none"> Produced using RE sources with zero emissions, such as by water electrolysis. Seen as holding the most significant promise for decarbonisation.

40. International Energy Agency, *The future of hydrogen: Seizing today's opportunities*, 2021, [iea.org/reports/the-future-of-hydrogen](https://www.iea.org/reports/the-future-of-hydrogen); Hydrogen Council, *Hydrogen scaling up: A sustainable pathway for the global energy transition*, 2017, [hydrogencouncil.com/wp-content/uploads/2017/11/Hydrogen-scaling-up-Hydrogen-Council.pdf](https://www.hydrogencouncil.com/wp-content/uploads/2017/11/Hydrogen-scaling-up-Hydrogen-Council.pdf).

2. SOUTH AFRICA'S OPPORTUNITY TO BECOME A SIGNIFICANT PLAYER IN THE HYDROGEN MARKET (CONTINUED)

Near-term production costs of renewable hydrogen are currently high compared to fossil-fuel alternatives. Costs for producing green hydrogen range between USD3 and USD6 per kg, while fossil alternatives range between USD1 and USD2 per kg.⁴¹ Climate-oriented policies, including NDC submissions, are expected to amplify demand for green hydrogen. In the medium to long term (2030-2050), the projected scaling of electrolyser capacity, along with a suite of alternative low-cost production routes and declining electricity costs, is expected to realise production costs competitive with present day fossil-based production.⁴² However, the trajectory of declining costs is dependent on the stimulus provided by governments to drive demand via, for example, instruments such as carbon taxes or clean-production credit schemes.⁴³

Many countries, including South Africa, have seen a reduction in the costs of RE and hydrogen technologies due to a significant increase in scale and investment in RDI. This has resulted in an 80% reduction in the global average price of RE, and a significant ramping up of global electrolysis capacity aimed at the production of green hydrogen.⁴⁴ The International Renewable Energy Agency has stated that "a combination of cost reductions in electricity and electrolysers, combined with increased efficiency and operating lifetime, can deliver 80% reduction in hydrogen cost".⁴¹

An increasing number of countries are ramping up investments in hydrogen, and some have launched a series of hydrogen-energy and technology roadmaps, aimed at reducing carbon emissions and unlocking the socioeconomic benefits of hydrogen. Countries such as Germany, Japan, South Korea and Australia are investing in policies and projects to unlock the opportunities offered by hydrogen – such as the application of hydrogen for grid stability in the wake of increased adoption of RE, heating in the built environment, hydrogen's potential for mobility, and its use in industrial processes.

However, most of these countries do not have the natural renewable resources to produce green or renewable hydrogen at scale. Germany and Japan, for example, have signalled their intention to import hydrogen from countries that have abundant renewable resources and the capacity to supply the deficit. The momentum in policy, investment and the adoption of transition strategies by major nations, energy companies, users and automotive companies will drive hydrogen demand and the development of a comprehensive hydrogen-energy system.

The race is on for countries with a comparative resource advantage to demonstrate the production of green hydrogen for export, at scale and at competitive prices, in response to this demand. The projected growth of demand for green hydrogen over the next 10 to 30 years offers an attractive growth area as the world shifts from carbon-intensive to zero-carbon-emission economies and industrial sectors; the emerging zero- or low-carbon hydrogen-energy system's momentum is rapidly growing.

The demand for hydrogen has increased by more than 20 million tonnes over the past decade. Oil refining, ammonia and methanol production account for 90% of current demand. According to the IEA, of the 70 million tonnes of hydrogen produced in 2018, 76% was made from natural gas and the balance mostly from coal.⁴⁵ Although future demand is expected to be for green hydrogen, less than 1% of the global production is currently green, with a current production of about half a million tonnes per year.⁴⁶ However, the green-hydrogen market is projected to increase to 8.7 million tonnes per year by 2030.⁴⁷

2.2 SOUTH AFRICA'S COMPETITIVE EDGE IN HYDROGEN PRODUCTION

South Africa currently produces approximately 2% of global hydrogen output (all grey hydrogen), with Sasol being the leading producer through its Fischer-Tropsch (FT) CTL-fuel process. With the world increasingly turning towards countries that have optimal RE resources to provide green hydrogen, South Africa is among the few in a position to decarbonise its economy and export green hydrogen or its derivatives, such as green ammonia and methanol through leveraging a host of competitive advantages.⁴⁸

2.2.1 Renewable-energy resources and land availability

South Africa has ideal weather conditions for solar and wind generation, which are the RE options typically deployed in green-hydrogen production. High solar and wind availability factors increase the utilisation of hydrogen electrolysers, ultimately lowering the cost of green-hydrogen production and making investments attractive to potential funders. South Africa has abundant year-round sunlight, appropriate wind conditions, available space for project construction, and an enabling regulatory environment to accelerate the growth of RE. The country has seen a significant cost reduction in RE and hydrogen technologies, largely due to substantial increases in scale and investment in RDI globally. With all the important factors – availability of land, ideal weather conditions and decreasing cost of RE, South Africa has the opportunity to position itself as a country that can produce renewable hydrogen at scale and at competitive prices, triggering an export market from which economic growth and energy independence can be derived.

41. International Renewable Energy Agency, *Green Hydrogen Cost Reduction: Scaling up Electrolysers to meet the 1.5°C Climate Goal*, 2020, irena.org/publications/2020/Dec/Green-hydrogen-cost-reduction.

42. For example, emerging and maturing technologies such as Anion Exchange Membrane (AEM) and Solid Oxide Electrolysis Cell (SOEC).

43. State of California, *Low Carbon Fuel Standard*, ww2.arb.ca.gov/our-work/programs/low-carbon-fuel-standard.

44. Hydrogen Council (2020). *A path to hydrogen competitiveness: A cost perspective*. https://hydrogencouncil.com/wp-content/uploads/2020/01/Path-to-Hydrogen-Competitiveness_Full-Study-1.pdf.

45. International Energy Agency, *The Future of Hydrogen*, 2019, iea.org/reports/the-future-of-hydrogen.

46. Institute for Energy Economics and Financial Analysis, *Great expectations: Asia, Australia and Europe leading emerging green hydrogen economy, but project delays likely*, 2020, ieefa.org/wp-content/uploads/2020/08/Asia_Australia_Euro-pe-Lead-Green-Hydrogen-Economy_August-2020.pdf.

47. Ibid.

48. Strategy and pwc.com, *Green Hydrogen Production Potential in South Africa*, June 2020.

2. SOUTH AFRICA'S OPPORTUNITY TO BECOME A SIGNIFICANT PLAYER IN THE HYDROGEN MARKET (CONTINUED)

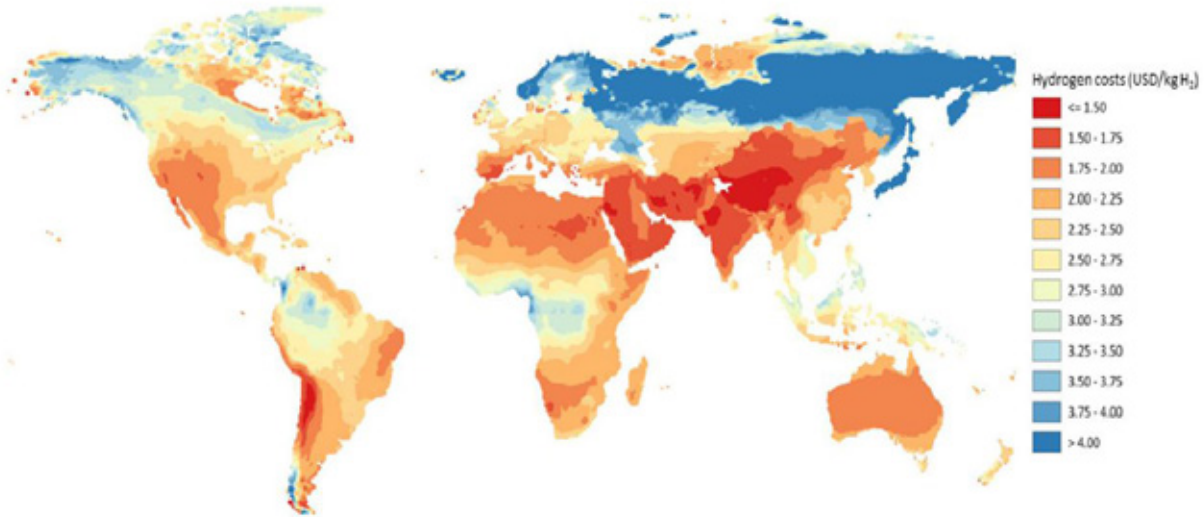


Figure 2.1: South African RE resources and projected green-hydrogen cost, relative to the rest of the world
Source: IEA 2021, Global Hydrogen Review

2.2.2 Fischer-Tropsch skills and capabilities

Hydrogen can be combined with CO₂ to produce synthetic hydrocarbons such as methane, diesel or jet fuel. In this regard, South Africa has the unique and patented FT process, owned by Sasol. The technical expertise and skills that have been developed around the Sasol processes provide South Africa with a competitive edge in the production of liquid fuels based on the hydrogen-production route.

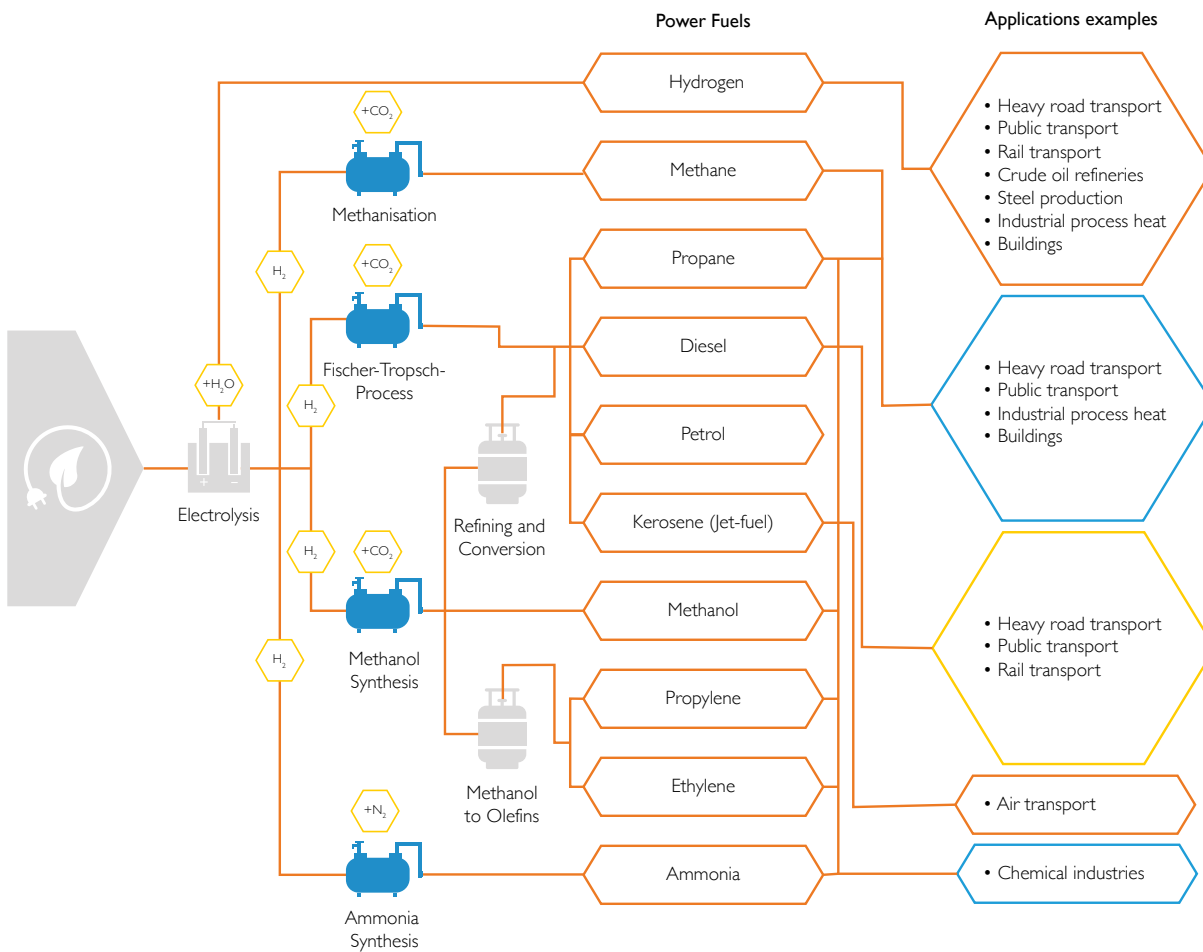


Figure 2.2: FT Process and RE power fuels

2. SOUTH AFRICA'S OPPORTUNITY TO BECOME A SIGNIFICANT PLAYER IN THE HYDROGEN MARKET (CONTINUED)

2.2.3 Platinum-group metals (PGMs)

South Africa is the world's largest producer of PGMs (platinum, palladium, ruthenium, rhodium, iridium and osmium), producing more than 75% of global PGM output.⁴⁹ However, much of this output is beneficiated outside South Africa. PGMs are a key component of electrolyzers in hydrogen production and catalysts in fuel cells, and South Africa has identified PGM beneficiation

as a key economic opportunity and a driving force for advancing hydrogen and fuel-cell RDI. The country has a window of opportunity to develop PGM-based components for hydrogen production to meet the demands of other countries that have developed policies to integrate hydrogen in their economies.

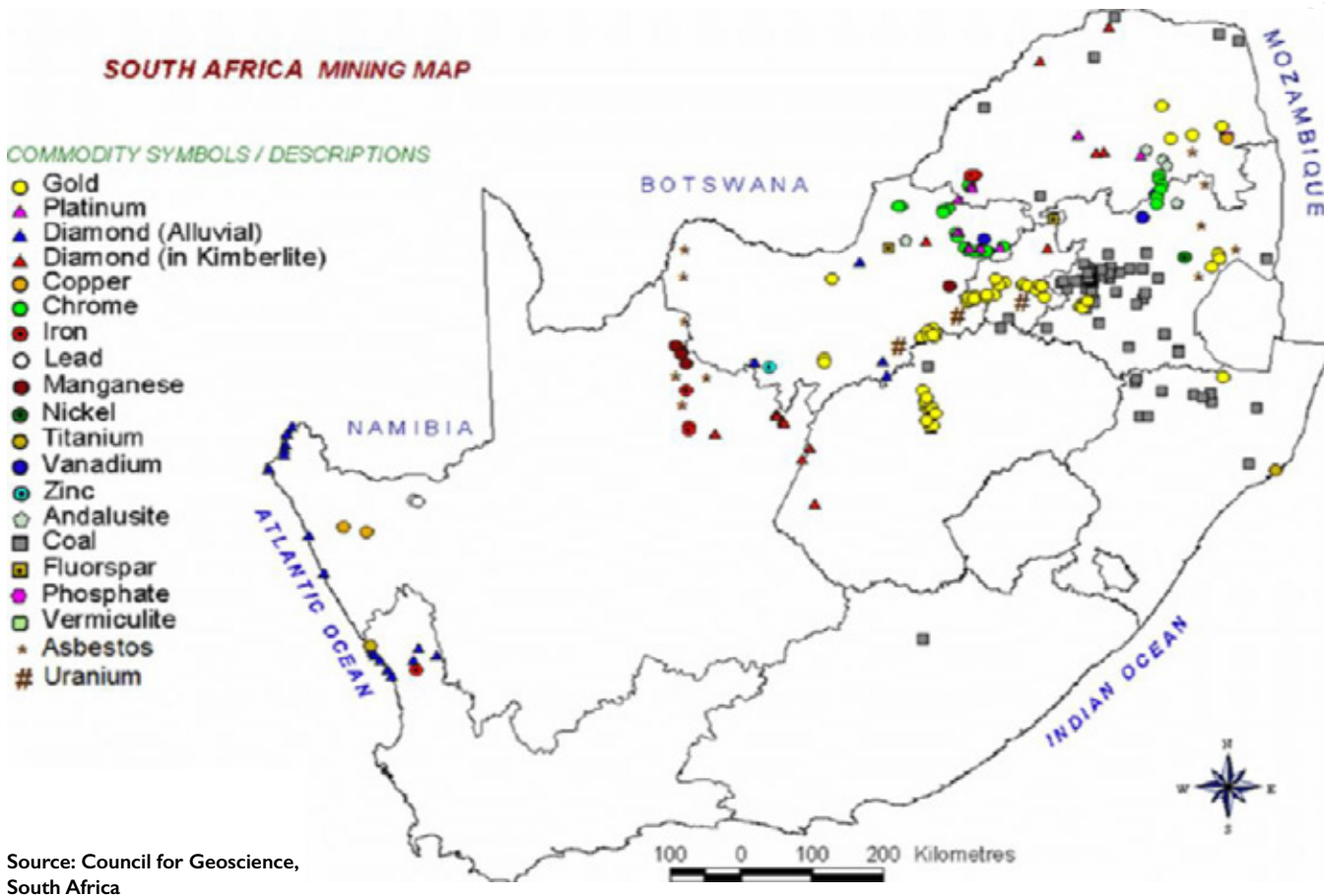


Figure 2.3: South African PGM reserves

2.2.4 Port infrastructure

With the existing GTL facility operated by PetroSA, much of the infrastructure already exists to supply pure hydrogen into the domestic and international markets. The infrastructure needed to export hydrogen is similar to existing natural gas networks. However, modifications may be required to accommodate high pressures or other parameters, depending on the product and transportation method that is deemed cost effective. South Africa could leverage its existing port infrastructure to support exports of hydrogen, protecting jobs and infrastructure that are declining as a result of the drop in global demand for coal exports.

2.2.5 Depleted gas fields

The natural-gas market may provide another solution in the form of hydrogen storage. Many of the gas fields off the coast of South Africa are depleted, yet the infrastructure linking these fields to the coast still exists. Similar to a solution being piloted in the UK, hydrogen could be produced on land and the carbon by-product pumped into the depleted gas fields for storage until it is needed.⁵⁰

49. Minerals Council South Africa, *The current state of the PGMs industry in South Africa. Presentation to the Johannesburg Indaba, 2020.* <https://www.mineralscouncil.org.za/industry-news/publications/presentations>.
50. Strategy and.pwc.com, *Green Hydrogen Production Potential in South Africa*, June 2020.

2. SOUTH AFRICA'S OPPORTUNITY TO BECOME A SIGNIFICANT PLAYER IN THE HYDROGEN MARKET (CONTINUED)



Figure 2.4: South Africa's existing port infrastructure
Source: <https://www.transnetportterminals.net>

2.2.6 Existing strategic trade partnerships with countries looking to import green hydrogen

In the medium to long term (10 years and beyond), Japan, South Korea and the European Union (EU) will emerge as the main potential export destinations for green hydrogen, given the advancement of policies in these countries. Japan expects to develop commercial-scale supply chains by 2030 to procure 300 000 tonnes of hydrogen annually. Developments in the EU also point towards the region being a potential off-taker of green hydrogen.

The recently released Hydrogen Roadmap Europe sets the scene for the development of the hydrogen economy in Europe, with plans to install 6 GW of RE-based hydrogen electrolysis by 2024 and 40 GW by 2030.⁵¹ The EU has identified Africa as a region with high RE potential and as a possible supplier of green hydrogen.

51. FCH, *Hydrogen Roadmap Europe*, 2020. https://www.fch.europa.eu/sites/default/files/Hydrogen%20Roadmap%20Europe_Report.pdf.

2. SOUTH AFRICA'S OPPORTUNITY TO BECOME A SIGNIFICANT PLAYER IN THE HYDROGEN MARKET (CONTINUED)

2.3 SOUTH AFRICA'S ECONOMIC RECONSTRUCTION AND RECOVERY PLAN

South Africa is home to 75% of the global reserves for PGMs. Most are used as value-added materials or catalysts in HFCT. The development of South Africa's hydrogen economy and market therefore opens the opportunity for local value addition or beneficiation of the PGMs mined in the country.

Currently, about 40% of the PGMs are used in catalytic converters for internal combustion engines (ICEs).⁵² However, the potential decline in ICEs due to climate-related restrictions threatens the existence of this market and the future demand for PGMs. Through the hydrogen economy, however, South Africa has the opportunity to mitigate this through the use of PGMs in hydrogen fuel-cell vehicles and green-hydrogen production technologies. This could preserve jobs in the mining sector and create new jobs in the downstream industry through component manufacturing and deployment of HFCT.

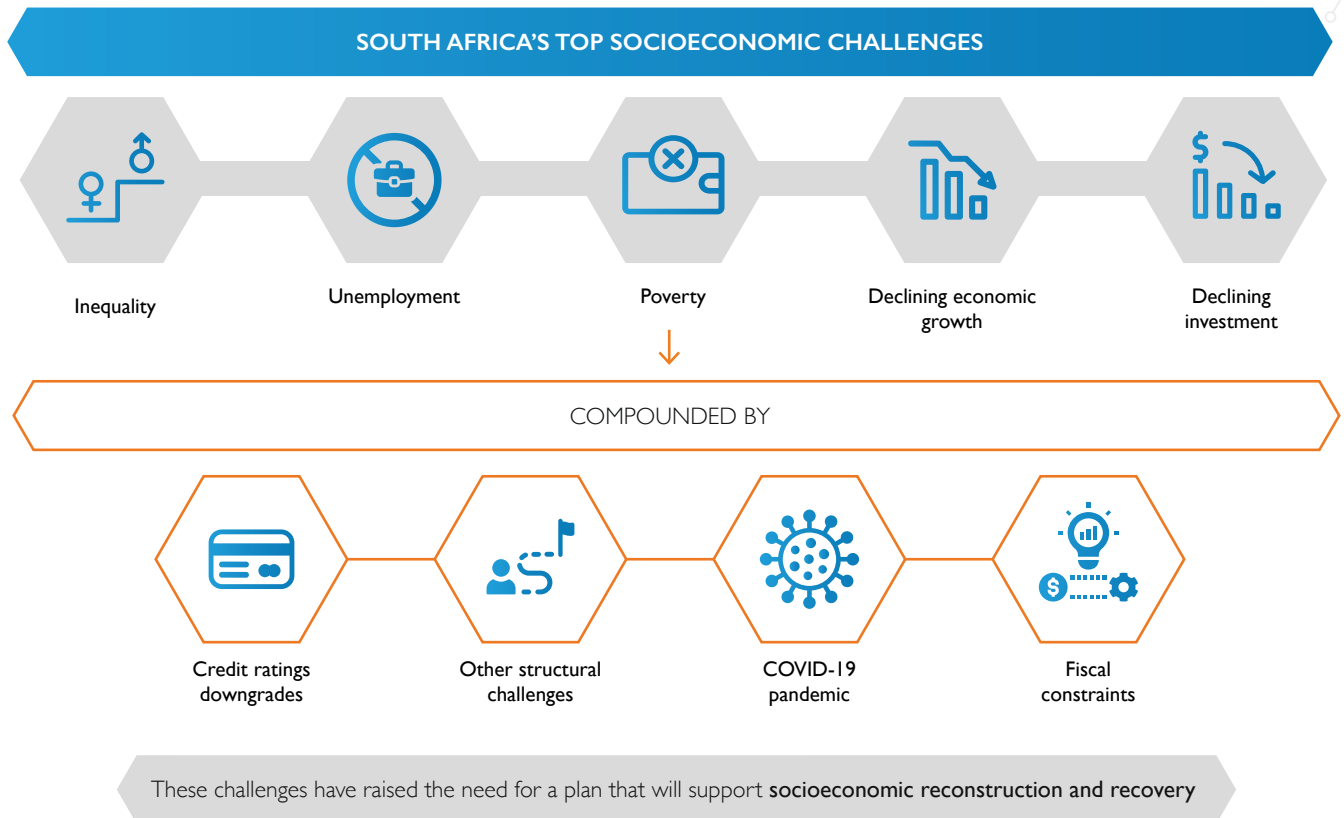


Figure 2.5: South African Economic Reconstruction and Recovery Plan (SAERRP) focused green economy

52. Minerals Council SA, 2019.

2. SOUTH AFRICA'S OPPORTUNITY TO BECOME A SIGNIFICANT PLAYER IN THE HYDROGEN MARKET (CONTINUED)

For years, South Africa has had to deal with shocks in price and supply related to oil-price imports. In 2018, the country's net import of foreign crude oil amounted to ZAR54 billion. Crude-oil price fluctuations and supply-security issues require the country to consider other options to reduce its dependence on foreign oil. The local production of hydrogen and its subsequent use in energy-related applications and as transport fuel could reduce capital outflows from South Africa, and improve the country's balance of payments. In addition, there would be other societal benefits such as lower transport-related emissions, energy independence, clean air, job creation and economic growth related to the export of green or renewable hydrogen.

The global growth in hydrogen demand, its wide variety of applications and decreasing technology costs make hydrogen an attractive investment opportunity, which could result in cumulative global investment of USD450 billion by 2030.⁵³ In conjunction with increased demand for hydrogen, countries are shifting away from a dependence on fossil fuels such as coal, which is a crucial export for South Africa. Green hydrogen offers the country an opportunity to replace the declining export of coal. The development of a new hydrogen industry could also have a positive impact on job creation. Given the country's large share of PGM resources and their significant contribution to the economy (ZAR187.6 billion in 2019), and the dire unemployment situation, it is essential to capitalise on the increased demand for hydrogen applications that require PGM metals. The PGM industry currently employs about 160 000 people, with two to three indirect jobs in other industries for each direct job, resulting in close to 400 000 jobs.⁵⁴ The potential for hydrogen to support the growth of the RE industry in South Africa as an energy-storage solution could also contribute to job creation.

2.4 JUST TRANSITION IS AT THE CENTRE OF FUTURE CLIMATE POLICY

Given the global move towards a low carbon economy, largely necessitated by the negative impact of climate change, there is a need to ensure inclusive participation in the transition and that the substantial benefits of a green economy are shared. The World Resources Institute⁵⁵ considers South Africa's national dialogue on just transitions one of the most advanced

and the country was the only one to have included a just transition in its NDCs in 2015. In early 2021, the Presidential Climate Change Coordinating Commission was established to coordinate South Africa's just transition. The large concentration of coal mining and power generation in Mpumalanga, as well as the potential decline in coal demand in the global market, means the need for a just transition in South Africa is particularly relevant in order to deal with the potential loss in jobs and economic activity in affected communities.

The recent update to the NDCs means that the country has to move with speed to respond to the global commitments on emissions reduction. Hydrogen and its application in various sectors has the potential to reduce emissions and create jobs in its various value chains, which could be used to support the just transition in South Africa.

2.5 THE EXISTING HySA PROGRAMME

South Africa's ambition to develop a hydrogen economy began with the approval of the HySA Strategy by Cabinet in 2007. The Department of Science and Technology, now the DSI, identified HFCT for their potential to reduce emissions and secure the country's energy future. This led to the subsequent establishment of the HySA Programme in September 2008. The objective of this 15-year programme was to promote proactive innovation and create human resources required to develop future industries in HFCT. Three Centres of Competence (Table 2.2) were established to implement the HySA Programme.

To build on these achievements, the DSI, in consultation with other Government departments, identified the need for a high-level roadmap for integrating hydrogen and related technologies into South African society. South Africa has a number of resources to leverage in order to become a significant player in the international hydrogen market.

Table 2.2: Current HySA Centres of Competence and focus areas

CENTRE NAME	RESEARCH FOCUS	HOST INSTITUTIONS
HySA Catalysis	<ul style="list-style-type: none"> Catalysts and catalytic devices for fuel cells and hydrogen production. 	<ul style="list-style-type: none"> University of Cape Town (UCT) South African Minerals Research Council (MINTeK)
HySA Infrastructure	<ul style="list-style-type: none"> Technologies for hydrogen, production, storage and distribution. 	<ul style="list-style-type: none"> North-West University (NWU) Council for Scientific and Industrial Research (CSIR)
HySA Systems	<ul style="list-style-type: none"> Systems integration and technology validation. 	<ul style="list-style-type: none"> University of the Western Cape (UWC)

53. Hydrogen Council (2017). Hydrogen scaling up: A sustainable pathway for the global energy transition. <https://hydrogencouncil.com/wp-content/uploads/2017/11/Hydrogen-scaling-up-Hydrogen-Council.pdf>.

54. Minerals Council South Africa (2020). The current state of the PGMs industry in South Africa. Presentation to the Johannesburg Indaba. <https://www.mineralscouncil.org.za/industry-news/publications/presentations>.

55. <https://www.wri.org/just-transitions/south-africa/>.



HySA developed fuel cell unit with onsite hydrogen storage and educational cartoons deployed at Poelano Secondary School near Ventersdorp, launched in April 2018

2. SOUTH AFRICA'S OPPORTUNITY TO BECOME A SIGNIFICANT PLAYER IN THE HYDROGEN MARKET (CONTINUED)

SOUTH AFRICA'S HYDROGEN ECONOMY JOURNEY

The HySA Programme incorporated a public-awareness, demonstration and education platform aimed at creating awareness of the benefits of hydrogen and fuel-cell technology. Key achievements in South Africa's Hydrogen journey are highlighted in Figure 2.6.

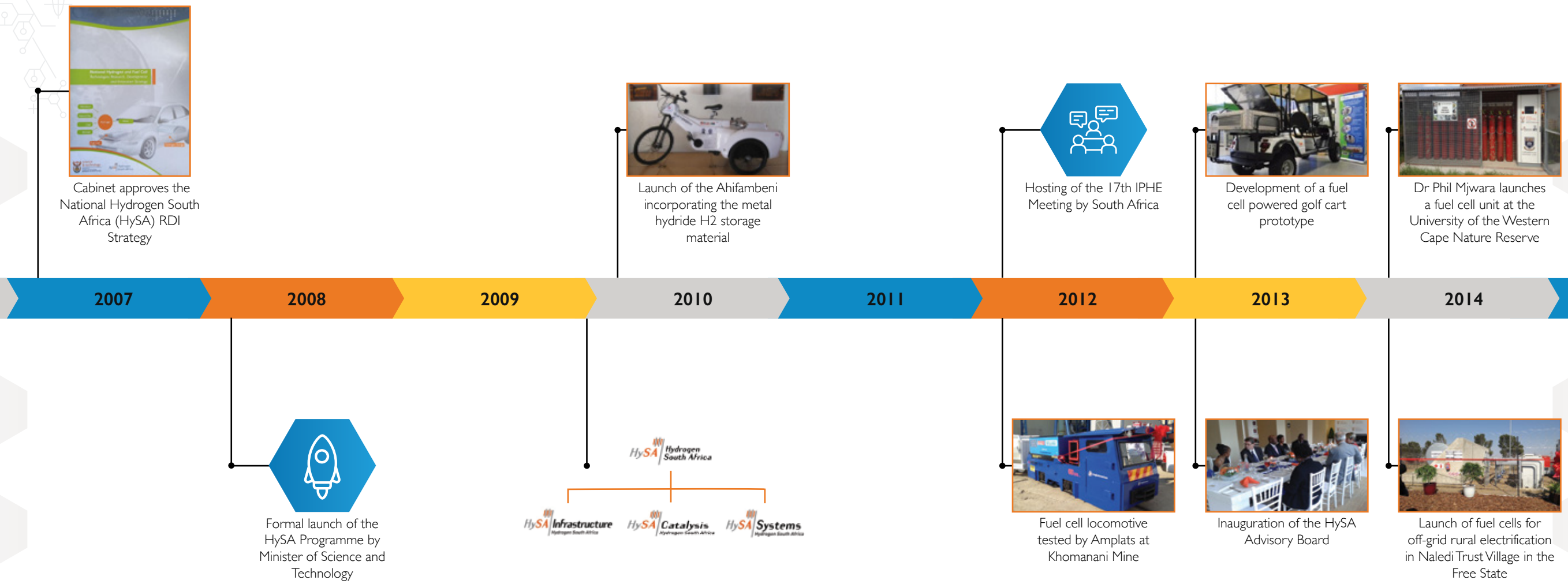
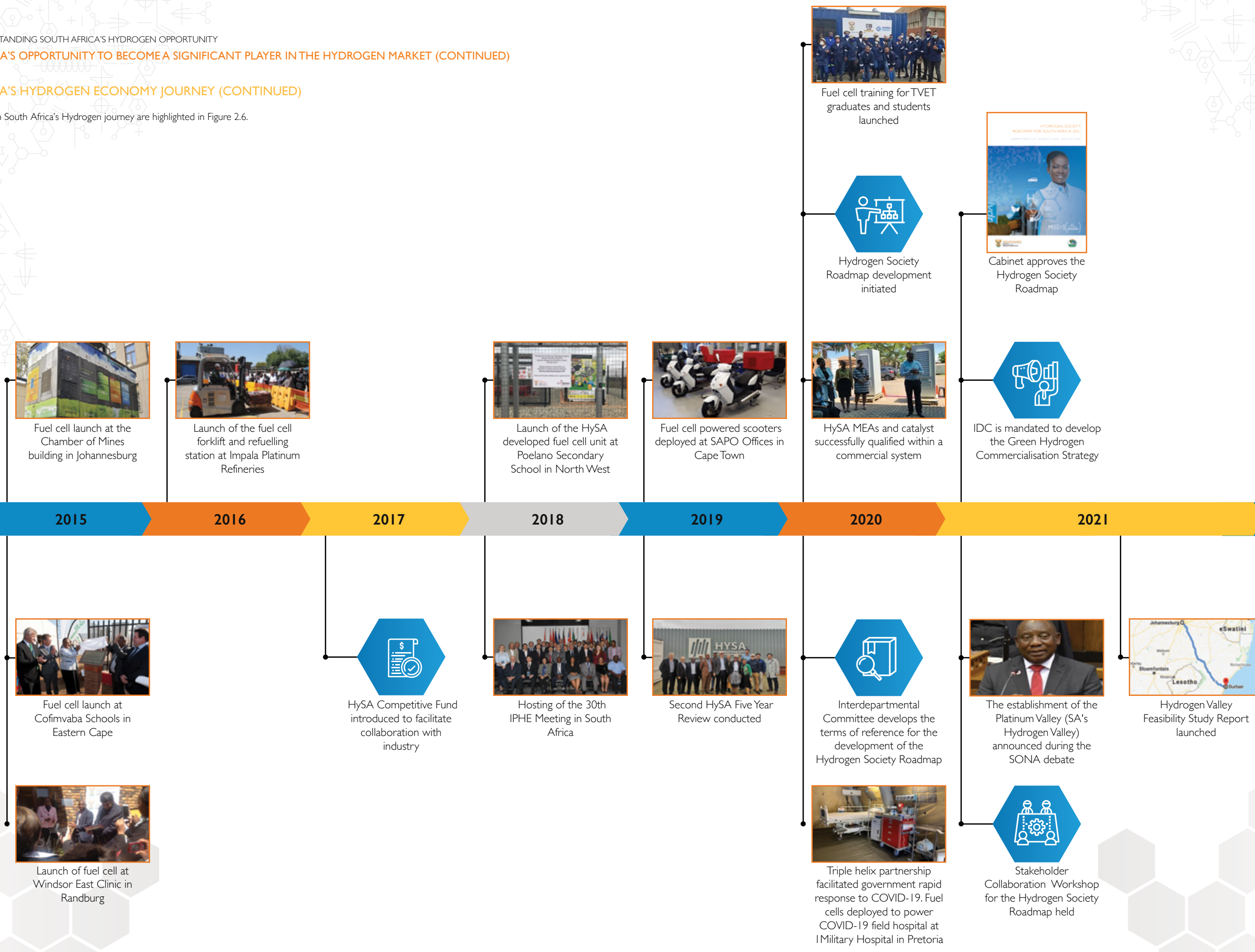


Figure 2.6: South Africa's journey towards a hydrogen economy

2. SOUTH AFRICA'S OPPORTUNITY TO BECOME A SIGNIFICANT PLAYER IN THE HYDROGEN MARKET (CONTINUED)

SOUTH AFRICA'S HYDROGEN ECONOMY JOURNEY (CONTINUED)

Key achievements in South Africa's Hydrogen journey are highlighted in Figure 2.6.



PHASE 2: SOUTH AFRICAN EXTENSION: 2014 / 2015 - 2018 / 2019

PHASE 3: SOUTH AFRICAN INNOVATION: 2019 / 2020 - 2022 / 2023

2.6 THE REGULATORY FRAMEWORK PRESENTS BOTH BARRIERS AND OPPORTUNITIES

While certain legislation within the current South African regulatory framework serves as a basis for introducing hydrogen, there are gaps that need to be addressed to realise the potential benefits of a hydrogen society.

2.6.1 Existing policies

There is currently no explicit policy, or considered policy direction, regarding the introduction and development (with associated targets and timelines) of a hydrogen society. However, several policy documents make oblique

references to hydrogen as a potential energy source. Table 2.3 indicates some existing policies that could be directed towards supporting the deployment of hydrogen-related technologies. (Some of these have already been discussed in Section 1.3.)

While not expressly providing policy in respect of hydrogen, the documents listed in Table 2.3 provide insights that can be extrapolated to what Government hydrogen policy intervention might require. An essential step is for Government to perform an in-depth assessment of each hydrogen application to identify measures that might guide the future policy landscape.

Table 2.3: Existing policies and plans that could be used to support hydrogen-related technologies

POLICY	LINK TO THE HYDROGEN SOCIETY
White Paper on Renewable Energy Policy (2003)	Increased RE contribution to the energy mix, which requires support from energy-storage technologies.
HySA Strategy (2007)	Supports the development of hydrogen and fuel-cell technologies through the 15-year Hydrogen South Africa RDI Programme.
National Energy Efficiency Strategy (2008)	Supports the development and deployment of energy-efficient technologies. Based on their low-carbon attributes and potential for use in demand-side management, hydrogen and fuel cells are attractive options.
National Climate Change Response White Paper (2011)	South Africa has committed to reduce emissions via a peak, plateau and decline trajectory, to which hydrogen could make a contribution.
Beneficiation strategy for minerals industry of South Africa (2011)	Supports the development of technologies that beneficiate the country's mineral resources locally for increased revenue.
Department of Public Works and Infrastructure Green Building Policy (2018)	Given their low-carbon footprint, hydrogen fuel cells are a viable option for deployment in public buildings and to power critical infrastructure.
Green Transport Strategy for South Africa (2018)	Advocates for the deployment of electric vehicles, including hydrogen fuel-cell powered vehicles, as a means for decarbonising the transport sector.
Integrated Resource Plan (2019)	Increased contribution of RE in the energy mix would require hydrogen for optimal usage and long-term storage.
National Development Plan 2030	Advocates for the transition to a low-carbon and diversified energy system.



2.6.2 Barriers and opportunities

Some amendments to existing policy measures will be required to “jump start” the hydrogen economy, until normal market forces take over and the hydrogen economy becomes self-sustaining. In some countries, declining incentives have been used to stimulate the deployment of hydrogen-related technologies (such as ENE-FARM in Japan).

As an example, the Gas Act No 48 of 2001 defines gas to include “hydrogen-rich gas”. Should it be considered feasible to use the existing piped-gas infrastructure or to develop and build on it for the distribution of hydrogen, then the Gas Act already provides basic coverage for the distribution of hydrogen and specifically governs hydrogen-rich gases. The piped-gas regulations, rules and standards will, however, need to be enhanced and developed to provide specifically for the deployment or injection of hydrogen into the piped-gas network, particularly with regards to the minimum and maximum pressures that are commercially viable and safe.

Safety and security in the production and use of hydrogen are critically important. Specific, significant regulatory reform will be required to ensure the safe commercialisation of hydrogen. Importantly, these regulations must be implemented across the entire hydrogen value chain to ensure safety and security in production, storage, distribution and transport, and end-user applications.

South Africa participates in the Regulations, Safety, Codes and Standards Working Group as well as the Task Force on Hydrogen Production and Analysis of the IPHE, which allows the country to learn from existing regulations in other countries.

In addition, the National Environmental Management Act (NEMA) may be used on a limited basis for developing regulations and standards around environmental impact (so too the Gas Act, which considers land rehabilitation after land is used for hydrogen storage). Policymakers will need to expand, enhance and develop environmental regulations and standards (such as motor-vehicle emission standards) to account for hydrogen production, storage, distribution and transportation, and usage. South African legislation will therefore require significant development to address the gaps in the current regulatory framework if the introduction and development of a hydrogen society are to be achievable.

Opportunities also exist to leverage existing tax and incentive mechanisms to support the deployment of hydrogen-related technologies (Table 2.4).

2. SOUTH AFRICA'S OPPORTUNITY TO BECOME A SIGNIFICANT PLAYER IN THE HYDROGEN MARKET (CONTINUED)

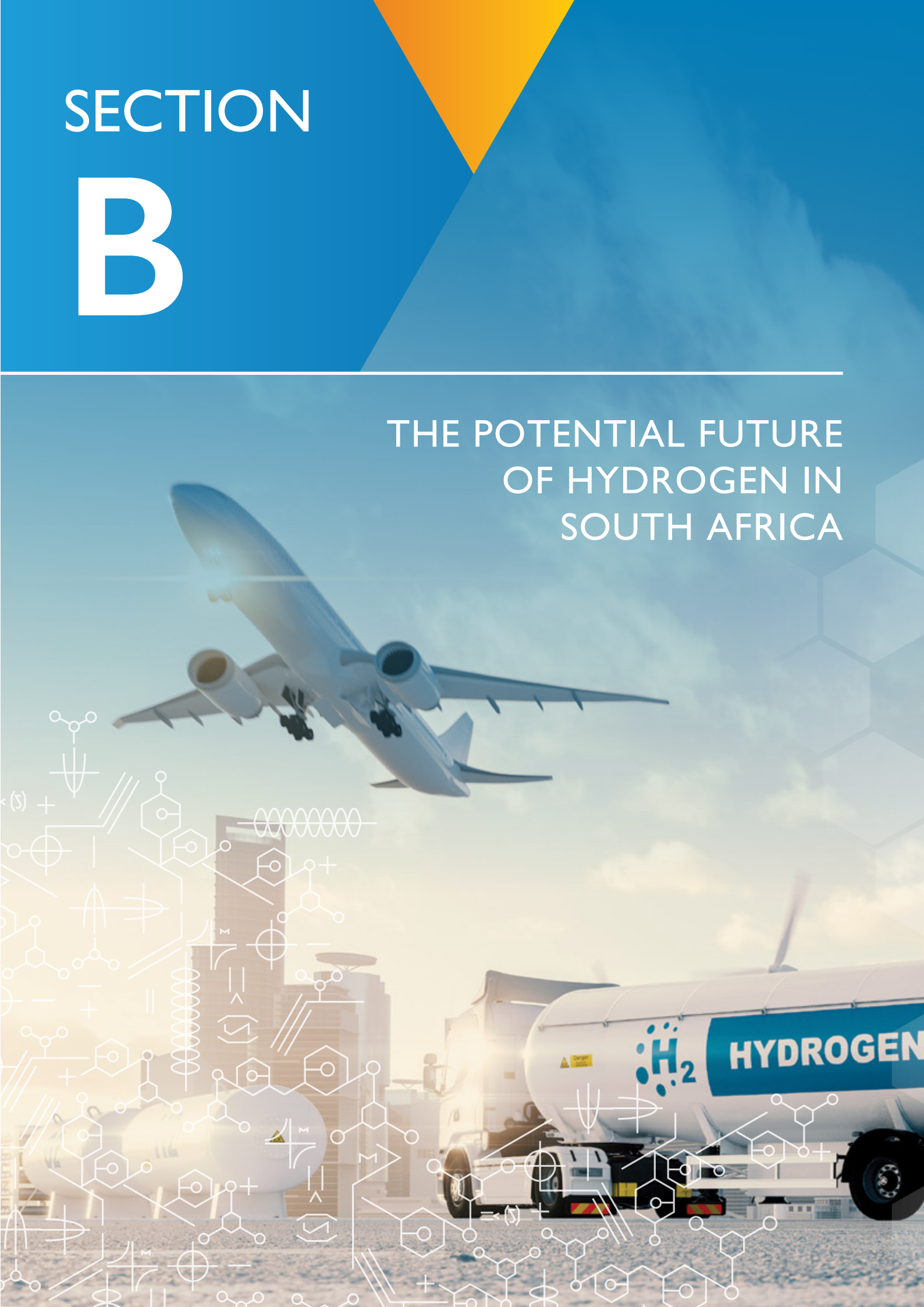
Table 2.4: Tax and incentive mechanisms that could support hydrogen-related technologies

TAX/INCENTIVE MECHANISM	APPLICATION TO THE HYDROGEN SOCIETY
Section 11D of the Income Tax Act No 58 of 1962 (R&D tax deduction)	Section 11D does not restrict the type of R&D undertaken and may therefore be used as a tax incentive to advance R&D specifically within the hydrogen landscape.
Section 12L of the Income Tax Act No 58 of 1962 (Energy Efficiency Allowance)	The section 12L tax deduction may be used to encourage taxpayers to move towards using hydrogen as an alternative fuel source, because hydrogen contributes to sustainability.
Special Economic Zones (SEZ)	A reduced corporate tax rate of 15% and accelerated 10% tax allowance on buildings, as set out in sections 12S and 12R of the Income Tax Act No 58 of 1962, apply to companies operating in geographically designated areas of South Africa set aside for specifically targeted economic activities.
Critical Infrastructure Programme (CIP)	Provided that the underlying infrastructure is deemed critical, the CIP may be used to advance hydrogen projects' investment (such as hydrogen pipelines or refuelling stations).
Capital Projects Feasibility Programme (CPFP)	The CPFP incentive may be used to reduce the cost of feasibility studies for hydrogen-related manufacturing projects in South Africa.
Support Programme for Industrial Innovation (SPII)	R&D features prominently in hydrogen-society strategies and is likely to be one of the key strategies for South Africa. The SPII may be used to promote and incentivise the development of hydrogen technologies.
Technology and Human Resources for Industry Programme (THRIP)	This incentive may be used to increase the number of people with the appropriate skills in hydrogen applications and technologies.
South African Automotive Masterplan (SAAM)	Even though this plan does not contain incentives that are specifically geared towards a shift to the production of hydrogen fuel-cell vehicles, these incentives may be used to promote investment in hydrogen technologies in the automotive sector.

SECTION

B

THE POTENTIAL FUTURE
OF HYDROGEN IN
SOUTH AFRICA



3. BUILDING BLOCKS FOR A SOUTH AFRICAN HYDROGEN SOCIETY



The Director-General, Dr Phil Mjwara, launches the fuel cell unit at the University of the Western Cape Nature Reserve-November 2014

3.1 THEORY OF CHANGE

To ensure that the development of the HSRM was comprehensive and inclusive, DSI reached out to stakeholders in both the public and private sectors and wider civil society to participate in the stakeholder consultation process. The purpose of the consultations was to align stakeholders on a common vision on hydrogen-related technologies in order to create an environment where investment decisions can be made to unlock the societal economic benefits for the country. The development of the HSRM was,

therefore, a collaborative, multi-stakeholder endeavour with the objective of coalescing all efforts towards unlocking the full potential of the country's hydrogen socioeconomic value.

The theory of change process enabled the DSI to bring together government, private sector and civil society to set the vision that defines success for the South African hydrogen journey. Figure 3.2 shows how the theory of change was applied to develop components of the HSRM.

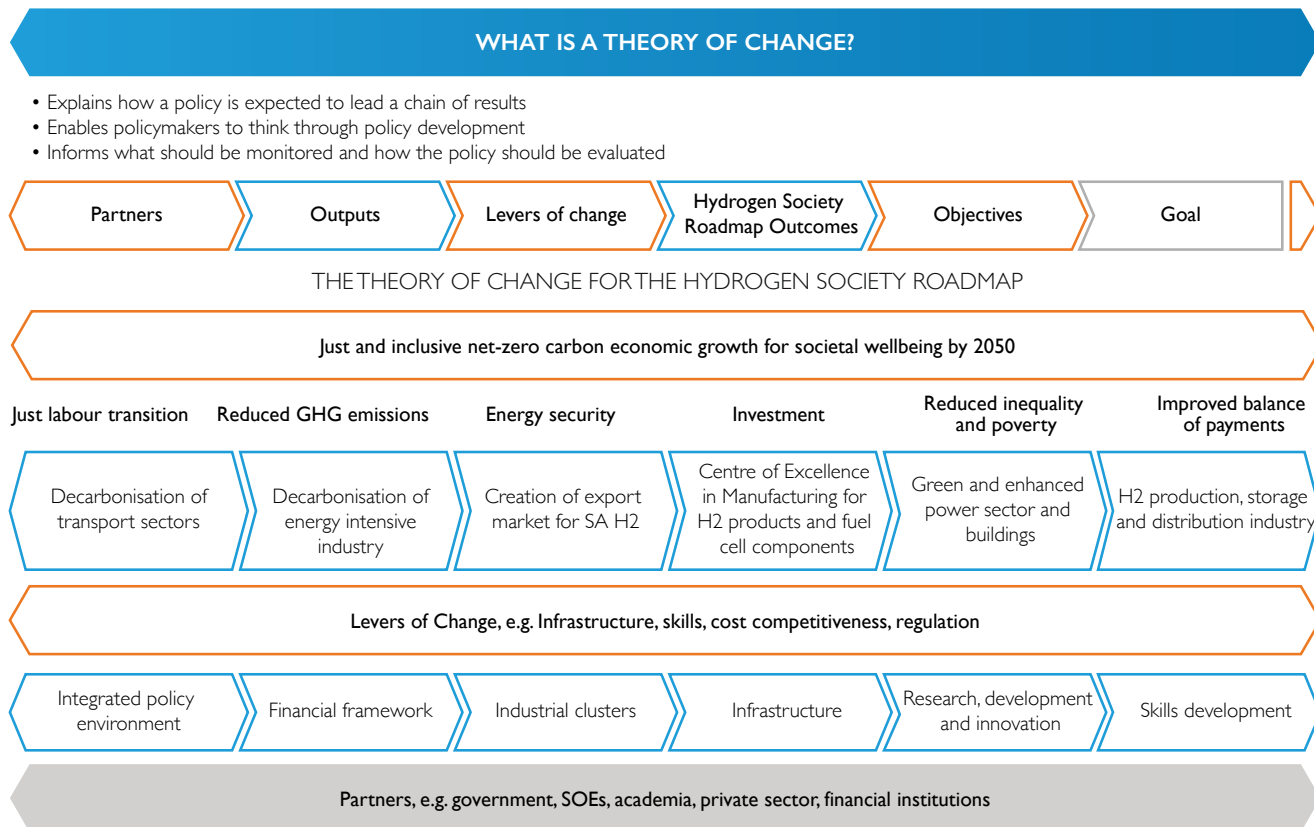


Figure 3.1: Theory of change for the HSRM

3. BUILDING BLOCKS FOR A SOUTH AFRICAN HYDROGEN SOCIETY (CONTINUED)

3.1.1 Vision

The vision of the HSRM is “an inclusive, sustainable and competitive hydrogen economy by 2050”.

The overall goal linked to this vision is “A just and inclusive net-zero carbon economic growth for societal wellbeing by 2050”.

3.1.2 Objectives

The HSRM will contribute to the goal of a just and inclusive net-zero carbon economic growth for societal wellbeing by 2050 through supporting the following interlinked objectives:

- **Inward investment and balance of payments**

The development of domestic manufacturing for hydrogen products and components, along with the greening of the economy and hydrogen exports, will encourage inward investment. Together with reduced oil imports, these changes will support improvements in the balance of payments.

- **Reduced GHG emissions**

The HSRM implementation will reduce GHG emissions by replacing fossil fuels in energy-intensive industry, road and rail transport, shipping and aviation. HSRM will also enable the greening of the power sector by providing RE storage to the grid, and reliable zero-carbon electric and thermal energy for off-grid applications.

- **A just labour transition**

The HSRM will support a just labour transition by providing new, high-quality green jobs in the generation and storage of hydrogen, manufacturing of hydrogen-related products such as fuel cells and electrolyzers, the beneficiation of minerals through the supply of value-added components in the hydrogen value chain, and the export of green hydrogen. Jobs will also be created in the local manufacture of hydrogen-related products and infrastructure construction, and will be preserved in the transport and industry sectors.

- **Energy security**

The HSRM will enable energy security by providing a zero-carbon contribution to the national electrification plan, and backup energy to the electricity grid for critical applications.

- **Reduced inequality and poverty**

The implementation of the HSRM will benefit society as a move towards a hydrogen economy can assist with the Sustainable Development Goals (SDG) with specific emphasis on SDG7 – affordable and clean energy, as well as SDG8 – decent work and economic growth. Economic growth will be underpinned by job growth which is required to reduce unemployment. Green hydrogen will enable decarbonisation in industrial clusters and improve air quality in disadvantaged communities, which are usually co-located near industrial clusters.

3.1.3 Outcomes

Six high-level outcomes have been identified for the HSRM based on the Theory of Change as shown in Figure 3.2. The outcomes include:

- **Decarbonisation of transport sectors**

The focus will be on the decarbonisation of heavy-duty vehicles, shipping, aviation and rail to reduce the 11% GHG emissions from the transport sector, the bulk of which (> 90%) comes from road transport.

- **Decarbonisation of energy-intensive industry**

Priority will be on the hard-to-abate sectors such as steel making, cement, mining, refineries and chemical production. According to the GHG Inventory 2017, manufacturing and construction, mineral and metal production, as well as mining, contribute 12% to the overall emissions, with more than half coming from the minerals and metal production.

- **Creation of an export market for South African hydrogen**

Leveraging the renewable energy resources such as wind and solar, the focus will be on renewable or green hydrogen production at a globally competitive price and selling it to the export market in various forms including green chemicals. The objective will be to at least double South Africa's current share of the global market (2%) in the form of green hydrogen exports by 2050.

- **Centre of Excellence in Manufacturing for hydrogen products and fuel cell components**

The focus will be on the manufacturing of value-added components for the hydrogen and fuel cell value chain, particularly in areas where South Africa could have a competitive advantage based on its natural resources.

- **Green and enhanced power sector**

The focus will be on greening and stabilising the power sector to support economic recovery while reducing the carbon intensity per unit of power produced, to reduce the current 43% of GHG emissions from electricity production. Given the negative impact of load shedding on the South African economy (which some analysts put at ZAR500 million per stage, per day), stabilising the grid to ensure energy security in support of economic recovery is key.

- **Hydrogen generation, storage and distribution**

The focus will be on scaling up the generation, storage and distribution of all forms of hydrogen to support the HSRM, while positioning the country to make a responsible transition from grey, blue and green hydrogen in response to market demand while supporting the achievement of climate change targets.

3. BUILDING BLOCKS FOR A SOUTH AFRICAN HYDROGEN SOCIETY (CONTINUED)

GOAL: JUST AND INCLUSIVE NET-ZERO CARBON ECONOMIC GROWTH FOR SOCIETAL WELLBEING BY 2050 (NDP)

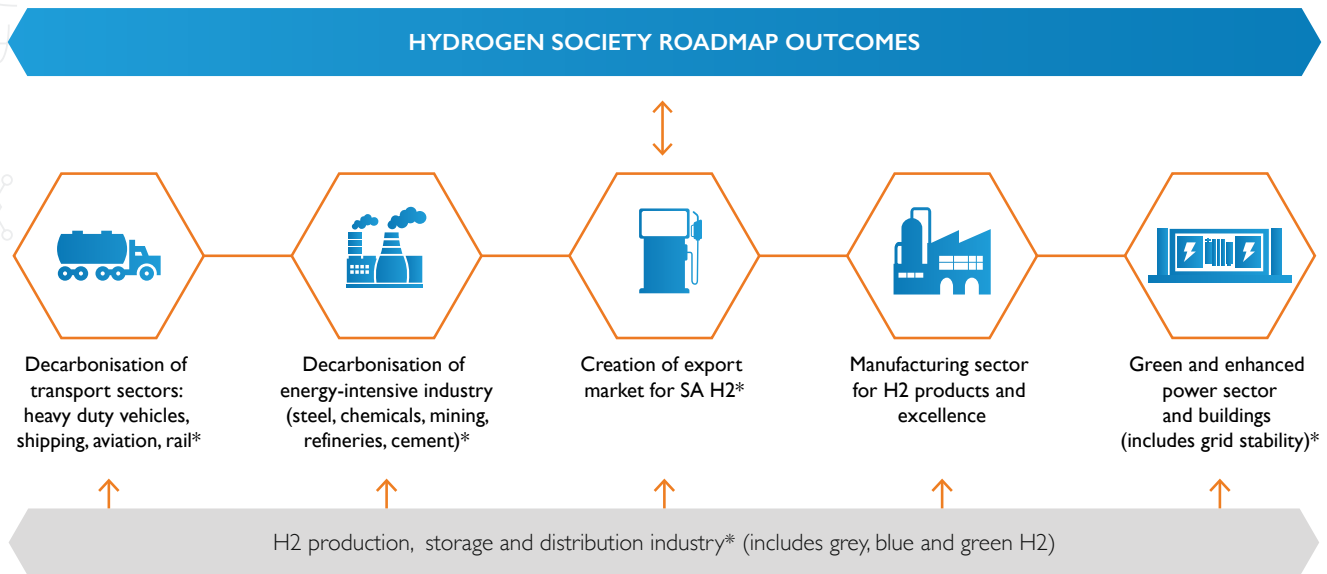


Figure 3.2: High-level outcomes of the HSRM

3.1.4 Levers of change

Levers of change comprise of the enablers that will facilitate the realisation of the high-level outcomes. The theory of change identified the following levers as being critical:

- Local and international demand for green hydrogen and green products;
- Compliance and regulation;
- Enabling infrastructure and policy that support hydrogen adoption and dis-incentivise alternatives;
- Attractive investment environment;
- Cost competitiveness with a focus on the levelised cost of green hydrogen;
- Corporate targets (e.g. carbon budgets);
- International commitments; and
- Innovative culture and skilled workforce.
- Financial framework that provides access to capital markets;
- Raw material availability ranging from PGMs to water;
- National and international partnerships;
- Demonstration of pilot projects including industrial clusters;
- Research, development and innovation; and
- Skills development.

3.1.6 Partners and their contributions

For each of the levers of change and associated outputs, the theory of change identified the stakeholders across the public and private sectors, as well as other organisations, who would take lead and supporting roles in the achievement of the outputs and the outcomes. The overarching theory of change (Figure 3.3) gives the high-level outcomes, outputs and the stakeholders expected to take a lead in their achievement. In Chapter 4, the detailed actions are given for each of the high-level outcomes.

3.1.5 Outputs

Some of the outputs envisaged from the theory of change process include:

- Market development/business cases;
- Favourable and integrated policy, fiscal measures and regulatory environment;

3. BUILDING BLOCKS FOR A SOUTH AFRICAN HYDROGEN SOCIETY (CONTINUED)



Source: HySA Infrastructure CoC.

3. BUILDING BLOCKS FOR A SOUTH AFRICAN HYDROGEN SOCIETY (CONTINUED)

VISION AND GOAL: JUST AND INCLUSIVE NET-ZERO CARBON ECONOMIC GROWTH FOR SOCIETAL WELLBEING BY 2050 (NDP)

*GESI (DWYPD)

DEPARTMENTS IN CHARGE FOR POLICIES



Figure 3.3: Overarching theory of change

3. BUILDING BLOCKS FOR A SOUTH AFRICAN HYDROGEN SOCIETY (CONTINUED)

3.2 THE INTERNATIONAL ENERGY AGENCY POLICY FRAMEWORK

The IEA has proposed five pillars of policy support for the development of domestic hydrogen economies, keeping pace with global climate ambition.⁵⁶ These pillars outline measures to promote domestic use and create export opportunities via the establishment of new global markets for carbon-neutral commodities:

3.2.1 Establish targets and/or long-term policy signals

A national hydrogen strategy should clearly define the role of hydrogen in the economy. It should identify priority sectors, either domestic or export, and a timeframe for scaling deployment. It should ensure coherence across key policy and planning frameworks, adhering to the ambitions of the country's NDC and national development plans. For example, overarching national energy policies, and masterplans for the automotive, steel, RE and gas sectors should stipulate low-carbon or carbon-neutral alternatives in their respective supply chains, with specific implementation targets. This in turn could stimulate manufacturing associated with producing hydrogen, and its associated technologies such as fuel-cell and electrolyser components. Australia, for example, has indicated its willingness to export hydrogen in the near term, and has developed infrastructure in readiness; while Germany has drafted a power-to-liquids roadmap that creates opportunities for its domestic market in hydrogen-derived fuels (such as jet fuel) to decarbonise its aviation sector.

3.2.2 Support demand creation

Portfolios should be established that set minimum targets for utilisation in priority sectors, in sync with emissions and employment targets, to incubate green value chains. In industrial and transport applications where candidate sectors present ideal catalysts (such as iron and steel, long-haul heavy-duty transport, industrial heat, chemicals and synfuels), clean-production portfolios should be mandated to create an enabling environment. Public infrastructure such as transport and buildings could provide opportunities to demonstrate technology readiness and signal intent to private-sector entrants. Stringent emissions standards, such as the NEM: AQA, should be enforced to facilitate the rapid introduction of clean-production technologies across the economy. Sales of internal-combustion vehicles in key markets (EU, the United Kingdom (UK) and North America) are slated to cease by 2030 in response to climate change; in particular, diesel vehicles, which predominate in heavy-duty transport, are due for earlier removal as a consequence of their impact on local air quality.

3.2.3 Mitigate investment risks

In the face of several identified opportunities that lack clear timeframes or proof of future market demand, a nascent hydrogen sector requires investment certainty. The EU and several other countries have established funding mechanisms to catalyse projects and drive private-sector participation. Germany has included green hydrogen under its ambitious *Energiewende*, and has initiated the H2-Global mechanism to accelerate renewable-electricity generation globally by promoting industrial-scale green-hydrogen value chains such as those involved in the production of ammonia, methanol, aviation fuel and chemicals. The mechanism's ten-year purchase agreements provide a

roadmap for scaling clean supply and value chains. Varying funding vehicles have been created that are either hydrogen specific (for example, in Chile, Morocco, and the UK) or stipulate clean production, which would include hydrogen (via eligible production routes and technologies, for instance, fuel cells and electrolysers). The UK has specific policies targeting low-carbon hydrogen, intended to mitigate project-development costs.

South Africa has an impressive record of establishing world-class industries, with exemplars including Eskom, Transnet, Iscor and Sasol. Public-investment institutions such as the Industrial Development Corporation, Public Investment Corporation and the African Development Bank have key roles to play in identifying market opportunities for the green-hydrogen economy and nurturing private-sector participation.

3.2.4 Promote R&D, innovation, strategic demonstration projects and knowledge-sharing

To achieve a cost-competitive hydrogen value chain, continued investment in R&D is required to stimulate innovation in carbon-neutral hydrogen production and its applications. South Africa's HySA network of R&D hubs is a centre of such activity, and mirrors similar institutions internationally, most notably the H2@Scale programme in the United States of America (USA). Beyond research, the bridge to success is strategic support for embryonic projects that demonstrate commercial viability in a climate-neutral global economy. This requires partnerships across the public-private domain, extending regionally and internationally to facilitate rapid scaling of the hydrogen economy. South Africa and Namibia both enjoy world-leading RE resources, and the recent announcement by both countries of hubs to be developed in expectation of global trade provides an impetus for such regional cooperation.⁵⁷

3.2.5 Harmonise standards and remove barriers

Appropriate standards and regulations need to be developed to govern the production, processing and application of hydrogen. Hydrogen is already utilised in diverse applications, such as providing feedstock in refineries and functioning as a heat-transfer medium in thermal power plants. Deploying hydrogen at the scale envisaged to meet climate goals requires relevant regulations to keep pace with, and reflect, emerging markets. In addition to existing engineering standards that, inter alia, cover safe handling and requisite quality control (for example, the necessary purity of hydrogen per application), new interpretations may be necessary. China, for instance, reclassified hydrogen as an energy carrier so that it is no longer subject to the more stringent regulations governing hazardous substances.

Competition with cheaper fossil-fuel alternatives presents another barrier. Carbon border-adjustment mechanisms – tabled in the EU and echoed in the USA – are designed to address this barrier by prioritising carbon-neutral value chains via favourable tariff schemes. The development of coherent carbon-accounting frameworks to assess the carbon intensity of value chains is therefore another potential vehicle for hydrogen adoption, minimising risk to existing trade markets such as agriculture, and encouraging new trade in the energy transition, such as in the production of ammonia, aviation fuel, machinery and iron and steel.

56. IEA, *Global Hydrogen Review 2021 – Progress in five key areas for hydrogen policymaking*, 2021, [ea.org/reports/global-hydrogen-review-2021](https://www.iea.org/reports/global-hydrogen-review-2021).

57. Federal Ministry of Education and Research (Germany), *Karliczek: Germany and Namibia form partnership for green hydrogen*, n.d. [bmbf.de/bmbf/shareddocs/kurzmeldungen/en/Karliczek-Germany-and-Namibia.html](https://www.bmbf.de/bmbf/shareddocs/kurzmeldungen/en/Karliczek-Germany-and-Namibia.html).

3. BUILDING BLOCKS FOR A SOUTH AFRICAN HYDROGEN SOCIETY (CONTINUED)

3.3 KEY MILESTONE/ACTIVITIES

Creating an enabling environment to scale up hydrogen use across all sectors in support of South Africa's move towards a net-zero carbon economy will require a comprehensive and coordinated response across government. The IEA has outlined a policy framework that was used to classify the key actions which were identified by the private sector, academia and government to speed up the process of moving hydrogen to become an energy vector in the South African energy system. During expert working group meetings held in September 2020 and subsequently at the Theory of Change workshops held in February 2021, 70 key actions were identified.

With regards to the six outcomes the majority (28%) focus on scaling up the consumption of hydrogen as well as the transition from grey to blue to green hydrogen essentially ensuring that clean hydrogen is integrated as an energy vector in the South African energy system. The sector with the second largest number of key actions at 22.8% is the enhanced and green power sector plans to increase the role of hydrogen to support an increase in RE deployments while improving flexibility and creating opportunities for the private sector to self-generate. For the private sector this will improve energy security while reducing exposure to scope 2 emissions. The building sector will have more options that support access to modern forms of energy in the residential sector and improving service delivery as public buildings will have sustainable back-up power.

The key actions (12.8%) identified the need for the creation of an export market for South African green hydrogen focused on mitigating investment risk for the private sector, which is largely expected to take a lead in ensuring that South Africa's aspirations to participate in the global green hydrogen sector are realised. Currently, South Africa provides 2% of the global grey hydrogen demand. However, plans to move the market from grey to green hydrogen while increasing exports will require strategic international partnerships and public-private partnerships to be strengthened in the short

term. Given the global nature of the export sector it is not surprising that the second largest number of key actions were within the "harmonise standards and remove barriers area" and South Africa's participation in global forums to ensure the harmonisation of standards, especially for products expected to penetrate the global market, will be key.

The key actions in the Energy-Intensive Industry (11.4%) are focused on supporting early adopters to mitigate investment risk by reducing cost of fuel cell technologies so that sufficient economies of scale for fuel cell technology adoption in industry will allow the movement from a technological niche to a market. The pressure to reduce GHG emissions while retaining competitiveness is critical, especially with South Africa's concerted attempts to recover from the economic downturn experienced during national lockdown. The transport sector has the smallest number of key actions and none in the area of establishing targets and setting policy signals. The Green Transport Strategy was one of the earliest South African policies that included a role for fuel cell technologies and hydrogen. Hence the focus over the next three years should be on speeding up the implementation of the Green Transport Strategy through the harmonisation of standards while supporting demand creation through public procurement in buses and government fleets, thus scaling up domestic consumption of hydrogen in the transport sector.

The aspirations of the Minerals Beneficiation Strategy will be fast-tracked if the draft Beneficiation Masterplan is finalised and aligned with the HSRM. The opportunity to provide value-added products and components to both the domestic and export market will require that the manufacturing sector prioritise the harmonisation of standards for locally developed technologies. The 70 key actions are summarised in Figures 3.4 and 3.5 while Figure 3.6 gives some numbers for key indicators such as electrolyser capacity, hydrogen production and jobs expected from implementing some of the catalytic projects discussed in Chapter 5, as well as some key actions and milestones.

3. BUILDING BLOCKS FOR A SOUTH AFRICAN HYDROGEN SOCIETY (CONTINUED)



HYDROGEN PRODUCTION, STORAGE, DISTRIBUTION

ESTABLISH TARGETS AND POLICY SIGNALS

- Finalise Green Hydrogen Commercialisation Strategy to support HSRM
- Revise NDCs taking into account GH2 to support a move towards a net-zero economy especially in hard-to-abate sectors
- Complete feasibility study on water resource availability and desalination
- Complete feasibility studies on new H2 corridors and valleys in SA
- Finalise Just Transition Framework
- Develop grey H2 phase-out plan if green H2 reaches parity

MITIGATE INVESTMENT RISK

- Gazette Strategic Integrated Infrastructure Project on Hydrogen
- Revise Critical Infrastructure Programme Framework

HARMONIZE STANDARDS AND REMOVE BARRIERS

- Improvement of grey H2 infrastructure including technology upgrade

STRATEGIC DEMONSTRATION AND DEPLOYMENT PROJECTS

- Pilot CCUS in Mpumalanga Priority Area
- Pilot CCUS on a national scale

PROMOTE RDI

- Develop RDI Strategy to support HSRM
- Establish international partnerships to support electrolyser research
- Call for proposals on improving cost and efficiency of hydrogen solutions

SKILLS DEVELOPMENT AND PUBLIC AWARENESS

- Establish an overarching body to coordinate relevant players in the quadruple helix around hydrogen economy
- Develop a communication plan to promote awareness of hydrogen across all sectors
- Develop framework for reskilling people and preserving jobs in sectors affected by transition
- Establish international partnerships to scale up training required for hydrogen economy
- Develop a skills development roadmap which spans across TVETs, UoTs and universities

SUPPORT DEMAND CREATION

- Implement catalytic projects such as Boegoebaai SEZ, Platinum Valley Initiative (SA's Hydrogen Valley) CoalCO₂-X
- Demonstration and SAF project



CREATION OF EXPORT MARKET FOR SA GREEN HYDROGEN

ESTABLISH TARGETS AND POLICY SIGNALS

- Develop hydrogen export strategy to inform business case for green H2 (including derivatives) export

MITIGATE INVESTMENT RISK

- Conduct market analysis identifying export opportunities, obstacles and gaps including potential partners and investors
- Put in place international partnerships with key countries willing to purchase GH2
- Expand regional cooperation/partnerships on GH2
- Integrate H2 exports into existing national port and rail strategies
- Invest in rail and port infrastructure to support GH2 export

HARMONIZE STANDARDS AND REMOVE BARRIERS

- Participate in relevant task teams on hydrogen certification and hydrogen trade rules of the IPHE
- Review, develop and publish harmonized policy, regulations, codes to ensure GH2 export by 2024

PROMOTE RDI

- Invest in RDI focused on the most efficient generation, storage and shipping methods to make SA green H2 cost competitive
- Continue to invest in RDI focused on the most efficient generation, storage and shipping methods to make SA green H2 cost competitive
- Continue to innovate to remain globally competitive for GH2 export



DECARBONISATION OF INDUSTRY

ESTABLISH TARGETS AND POLICY SIGNALS

- Develop policies and strategies that stimulate demand for hydrogen-related applications in the energy-intensive industries (mining, cement, steel, refineries)
- Align Steel Masterplan to the HSRM

MITIGATE INVESTMENT RISK

- Develop local market framework with incentives that support domestic consumption of GH2 and ammonia in industry
- Feasibility studies on developing hydrogen industrial hubs at South African ports that link with shipping, truck and aviation routes
- Provide incentives for companies to start using GH2 and ammonia for power generation to create domestic demand

HARMONIZE STANDARDS AND REMOVE BARRIERS

- Reduce the administrative timelines required for approval for self-generation projects

SKILLS DEVELOPMENT AND PUBLIC AWARENESS

- Establish a national Hydrogen Industry Association tasked with advocacy for hydrogen and stimulating investment in the industrial sector

STRATEGIC DEMONSTRATION AND DEPLOYMENT PROJECTS

- Convert heavy goods vehicles (HGVs) for mining into hydrogen fuel cell powered vehicles as part of showing proof of concept



DECARBONISATION OF TRANSPORT SECTORS

MITIGATE INVESTMENT RISK

- Create an enabling environment for investment in refuelling infrastructure
- Classification of hydrogen as a transport fuel

HARMONIZE STANDARDS AND REMOVE BARRIERS

- Develop policy and regulatory framework that incentivises or rewards transport users that use hydrogen as a fuel to generate scale
- Develop regulations, codes, and standards for hydrogen refuelling
- Develop regulatory framework to support zero emission transport across all modes (road, rail, ship)

SUPPORT DEMAND CREATION

- Conduct feasibility studies to develop demand-driven business cases for municipal transport, heavy good vehicles, buses and taxis
- Scale up conversion of government fleets and municipal vehicles to use hydrogen as a fuel

STRATEGIC DEMONSTRATION AND DEPLOYMENT PROJECTS

- Implement refuelling station pilots for buses, heavy goods vehicles and taxis



ENHANCED AND GREEN POWER SECTOR

ESTABLISH TARGETS AND POLICY SIGNALS

- National electrification plan to be divided into main and micro-grids
- Finalise the Renewable Energy Masterplan
- Update the NDCs to align with HSRM with a specific focus on the power generation sector
- Prepare a position paper to specifically fund H2 use in subsectors (buildings, micro-grids)

HARMONIZE STANDARDS AND REMOVE BARRIERS

- Develop a national set of standards on energy within the built environment to enable use of H2 in buildings
- Incorporate and couple H2 production into existing PPA
- Revise IRP to include hydrogen gas for power generation

SUPPORT DEMAND CREATION

- Subsidies to telco applications for FC deployment to scale up
- Use public procurement to stimulate hydrogen and FC demand in public buildings sector
- Adopt hydrogen and FCs to power critical infrastructure
- Connect households to either main or micro-grids using FCs

PROMOTE RDI

- Solar Research Facility plan approved for funding

STRATEGIC DEMONSTRATION AND DEPLOYMENT PROJECTS

- Pilot fuel cells in data centres for proof of concept
- Pilot fuel cells in informal settlements keeping the same standards as main grid

SKILLS DEVELOPMENT AND PUBLIC AWARENESS

- Create awareness of hydrogen economy through different building-related bodies around H2 and HFCT in buildings
- Create a marketing and advocacy plan for hydrogen use in the electricity sector (main, micro-grid)



CENTRE OF EXCELLENCE IN MANUFACTURING

ESTABLISH TARGETS AND POLICY SIGNALS

- Finalise Beneficiation Masterplan
- Conduct study and develop export strategy for H2 products and FC components
- Develop GH2 product and component manufacturing strategy and business cases aligned with Automotive Masterplan and Minerals Masterplan

HARMONIZE STANDARDS AND REMOVE BARRIERS

- Adopt and implement regulatory framework including establishing independent H2 product and component testing and verification facilities

SUPPORT DEMAND CREATION

- Develop a policy framework that incentivises the use of locally manufactured components in various applications (FC vehicles, stationary FCs, electrolysers)

MITIGATE INVESTMENT RISK

- Develop strategy for attracting FDI in vehicle manufacturing sectors
- Implement manufacturing strategy in collaboration with global OEMs

PROMOTE RDI

- Develop and implement RDI strategy to support H2 product and component manufacture

SKILLS DEVELOPMENT AND PUBLIC AWARENESS

- Identify skills needed to support the implementation of the manufacturing strategy and develop a skills development roadmap

Figure 3.4: Summary of key actions_1

Figure 3.5: Summary of key actions_2

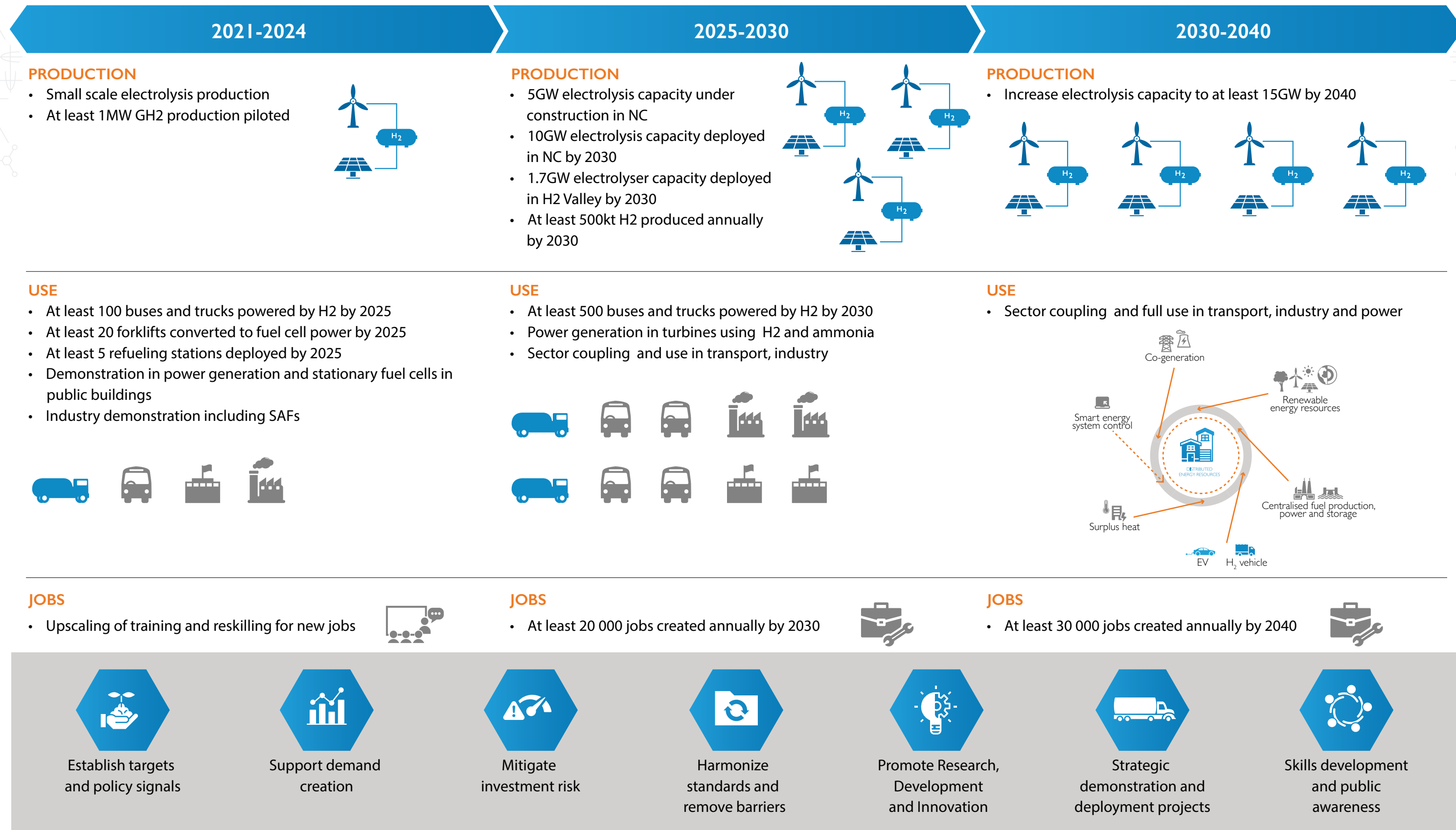


Figure 3.6: Some high-level numbers on the catalytic projects and some key actions and milestones

4. SOUTH AFRICAN HYDROGEN-SOCIETY OUTCOMES



Mining Haul Truck at rock dump at the Mogalakwena Platinum Mine

Source: Anglo American Platinum

The six high-level outcomes of the HSRM are each represented graphically (Figures 4.1 to 4.9) to give the high-level objective/s, the levers of change as well as the stakeholders who are expected to take a lead in the proposed and detailed action plans provided in the corresponding tables (tables 4.1 to 4.6). The action plans are proposed over the following timeframes:

- Short term: 2021-2024;
- Medium term: 2025-2030 and 2030-2040; and
- Long term: 2040-2050.

4.1 DECARBONISATION OF TRANSPORT

According to the global Hydrogen Review Report 2021, the transport sector accounts for 20% of global GHG emissions, and 25% of final energy demand, mostly due to the use of oil products.⁵⁸ While the use of hydrogen in the transport sector has historically stayed below 0.01%, hydrogen and hydrogen-based fuels offer opportunities to reduce emissions, particularly in heavy-duty trucks, shipping and aviation. In a net-zero emissions scenario, hydrogen and hydrogen-based fuels are expected to contribute more than 25% of total transport energy demand by 2050, up from 2.6% in 2030. In this scenario, more than 15 million fuel-cell electric vehicles (FCEVs) are projected across all modes, but the bulk of them will be in the light-duty segment.

Globally, more than 40 000 FCEVs were on the road by June 2021, most of them passenger vehicles. However, hydrogen-powered heavy-duty trucks and trains are also making their way into the market. In addition, pilot projects have started in shipping and aviation, with commercial fuel-cell flights expected around 2035. In the materials-handling segment, more than 40 000 fuel-cell forklifts are currently in operation in the USA.

In South Africa, the transport sector is responsible for 10.8% of national GHG emissions, with road transport accounting for 91.2%.⁵⁹ The GTS 2018 advocates for the adoption of electric vehicles (battery and fuel-cell powered) to reduce emissions in the transport sector. To date, there are over 300 battery electric vehicles in South Africa, while hydrogen fuel cells have been demonstrated in a mining locomotive, in golf carts, forklifts and scooters. As a follow-up to the mining locomotive project, Anglo American Platinum plans to test a fuel-cell mining truck at its Mogalakwena Mine in Limpopo. The South Africa Hydrogen Valley Feasibility Study Report proposes catalytic projects in the mobility sector, which will involve hydrogen fuel-cell powered buses, forklifts, and heavy-duty and mining trucks (see Chapter 5 for further details).⁶⁰

The total cost of ownership (TCO) for heavy-duty trucks is 10-45% higher than for diesel trucks, but is predicted to drop 30-40% by 2030 and 50-60% by 2050, mainly due to the scale-up of manufacturing of fuel cells, station components and hydrogen-production technologies, coupled with increased hydrogen refuelling-station utilisation. Depending on refuelling and charging-infrastructure utilisation, fuel-cell and battery electric trucks have comparable TCOs at a range of 500 km. Beyond 500 km, fuel-cell trucks are expected to have a lower TCO.

The HSRM supports the objective of decarbonisation of transport by 2050. The initial focus will be road transport, which accounts for the majority of transport emissions, and where the technology is most developed to use hydrogen to power heavy-duty vehicles (Figure 4.1). Rail, shipping and aviation will be addressed in the medium term (2025-2030). A summary of the proposed actions for the decarbonisation of transport is given in Table 4.1.

58. Global Hydrogen Review 2021, International Energy Agency.

59. GTS 2018.

60. South Africa Hydrogen Valley Final Report, October 2021.2

4. SOUTH AFRICAN HYDROGEN-SOCIETY OUTCOMES (CONTINUED)

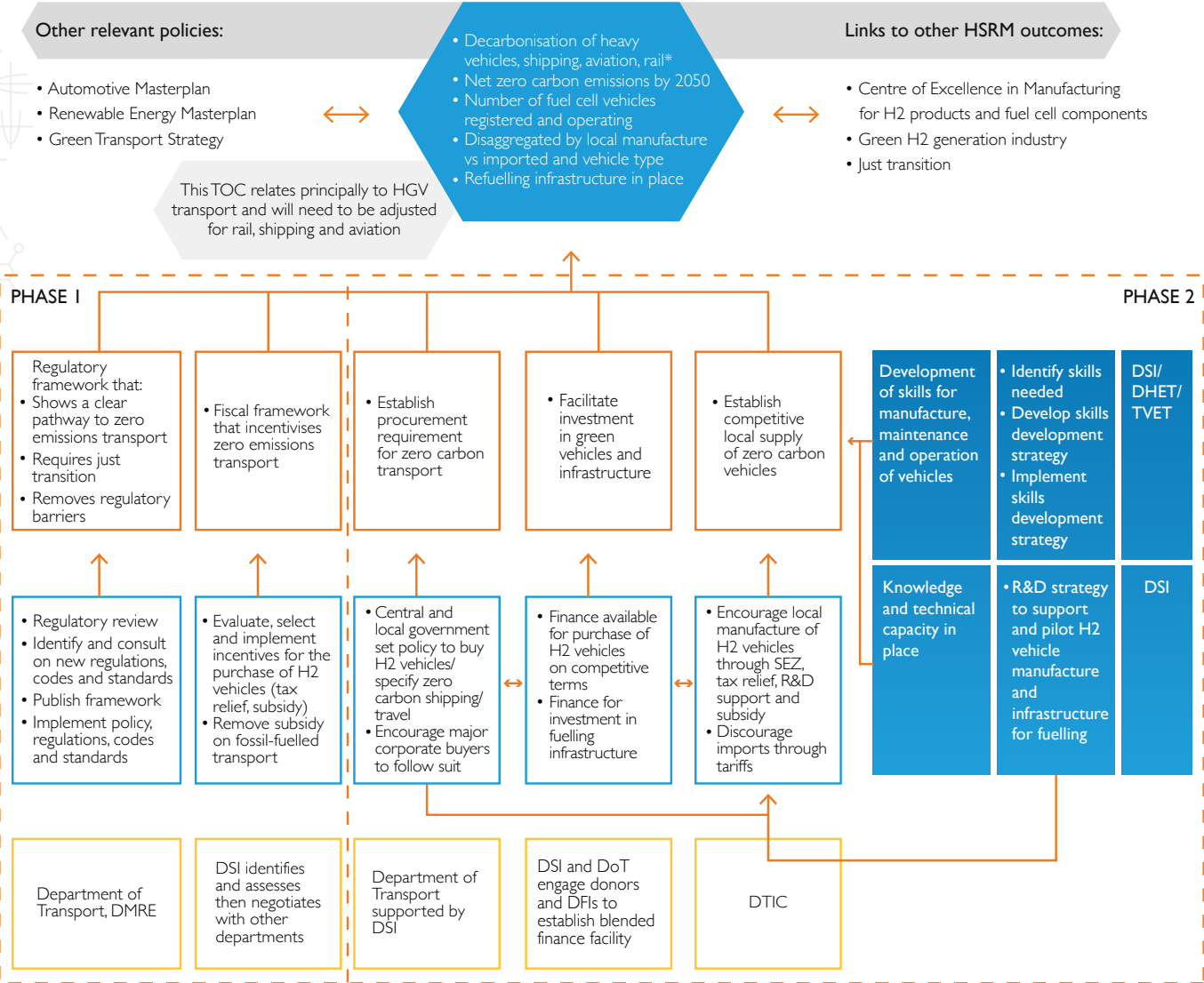
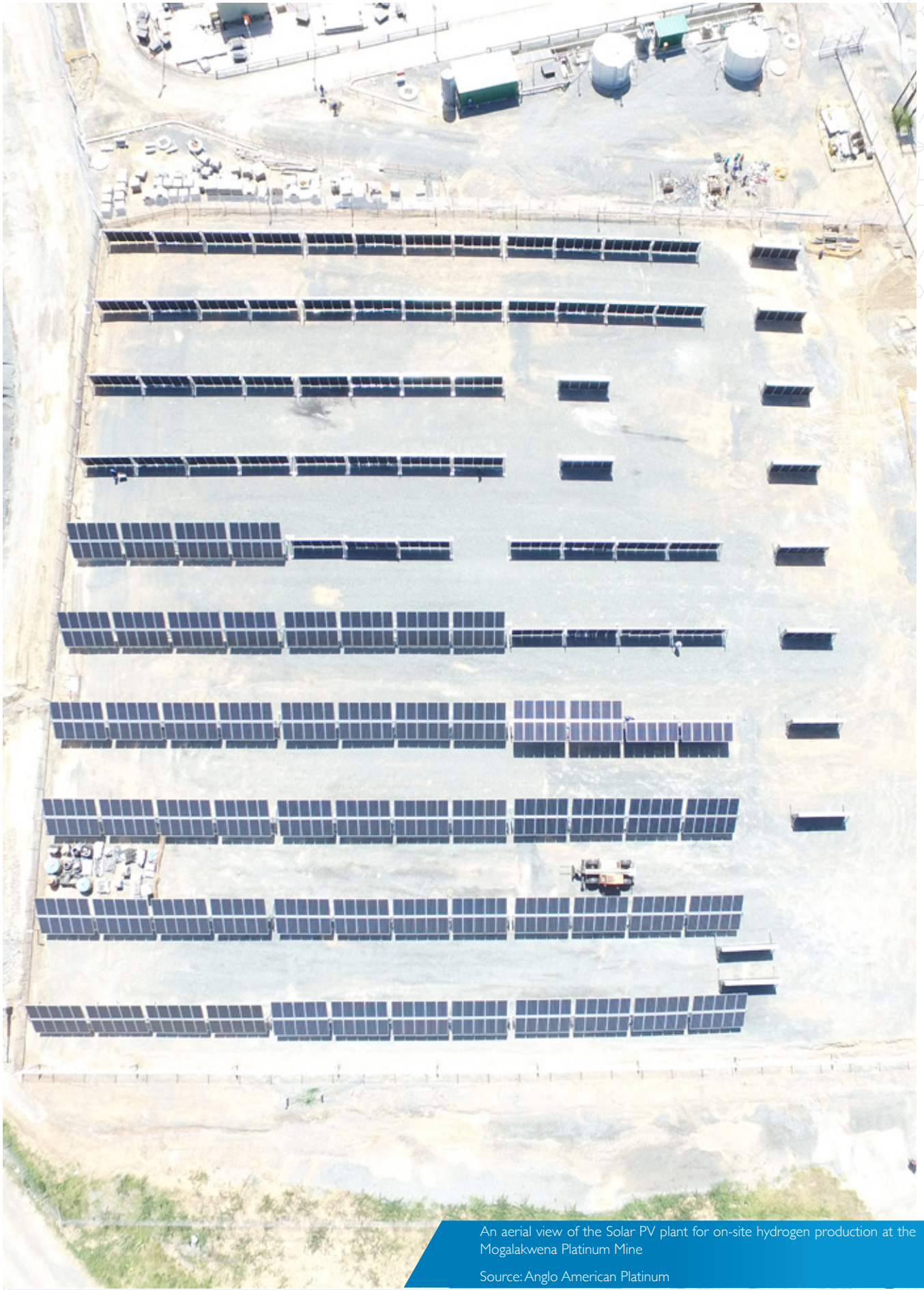


Figure 4.1: Theory of change for decarbonisation of heavy vehicles, shipping, aviation and rail



An aerial view of the Solar PV plant for on-site hydrogen production at the Mogalakwena Platinum Mine

Source: Anglo American Platinum

Table 4 1: Action plan for decarbonisation of heavy vehicles, shipping, aviation and rail

SECTOR: ROAD TRANSPORT

ACTION	CHAMPION	SUPPORTING INSTITUTIONS OR ORGANISATIONS	HOW WILL GESI/JUST TRANSITION AND RDI BE INCLUDED?	HOW WILL WE MONITOR PROGRESS?
2021-2024				
1. Develop policy and regulatory framework that incentivises or rewards transport users that use hydrogen as a fuel to help generate scale	DoT	DMRE, DTIC, National Treasury	GESI: Engage women and youth in developing framework and implications to address any job losses RDI: Centre of Excellence on techno-economic analysis on the cost of GH2 as a fuel	<ul style="list-style-type: none"> • Policy and regulatory framework developed • Number of vehicles using GH2 as a fuel
2. Conduct feasibility studies to develop demand-driven business cases for municipal transport, heavy goods vehicles, buses and taxis	DoT	COGTA, National Treasury, metro municipalities, taxi associations	RDI: Centre of Excellence on techno-economic analysis on technology and market readiness	<ul style="list-style-type: none"> • Feasibility studies completed
3. Develop regulations, codes and standards (RCS) for hydrogen refuelling	DMRE	DTIC, SABS	RDI: Research on high pressure storage	<ul style="list-style-type: none"> • Regulations developed and in use
4. Implement refuelling station pilots for buses, heavy goods vehicles and taxis		Government, private sector/PetroSA/CEF	GESI: Consider participation of women-led SMMEs in the piloting of refuelling infrastructure.	<ul style="list-style-type: none"> • Number of refuelling stations in operation • % women- and youth-led SMMEs involved
5. Develop a regulatory framework to support a zero emission transport across all modes (road, rail, ship)	DoT	DPE, Transnet	GESI: Consider participation of women- and youth-led SMMEs in the framework RDI: SARChI on legislative and regulatory frameworks	<ul style="list-style-type: none"> • Regulatory framework developed
6. Classification of hydrogen as a transport fuel	DMRE,	CEF, private sector	Not necessarily	<ul style="list-style-type: none"> • Share of hydrogen used as transport fuel
2025-2030				
7. Scale up the conversion of government fleets and municipal vehicles to use hydrogen as a fuel through public procurement	DoT	DMRE, DTIC, COGTA, National Treasury, metros, municipalities	GESI: Consider participation of women-led SMMEs in the supply chains RDI: Research on conversion technology with a focus on performance of locally developed components	<ul style="list-style-type: none"> • Number of hydrogen-fuelled vehicles • Jobs gained/lost • Number of women-led SMMEs involved
8. Create an enabling environment for investment in refuelling infrastructure	CEF	SASOL/petrochemical sector/PetroSA, operators/fuel providers	GESI: Consider role of SMMEs in the establishment, ownership and operation of the infrastructure	<ul style="list-style-type: none"> • Number of SMMEs involved in the supply chain
9. Implement incentives and compliance programmes.	DTIC	DMRE/National Treasury, DOT, private sector	GESI: Consider participation of women- and youth-led SMMEs in the incentive schemes	<ul style="list-style-type: none"> • Uptake of the incentives • % women- and youth-led SMMEs involved

4. SOUTH AFRICAN HYDROGEN-SOCIETY OUTCOMES (CONTINUED)

4.2 DECARBONISATION OF ENERGY-INTENSIVE INDUSTRY

Industry accounts for 26% of the global energy system CO₂ emissions with 6% of the industrial energy demand used to produce hydrogen. Industry demand for hydrogen, which is used as a feedstock in chemical as well as iron and steel production, is approximately 51 million tonnes (Mt) annually. In 2020, 65% of hydrogen went into ammonia production, 25% to methanol production, 10% into steel production through direct reduction of iron and less than 1% was used for other industrial uses. Ammonia production generates about 2.9 tonnes of CO₂ per tonne of product while methanol production generates 2.2 tonnes CO₂ per tonne of product.

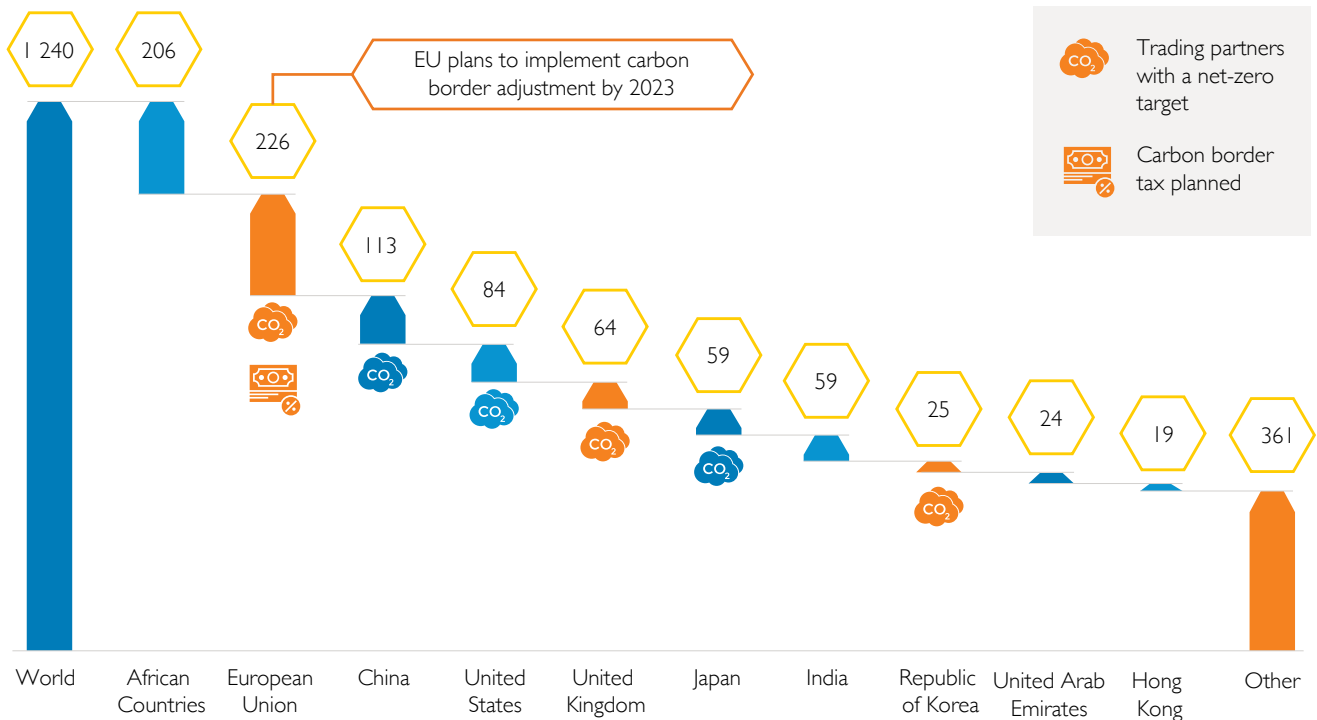
The National Business Initiative (NBI) report on decarbonising South Africa's Petrochemicals and Chemicals Sector⁶¹ indicates that the petrochemicals and chemicals sector, mining, manufacturing and construction, as well as minerals and metals production contribute about 25% of the total GHG emissions in South Africa. Just over 50% of those emissions come from the petrochemicals and chemicals sector. It South Africa's four crude oil refineries need ZAR60-70 billion investment for upgrades to Clean Fuels II Standard as well as further investments to maintain competitiveness. Given that Clean Fuels II is effective from 2023, petrochemicals imports are expected to increase significantly up to 2030, as a result of the potential decline in domestic refinery capacity. However, depending on the speed at which the transport sector decarbonises,

the NBI report projects that demand for conventional liquid fuels could drop by 50-100% due to the replacement by decarbonised alternatives.

One of the key findings from the NBI report is that South Africa has the opportunity to use green hydrogen and sustainable sources of carbon to decarbonise its petrochemicals and chemicals sector (responsible for 13% of the GHG emissions) to become a leading producer of green fuels and chemicals for both the domestic and export market.

In this regard, the South African industry needs to decarbonise in response to the changing global trade environment. The EU, South Africa's biggest trading partner by revenue (Figure 4.2) intends to implement the Carbon Border Adjustment Mechanism in 2023, which could have a negative impact on South Africa's exports.

The HSRM will support the objective of decarbonisation of industry by 2050. The initial focus will be on the steel, mining, chemicals, refineries and cement sectors (Figure 4.3) which together account for the majority of energy used in industry.



Source: World Integrated Trade Solution. 2018. 'Press research.'

Figure 4.2: Volumes of South Africa's exports to leading partners in 2018 (ZAR billion)
Source: NBI Report 2021

61. Decarbonising South Africa's Petrochemicals and Chemicals Sector, NBI Report 2021.

4. SOUTH AFRICAN HYDROGEN-SOCIETY OUTCOMES (CONTINUED)

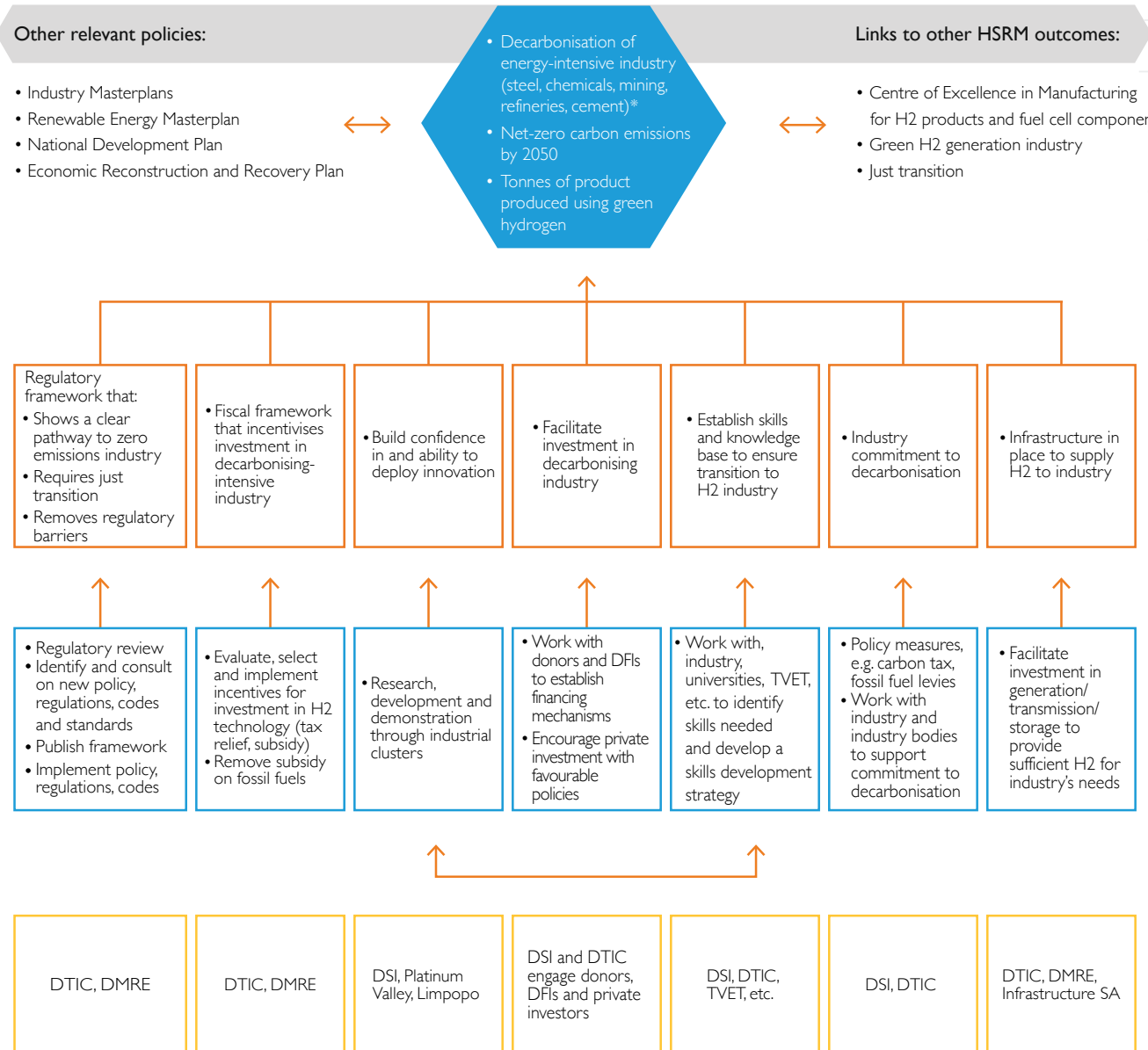


Figure 4.3: Theory of change for decarbonisation of energy-intensive industry

Table 4.2: Action plan for decarbonisation of energy-intensive industry

ACTION	CHAMPION	SUPPORTING INSTITUTIONS OR ORGANISATIONS	HOW WILL GESI/JUST TRANSITION AND RDI BE INCLUDED?	HOW WILL WE MONITOR PROGRESS?
2021-2024				
1. Establish a national Hydrogen industry association tasked with advocacy for hydrogen and stimulating investment in the industrial sector	DTIC/NBI	PICC/DMRE Private sector	GESI: Membership of women- and youth-led SMMEs paid by the DTIC	<ul style="list-style-type: none"> • % of membership which is women and youth
2. Conduct feasibility studies on developing hydrogen industrial hubs at South African ports that link with shipping, truck and aviation routes	DTIC/IDC	DSI Private sector	Not necessarily	<ul style="list-style-type: none"> • Study completed; hydrogen industrial hubs identified
3. Align Steel Masterplan to the HSRM	DTIC	SAISI	Not necessarily	<ul style="list-style-type: none"> • Policy revised and approved
4. Develop policies and regulations that will stimulate demand for hydrogen-related applications in the energy-intensive industries (mining, cement, steel, refineries)		DMRE, DTIC private sector	Not necessarily	<ul style="list-style-type: none"> • Policies developed and approved
5. Develop the local market framework with incentives that support domestic consumption of green hydrogen and ammonia	National DTIC Treasury/		GESI: Set aside opportunities for youth- and women-led businesses	<ul style="list-style-type: none"> • % women- and youth-led businesses involved in the value chain
6. Reduce the administrative timeframes required for approval for self-generation projects	DMRE/NERSA		GESI: Consider role of women-led SMMEs in approved projects	<ul style="list-style-type: none"> • MWh of electricity generated • % women-led SMMEs in approved projects
7. Provide incentives for mining companies to start using hydrogen for power generation to create domestic demand	National DMRE Treasury/		GESI: Participation of women and youth in incentive schemes	<ul style="list-style-type: none"> • Number of incentives in place • Tonnes of GH2 used
8. Convert the heavy goods vehicle for mining into hydrogen and fuel-cell-powered vehicles as part of showing proof of concept	DoT	Minerals Council SA	GESI: Participation of women- and youth-led SMMEs in the supply chains	<ul style="list-style-type: none"> • Number of HGVs converted • % women-led SMMEs involved
2025-2030				
9. Continue incentives for mining companies to use hydrogen for power generation until the penetration has reached a level where the niche market no longer needs to be supported	DMRE	National Treasury, Minerals Council SA	GESI: Participation of women and youth in incentive schemes	<ul style="list-style-type: none"> • Number of incentives in place • Tonnes of GH2 used
10. Continue to convert the heavy-duty vehicle for mining into hydrogen and fuel-cell-powered vehicles aligning with the targets set out in the HSRM for the 2025-2030 timeframe	DoT	DMRE	GESI: Participation of women- and youth-led SMMEs in the supply chains	<ul style="list-style-type: none"> • Number of HDVs converted • % women-led SMMEs involved
2030-2040				
11. Review incentives for mining companies to use hydrogen for power generation until the penetration has reached a level where the niche market no longer needs to be supported	DMRE,	National Treasury, Minerals Council SA	GESI: Participation of women and youth in incentive schemes	<ul style="list-style-type: none"> • Number of incentives in place • Tonnes of GH2 used
12. Continue to convert the heavy goods vehicle for mining into hydrogen and fuel-cell-powered vehicles aligning with the targets set out in the HSRM for the 2030-2040 timeframe	DoT	DMRE, NAAMSA: ABC	GESI: Participation of women- and youth-led SMMEs in the supply chains	<ul style="list-style-type: none"> • Number of HGVs converted • % women-led SMMEs involved
2040-2050				
13. Continue incentives for mining companies to start using hydrogen for power generation until the penetration has reached a level where the niche market no longer needs to be supported	DMRE	National Treasury, Minerals Council SA	GESI: Participation of women and youth in incentive schemes	<ul style="list-style-type: none"> • Number of incentives in place • Tonnes of GH2 used

4. SOUTH AFRICAN HYDROGEN-SOCIETY OUTCOMES (CONTINUED)

4.3 CREATION OF AN EXPORT MARKET FOR SOUTH AFRICAN HYDROGEN

The IEA Net-zero study⁶² projects global hydrogen use to increase from about 90 Mt in 2020 to more than 200 Mt in 2030, with a corresponding increase in the share of low carbon hydrogen from 10% to 70%, split equally between green hydrogen and blue hydrogen. In 2050, the IEA projects a global hydrogen demand of 530 Mt, with a 60:40 split between green and blue hydrogen respectively. Figure 4.4 indicates Japan's intention to import hydrogen and therefore could be a potential market for South African GH2.

South Africa currently produces 2 Mt of the global demand of hydrogen, all of which is grey hydrogen produced mostly from natural gas by Sasol. According to the NBI report⁶³ on decarbonising South Africa's power system, the country could produce green hydrogen at a competitive price of USD1.60 per kg by 2030 due to its excellent renewable energy resources. The use of green hydrogen in South Africa's power sector could replace natural gas in electricity generation and energy storage, stimulating a local demand of 1.4 Mt in green hydrogen by 2050.

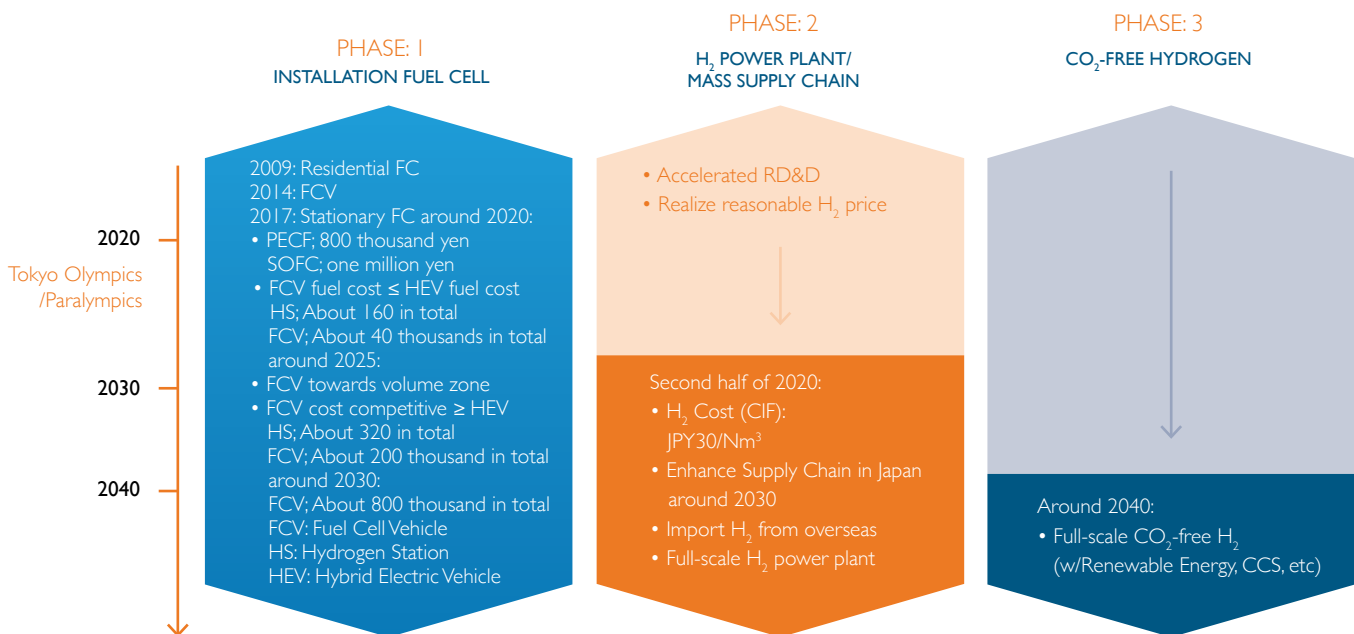


Figure 4.4: Extract from the Japanese roadmap indicating their interest in importing hydrogen

One of the key outcomes of the HSRM will be the creation of an export market for SA green hydrogen as illustrated in Figure 4.5. International climate commitments will drive the demand for green hydrogen. Demand from

international buyers will be influenced by South Africa's green hydrogen cost competitiveness, confidence in the South African hydrogen market, and an enabling export infrastructure.

62. International Energy Agency, Net-zero study.
63. Decarbonizing South Africa's Power System, NBI Report Chapter I.

4. SOUTH AFRICAN HYDROGEN-SOCIETY OUTCOMES (CONTINUED)

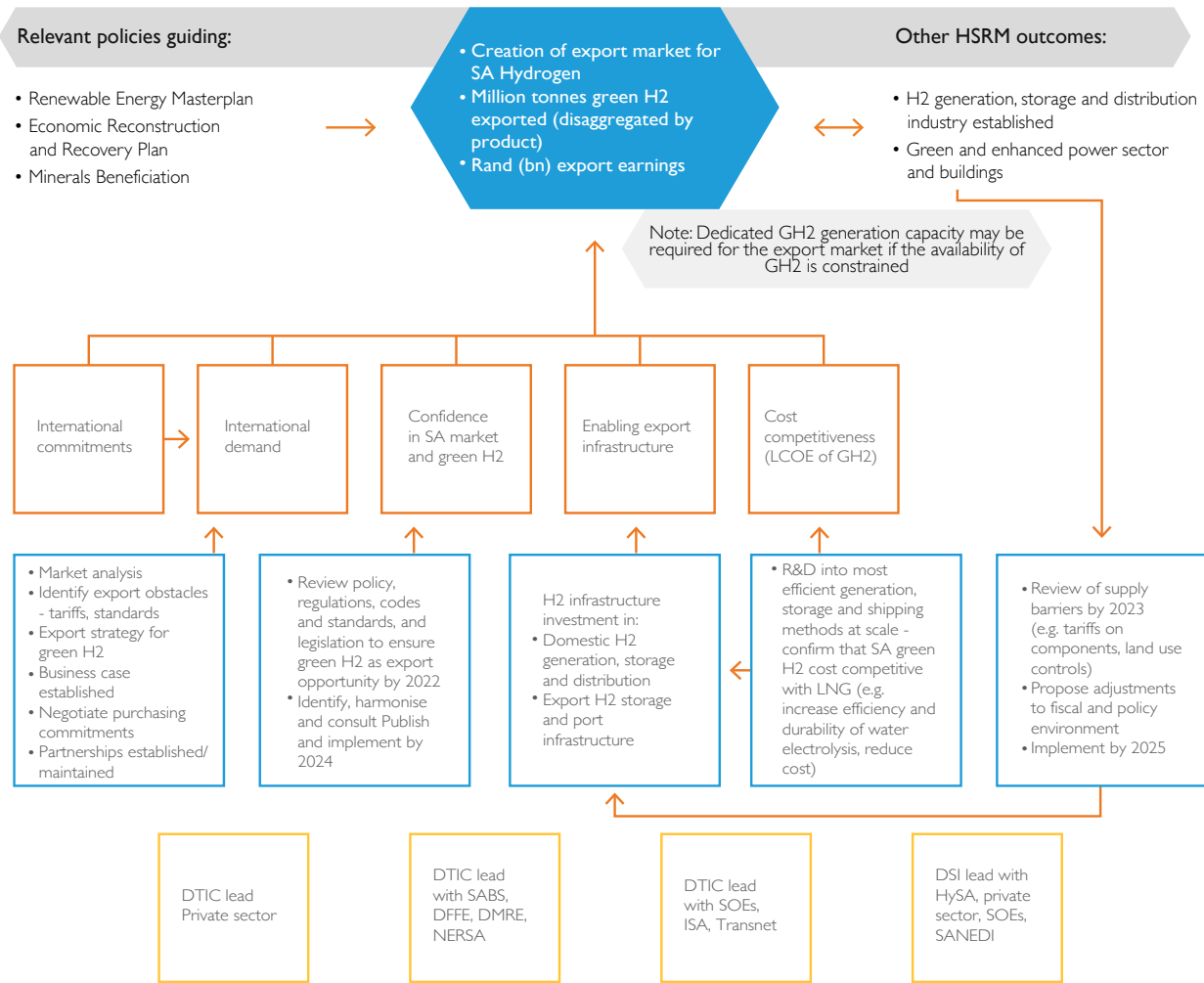


Figure 4.5: Theory of change for the creation of an export market for SA green hydrogen

Table 4.3: Action plan for the creation of an export market for SA green hydrogen

SECTOR: HYDROGEN EXPORT				
ACTION	CHAMPION	SUPPORTING INSTITUTIONS OR ORGANISATIONS	HOW WILL GESI/JUST TRANSITION AND RDI BE INCLUDED?	HOW WILL WE MONITOR PROGRESS?
2021-2024				
1. Conduct market analysis that will identify the export opportunities, obstacles and gaps, as well as potential partners and investors	DTIC lead	DIRCO Private sector	Just Transition: Just transition considered in discussions with potential investors	<ul style="list-style-type: none"> International commitments International demand Number of potential partners and investors engaged
2. Put in place international partnerships with key countries willing to purchase GH2	DIRCO	DTIC, DSI	GESI: Targets for women- and youth-led SMMEs in partnerships	<ul style="list-style-type: none"> Number of secured partnerships % women- and youth-led SMMEs involved
3. Expand regional cooperation/partnerships on GH2	DIRCO	DSI, SADC	GESI: Consider GESI in partnerships and supply chains	<ul style="list-style-type: none"> Investment made in support of regional integration Tonnes of GH2 traded across the region
4. Develop a hydrogen export strategy to inform the business case for green H2 (including derivatives) export	DTIC lead	DIRCO National Treasury, DPE, private sector	GESI: Targets for women- and youth-led SMMEs considered in export strategy	<ul style="list-style-type: none"> Approved GH2 export strategy Markets identified Business cases developed
5. Participate in relevant task teams on hydrogen certification and hydrogen trade rules of the IPHE	DSI lead	in facilitating participation by DTIC and DFFE	GESI: Targets for women participation in task teams	<ul style="list-style-type: none"> International codes and standards adopted for use in South Africa Locally produced H2 products traded on the global market
6. Review, develop and publish harmonised policy, regulations, codes and standards, and legislation to ensure green H2 as export opportunity by 2024	DTIC lead with SABS	DFFE	Not necessarily RDI: Centre of Excellence on legislative and regulatory frameworks	<ul style="list-style-type: none"> Harmonised regulatory environment and investments made in GH2, Confidence in SA GH2 market
7. Invest in RDI focused on the most efficient generation, storage and shipping methods to make SA GH2 cost competitive	DSI lead with SANEDI	Private sector, SOEs	RDI: Centre of Excellence on techno-economic analysis	<ul style="list-style-type: none"> Cost competitiveness (LCOE of GH2)
8. Integrate hydrogen exports into existing national port and rail strategies	DTIC lead with Transnet,	CEF, ISA	GESI: Address job losses/negative effects)	<ul style="list-style-type: none"> Number of facilities earmarked for or dedicated to GH2 export
2025-2030				
9. Implement export strategy including negotiation of purchasing commitments, establishing partnerships, and commence exports	DTIC lead	DIRCO National Treasury, DPE, SOEs (Transnet, CEF)	GESI: Targets for women- and youth-led SMMEs in supply chain	<ul style="list-style-type: none"> Number of partnerships established Strategy implemented Purchasing commitments made Tonnes of GH2 exported
10. Adopt and implement harmonised policy, regulations, codes and standards, and legislation for GH2 export	DTIC lead with SABS	DFFE	GESI: Targets for women- and youth-led SMMEs in supply chain	<ul style="list-style-type: none"> Investments made in GH2-related projects Tonnes of GH2 produced
11. Invest in rail and port infrastructure to support GH2 export	DTIC lead ISA	DFIs (IDC, DBSA), SOEs (CEF, Transnet)	GESI: Action plans to address job losses/negative effects) and in supply chains	<ul style="list-style-type: none"> Enabling export infrastructure Dedicated green hydrogen generation capacity
12. Invest in RDI focused on the most efficient generation, storage and shipping methods for SA GH2 to be cost competitive	DSI lead with SANEDI	HySA, private sector, SOEs,	Just Transition: Consider just transition in the recruitment of RDI personnel and human capital development	<ul style="list-style-type: none"> Cost competitive GH2 Intellectual property rights filed/granted
2030-2040				
13. Implement export strategy including commercial export and increasing market size	DTIC lead,	National Treasury, DPE, private sector	GESI: Targets for women- and youth-led SMMEs in supply chain	<ul style="list-style-type: none"> Tonnes of GH2 exported % of global GH2 market
14. RDI – continue to innovate to remain globally competitive for GH2 export	DSI lead with SANEDI	HySA, private sector, SOEs	RDI: Centre of Excellence on techno-economic analysis	<ul style="list-style-type: none"> Cost competitive GH2 Intellectual property rights filed/granted

4.4 CENTRE OF EXCELLENCE IN MANUFACTURING FOR HYDROGEN PRODUCTS AND FUEL CELL COMPONENTS

The cost of fuel cells for the automotive sector has fallen by close to 70% since 2008. Current system costs are in the range USD250-400 per kW with projections indicating that scaling up manufacturing from 1 000 to 100 000 systems per year would reduce costs by more than 70%. Global fuel cell manufacturing capacity is expected to exceed 200 000 systems per year by end of 2021 and to reach 1 300 000 systems a year by 2030 based on announcements. Technology development aimed at improving cell durability, cost reduction and improving efficiency are required. Key research and development focus areas include the PGM-based fuel cell catalyst, membranes and electrolytes, as well as bipolar plates.

The average platinum loading on fuel cells has decreased by 30% since 2008, without a decrease in performance. While palladium demand will drop through the replacement of ICE by FCEVs because of the high palladium content in catalytic converters, platinum demand is expected to increase despite the reductions in the platinum loading in fuel cells, mainly due to the increased adoption of fuel cell technology.

The establishment of a manufacturing sector for hydrogen products and components is one of the key outcomes for the HSRM (Figure 4.6), which will encourage inward investment and support the Just Labour Transition by providing high quality jobs. This sector will support the transition from ICE to electric vehicle manufacturing, produce products for export and will contribute to the beneficiation of South African minerals through the supply of value-added components in the hydrogen value chain. Potential already exists to manufacture hydrogen fuel cells, electrolysers, membrane-electrode assemblies (MEAs) and their subcomponents.

To drive this sector development, a clear regulatory and investment environment is needed which incentivises the manufacture of hydrogen products and components as well as an innovative culture developing hydrogen products and processes and the associated skilled workforce.



A student at HySA Catalysis-University of Cape Town, examining a membrane electrode assembly (MEA)

4. SOUTH AFRICAN HYDROGEN-SOCIETY OUTCOMES (CONTINUED)

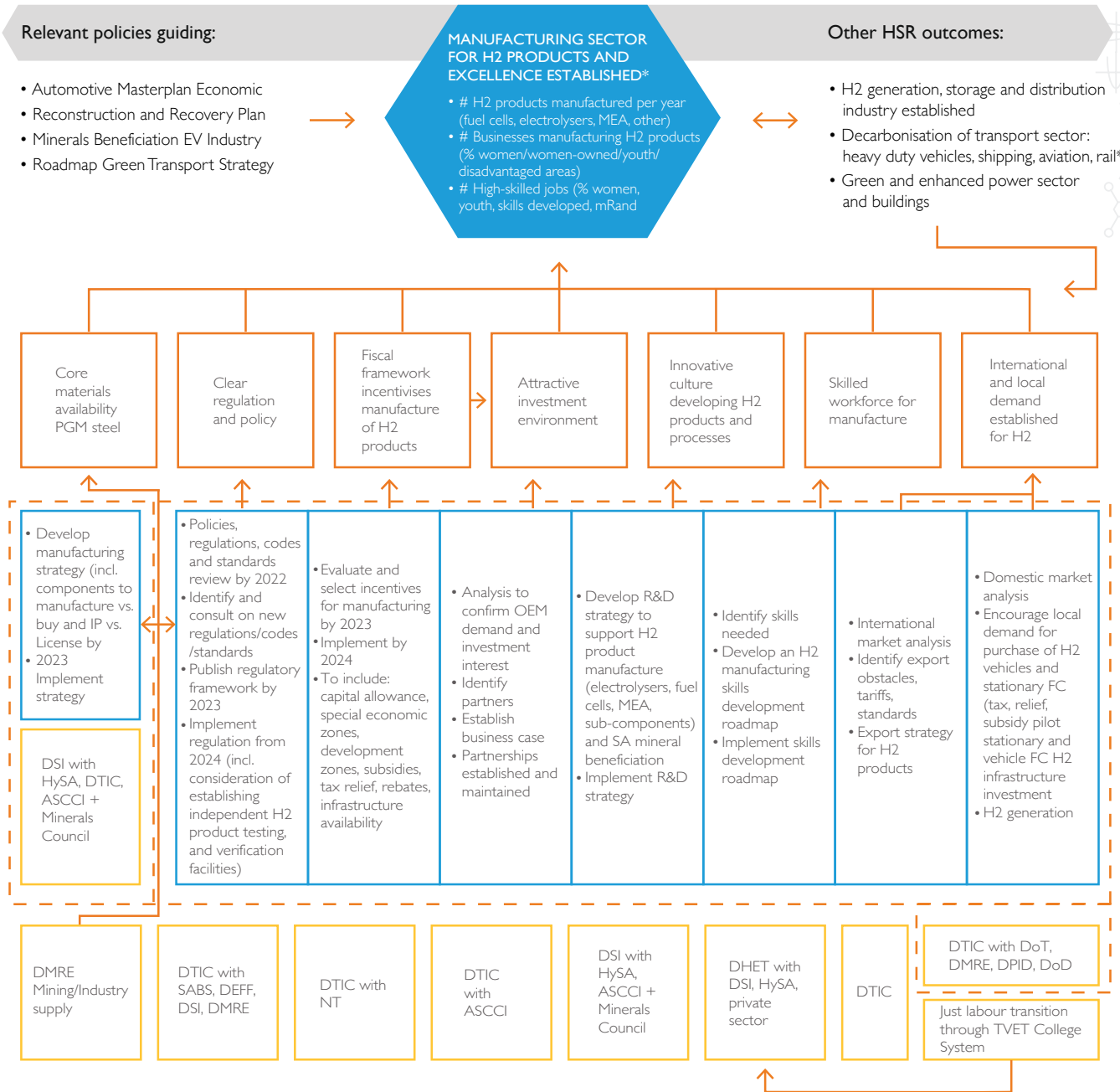


Figure 4.6: Theory of change for Centre of Excellence in Manufacturing for hydrogen products and fuel cell components

4. SOUTH AFRICAN HYDROGEN-SOCIETY OUTCOMES (CONTINUED)

Table 4.4: Action plan for Centre of Excellence in Manufacturing for hydrogen products and fuel cell components

SECTOR: CENTRE OF EXCELLENCE IN MANUFACTURING FOR HYDROGEN PRODUCTS AND FUEL CELL COMPONENTS

ACTION	CHAMPION	SUPPORTING INSTITUTIONS OR ORGANISATIONS	HOW WILL GESI/JUST TRANSITION AND RDI BE INCLUDED?	HOW WILL WE MONITOR PROGRESS?
2021-2024				
1. Develop a GH2 product and component manufacturing strategy and business case aligned with Automotive Masterplan and Minerals Beneficiation Masterplan	DTIC, DSI	HySA, ASCCI, OEMs, and Minerals Council	GESI: Include plans to increase % of jobs for women and disabled Consider location of facilities in disadvantaged areas	<ul style="list-style-type: none"> Approved Commercialisation/Manufacturing Strategy
2. Conduct study and develop export strategy for H2 products and fuel cell components	DTIC	with private sector, ASCCI	RDI: Centre of Excellence on techno-economic analysis	<ul style="list-style-type: none"> International demand for H2 products established Number of purchasing commitments in place
3. Develop a policy framework that incentivises the use of locally manufactured components in various applications (FC vehicles, stationary FCs, electrolysers)	DTIC with DoT	DMRE, DPWI, DoD, NT, ASCCI	GESI: Participation of women- and youth-led SMME incentives developed and in procurement	<ul style="list-style-type: none"> Domestic demand established for H2 products Targets for integrating hydrogen-related products in the domestic market in place
4. Develop and implement RDI strategy to support H2 product and component manufacture (electrolysers, fuel cells, MEA, subcomponents)	DTIC with DSI	SANEDI, HySA, ASCCI and Minerals Council	GESI/Just Transition: Consider Just Transition in support for local manufacturing	<ul style="list-style-type: none"> Innovative culture developing H2 products and processes Number of H2 products and components manufactured locally
5. Identify skills needed to support the implementation of the manufacturing strategy and develop a skills development roadmap	DHET with DSI	SANEDI, HySA, private sector	GESI: Consider GESI in plans Include plans to encourage women to train and enter market	<ul style="list-style-type: none"> Skills development roadmap developed % women in skilled workforce for local manufacturing
6. Develop strategy for attracting FDI in vehicle manufacturing sectors	DTIC with National Treasury	NAAMSA: ABC	GESI/Just Transition: Participation of women- and youth-led SMMEs in sector	<ul style="list-style-type: none"> FDI investment in the manufacturing sector
7. Finalise Minerals Beneficiation Masterplan	DMRE	Minerals Council	GESI/Just Transition: Participation of women- and youth-led SMMEs in sector	<ul style="list-style-type: none"> Masterplan approved for implementation
2025-2030				
8. Adopt and implement regulatory framework including establishing independent H2 product and component testing and verification facilities	DTIC with SABS	DSI, ASCCI	GESI/Just Transition: Participation of women- and youth-led SMMEs in product and component testing	<ul style="list-style-type: none"> Establishment of testing facility Number of H2-related products and components tested and certified
9. Implement targeted manufacturing incentives (to include allowances, special economic zones, subsidies, tax relief, rebates, infrastructure availability)	DTIC with National Treasury	private sector	GESI: Consider GESI and role of SMMEs in the supply chains	<ul style="list-style-type: none"> Fiscal framework incentivises manufacture of H2 products Industry awareness of policy, awareness of benefits
10. Implement manufacturing strategy in collaboration with global OEMs	DSI with DTIC	OEMs, ASCCI and Minerals Council	GESI/Just Transition: Participation of women- and youth-led SMMEs in manufacturing	<ul style="list-style-type: none"> Number of H2-related products and components manufactured locally
11. Implement skills development roadmap and embed in existing TVET and higher education sectors	DHET	DSI	GESI/Just Transition: Target women in recruitment of trainees	<ul style="list-style-type: none"> Number of engineers/scientists/artisans trained (disaggregated)
12. Conduct RDI to support H2 product and component manufacture (electrolysers, fuel cells, MEA, subcomponents)	DSI with SANEDI,	HySA, ASCCI and Minerals Council	GESI: Consider GESI in recruitment of knowledge workers	<ul style="list-style-type: none"> IP generated on components and system level performance

4. SOUTH AFRICAN HYDROGEN-SOCIETY OUTCOMES (CONTINUED)

4.5 GREEN AND ENHANCED POWER SECTOR

Fuel cells running on hydrogen, methanol or natural gas have been deployed in residential, commercial or public buildings as well as data centres to provide primary or back-up power. Proton exchange membrane technology has dominated the deployments in the residential sector, spurred by government support in the form of incentives (Japan), tax credits (USA) and renewable energy certificates (Korea).

A number of pilot projects looking at blending of hydrogen into existing natural gas network with a focus on hydrogen use in buildings have been initiated globally. These include the project at the island of Ameland (Netherlands), the GRHYD project in France and the HyDeploy project in the UK where up to 20% hydrogen by volume was injected into the natural gas grid. The objective of the projects has been to assess the level of safety that could be tolerated by existing domestic appliances.

In South Africa, fuel cells have been deployed in stationary applications to provide backup power for telecommunications infrastructure and primary power for public buildings (schools and hospitals), with methanol and pure hydrogen used as fuel. To date, Vodacom has deployed over 300 fuel cell units as backup power for cell phone base stations. The 100 kW fuel cell unit (running on natural gas) at the Minerals Council building in Johannesburg and the fuel cells deployed at 1 Military Hospital in Pretoria to provide primary power to COVID-19 field hospitals and a vaccination centre are some of the examples of the deployments in buildings. Further deployments of hydrogen and fuel cells in the building sector will depend on cost of the

technology compared to incumbent technologies, such as diesel generators and supporting infrastructure. This is particularly important to provide clean off-grid power to critical infrastructure, such as hospitals and data centres.

However, hydrogen could be a game changer in the decarbonisation of the power sector through direct combustion in turbines as hydrogen-rich gas or 100% hydrogen. A 45 MW gas turbine operating on up to 95% hydrogen has been in operation at a refinery in Korea for more than 20 years. Gas turbines operating on pure hydrogen are expected by 2030, provided issues of higher nitrogen oxide (NOx) emissions resulting from higher combustion temperature can be addressed.

In South Africa, electricity production contributes in excess of 40% to the overall GHG emissions.⁶⁴ Hydrogen is capable of contributing to the achievement of a de-carbonised and enhanced power sector by providing RE storage and green power to the main electricity grid, thus improving overall grid stability as illustrated in Figure 4.7. This also includes benefits to the gas grid via power to hydrogen/gas applications. Through micro grids, hydrogen energy can supply back-up power to reduce power outages, supply power for information and communications technology applications and remote areas/islands (off- and on-grid), provide electricity and heat to commercial and public buildings and the residential sector. The IRP 2019 and the South African Renewable Energy Masterplan (SAREM) are the main interconnected national policies providing guidelines for hydrogen in the power sector.



Fuel Cell units incorporating HySA IP deployed to power COVID-19 field hospitals at 1 Military Hospital in Pretoria-August 2020

64. Decarbonising South Africa's Power System, NBI report Chapter 1, 2021.

4. SOUTH AFRICAN HYDROGEN-SOCIETY OUTCOMES (CONTINUED)

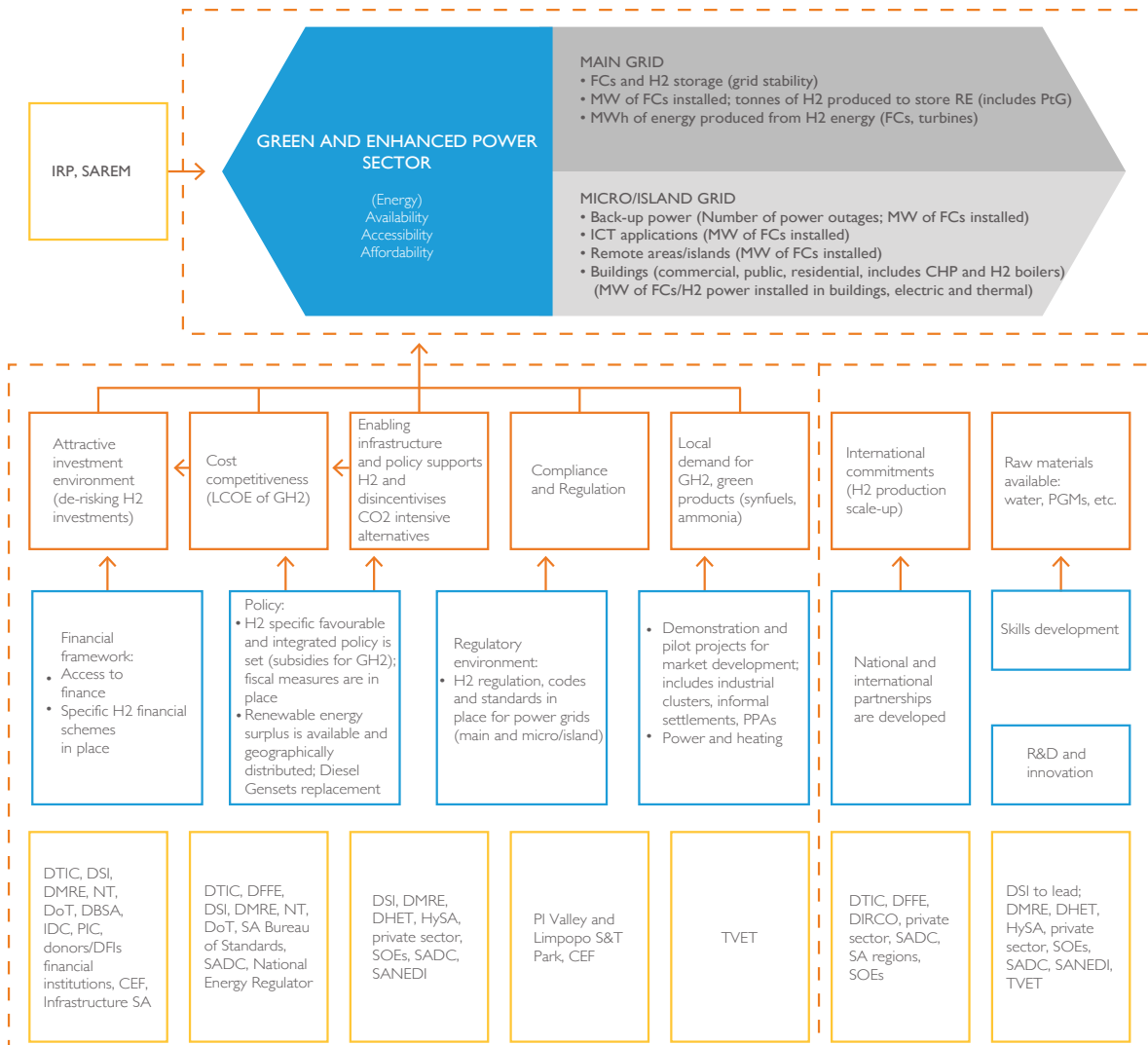


Figure 4.7: Theory of change for a green and enhanced power sector

Table 4.5: Action plan for a green and enhanced power sector

SECTOR: GREEN AND ENHANCED POWER SECTOR

2021-2024				
1. National electrification plan/target to be divided into main and micro-grids	DMRE	Eskom	GESI: Incorporate GESI into the electrification plans	• Number of micro-grids deployed
2. Finalise South African Renewable Energy Masterplan (SAREM)	DMRE with DTIC	DSI	GESI: Participation of women and youth in SAREM	• SAREM completed and approved
3. Align SAREM and Steel Masterplan with HSRM targets	DMRE	DSI, DTIC	GESI: Targets for women- and youth-led SMMEs	• Number of RE plants deployed in support of GH2 production
4. Update NDCs to align with HSRM with a specific focus on the power generation sector	DPFE	DSI, Science Councils	Not necessarily	• Updated NDCs
5. Subsidies to telco applications for FC deployment to scale up	National Treasury with DCTS	Telcos, DSI	GESI: Support for remote education due to COVID-19 RDI: Research into cost effective H2 distribution for telco applications	• Number of FCs deployed to support ICT infrastructure • Subsidies in place
6. Pilot FCs in data centres for proof of concept	DCTS with DSI		RDI: H2 back-up application featuring long-term storage	• Number of data centres powered by FCs
7. Pilot FCs in informal settlements keeping the same standard as main grid	DMRE with DSI		GESI: Targets for women- and youth-led SMMEs involved in deployments	• Number of FCs deployed in informal settlements
8. Develop a national set of standards on energy within the built environment to enable use of H2 in buildings	DPWI with DMRE	Eskom, Green Building Council (GBC)	RDI: Centre of Excellence on Legislation and Policy in hydrogen	• Standards developed and adopted
9. Create awareness of hydrogen economy through different building-related bodies around H2 and HFCT in buildings	DPWI with GBC	DSI, real estate entities	RDI: RE integration in built environment	• Number of buildings powered by FCs (primary or back-up power)
10. Use public procurement to stimulate H2 and fuel cell demand in public building sector	DPWI with DMRE	SANEDI, private sector	RDI: Centre of Excellence on techno-economic analysis GESI: Consider youth and women in procurement	• Public procurement policy developed and adopted • Number of public buildings that use FCs (primary and back-up)
11. Adopt H2 and FCs to power critical infrastructure	DoD with DPWI	DSI, private sector	GESI: Consider youth and women in procurement	• Number of critical infrastructure that use FCs (primary and back-up)
12. Create a marketing and advocacy plan for H2 use in the electricity sector (main, micro-grid)	GCIS with DMRE	DSI, DHET	GESI: Energy, poverty, air quality, safety, women	• Marketing and advocacy plan developed
13. Incorporate and couple H2 production into existing PPA	DMRE with IPP office	NT	GESI: Consider GESI in procurement	• Number of PPAs incorporating GH2
14. Facilitate the approval of the Solar Research Facility (SRF) plan for funding	DSI	private sector	GESI: Consider GESI in staffing and training	• Number of facilities established and supported
15. Prepare a position paper to specifically fund H2 use in sub-sectors (buildings, micro-grids)	National Treasury with DMRE,	DSI	RDI: Centre of Excellence on techno-economic analysis	• Position paper completed and recommendations adopted
2025-2030				
16. Complete establishment of the SRF	DSI	private sector	RDI: H2 production from solar energy GESI: Targets for women and youth in staff	• SRF up and running • % women and youth employed in the SRF
17. Connect households to either main or micro-grids using FCs	DMRE,	local municipalities	GESI: Targets for women and youth led SMMEs	• Number of grid-connected households, disaggregated by mini and main grid
18. Revise the IRP to include hydrogen gas for generation	DMRE		GESI: Targets for women and youth led SMMEs	• MWh of energy produced from H2 energy

4. SOUTH AFRICAN HYDROGEN-SOCIETY OUTCOMES (CONTINUED)

4.6 TRANSITION FROM GREY TO BLUE TO GREEN HYDROGEN

Figure 4.8 gives an indicative global transition of the various forms of hydrogen as presented in a recent report by the Hydrogen Council.⁶⁵ The actual transition and the proportion of the various shades of hydrogen will be largely driven by market forces. However, the report also notes that the phasing out of grey hydrogen will depend on the regulatory environment.

A carbon price and other policies, such as blending mandates for clean fuels or ammonia could be used to accelerate the phase-out. In the absence of such policies, relying on industry commitments and consumer pressure only will not meet the net-zero target.

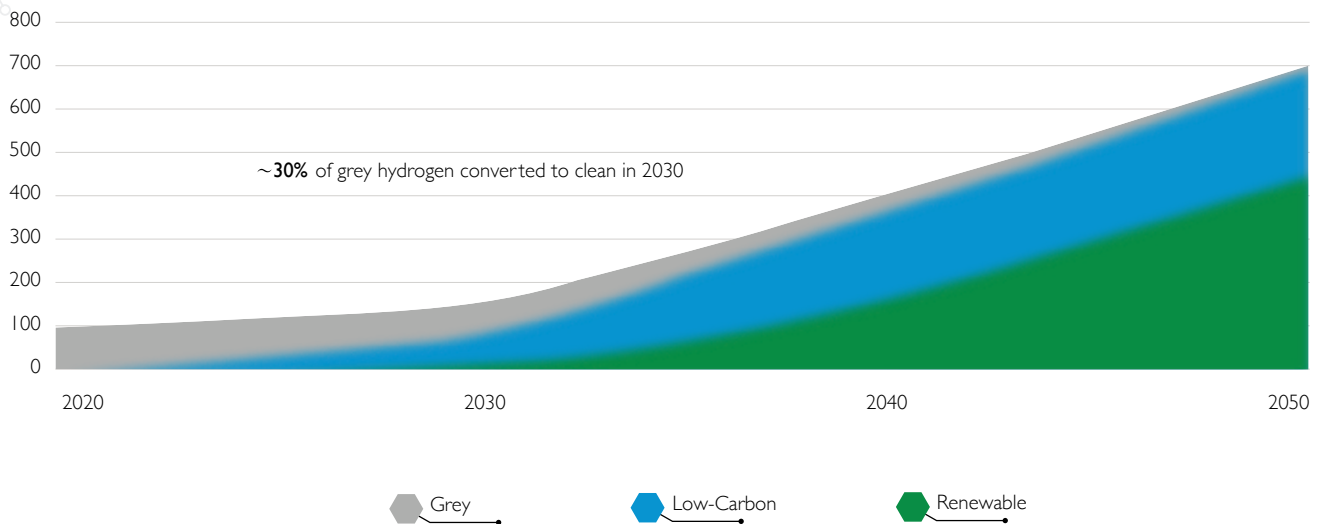


Figure 4.8: Indicative hydrogen supply by production method in million tonnes of hydrogen per annum

Source: Hydrogen Council 2021

South Africa's transition from the use of grey to blue to green hydrogen needs to be done in a manner that is consistent with national priorities while being agile enough to respond to demand. In the short term, South Africa will use catalytic projects to stimulate local demand for all forms of hydrogen in order to demonstrate commercial viability and scalability. This will then be used to prepare the country to respond to global demand for green hydrogen and capture a significant share of the projected demand of 530 Mt by 2050. In this regard, South Africa could target to at least double its current share of the global demand in green hydrogen by 2050. The use of green hydrogen in South Africa's power sector in electricity generation and energy storage is projected to be 1.4 Mt in green hydrogen by 2050.

Figure 4.9 gives the theory of change for the transition from grey to blue to green hydrogen while Table 4.6 gives the proposed action plan aimed at stimulating the upscaling of production, storage and distribution of hydrogen, which will also inform the transition from grey hydrogen to green hydrogen.

65. Hydrogen for Net-Zero, Hydrogen Council Report, November 2021.

4. SOUTH AFRICAN HYDROGEN-SOCIETY OUTCOMES (CONTINUED)

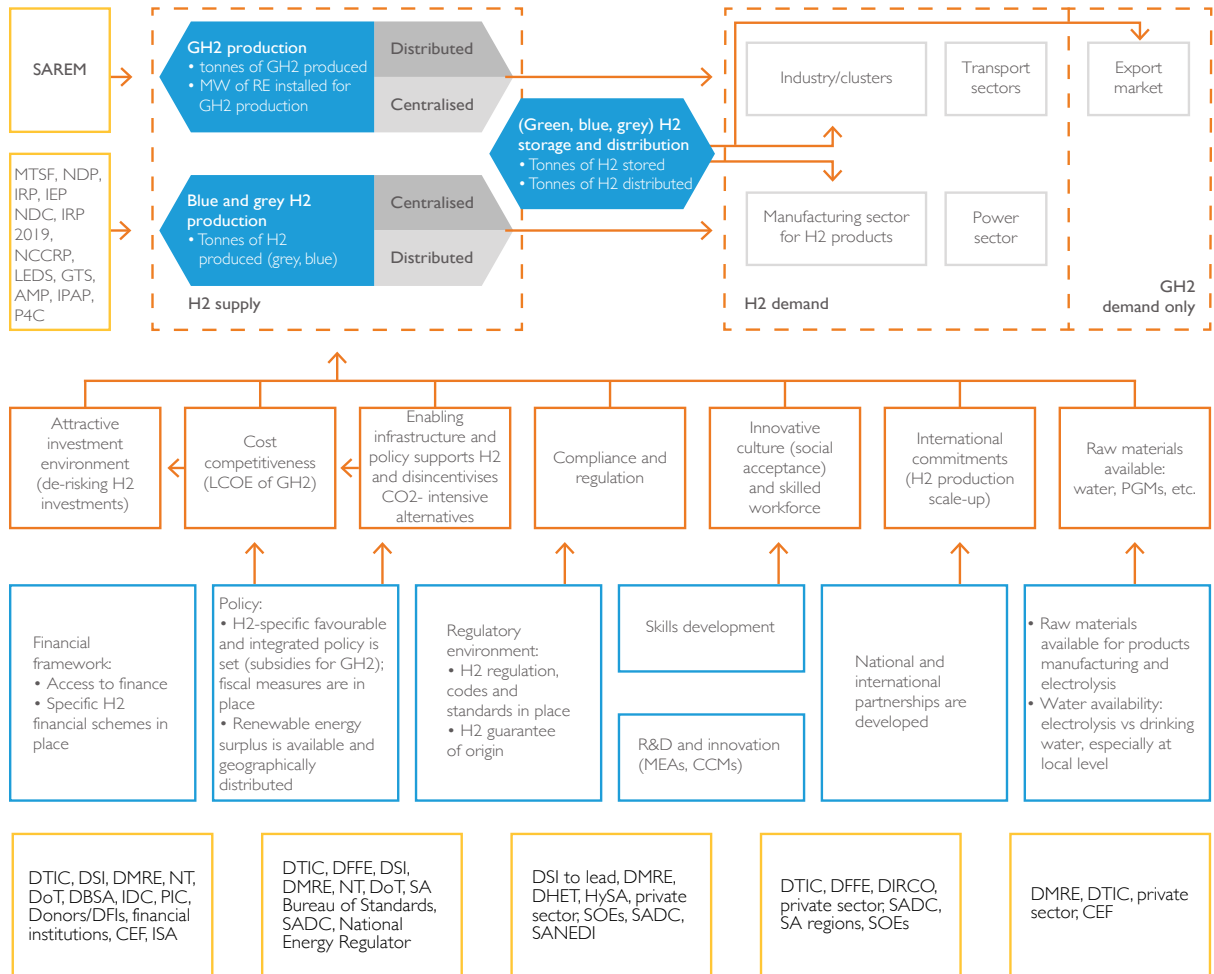


Figure 4.9: Theory of change for hydrogen generation, storage and distribution

Table 4.6: Action plan for hydrogen generation, storage and distribution

SOURCE: HYDROGEN GENERATION, STORAGE AND DISTRIBUTION

ACTION	CHAMPION	SUPPORTING INSTITUTIONS OR ORGANISATIONS	HOW WILL GESI/JUST TRANSITION AND RDI BE INCLUDED?	HOW WILL WE MONITOR PROGRESS?
2021-2024 Grey, blue, green				
1. Improvement of grey H2, blue H2 infrastructure deployment including technology upgrade	Infrastructure SA	Sasol, PetroSA, NCP Chloro-Chem, NERSA, DMRE, DSI	GESI: Have targets for the participation of women and youth in market deployment plan RDI: Research, development and demonstration of MW scale electrolysers focused on cost reduction of GH2	<ul style="list-style-type: none"> Market deployment plan to be in place Number of MW electrolysers deployed in SA Cost of GH2 per kg
2. Finalise Green Hydrogen Commercialisation Strategy to support the implementation of the HSRM	DTIC	DMRE, DSI, private sector, SOEs	GESI: Have targets for the participation of women and youth in GH2 supply chains	<ul style="list-style-type: none"> GH2 commercialisation strategy developed
3. Gazette Integrated Infrastructure Project (SIP) on Hydrogen	Infrastructure SA		GESI: Have targets for the participation of women and youth in SIP	<ul style="list-style-type: none"> Number of women and youth involved in SIP
4. Implement catalytic projects such as Boegoebaai SEZ, Platinum Valley Initiative (SA's Hydrogen Valley), CoalCO ₂ -X Demonstration and SAF project	Infrastructure SA with NCEDA	DSI, SANEDI, Sasol,	GESI: Have targets for the participation of women and youth in catalytic projects RDI: Research focused on cost reduction of GH2 and fuel cell components	<ul style="list-style-type: none"> Number of women and youth involved in catalytic projects Number of locally developed components integrated in catalytic projects
5. Develop a communication plan to promote awareness of hydrogen use across all sectors	GCIS with DMRE	DSI, DTIC	GESI: Women, youth framework in place including skills development, social acceptance	<ul style="list-style-type: none"> Number of women involved in the Communication Plan Number of women and youth trained
6. Revise the Critical Infrastructure Programme Framework to speed up the deployment of hydrogen-related infrastructure (refuelling stations, pipelines)	DTIC		GESI: Framework for women, youth participation in deployment of infrastructure RDI: Research aimed at improving performance of key components of critical infrastructure	<ul style="list-style-type: none"> Critical Infrastructure Programme revised Number of critical infrastructure programmes deployed
7. Develop an RDI Strategy to support the implementation of the Hydrogen Society Roadmap	DSI	private sector, academia	GESI: Participation of women and youth in RDI Strategy	<ul style="list-style-type: none"> RDI strategy developed Number of women and youth involved in implementing RDI Strategy
8. Pilot carbon capture and use (CCU) in Mpumalanga Priority Area	DSI with DMRE	DFFE, private sector, academia, SOEs, Provincial Government	GESI: Women, youth participation in CCU RDI: Research aimed at improving performance of CCU technology	<ul style="list-style-type: none"> CCU technology piloted
9. Develop a skills development roadmap which spans from TVETs, UoTs and Universities	DHET with DoL	DTIC, DSI	GESI: Women, youth participation in skills development	<ul style="list-style-type: none"> Skills development roadmap developed Number of women and youth trained
10. Develop a framework for reskilling people and preserving jobs in sectors affected by the transition to the Hydrogen Economy	DHET	DMRE, DFFE, DTIC, DSI	GESI: Women, youth considered for reskilling	<ul style="list-style-type: none"> Framework for job preservation through reskilling developed
11. Establish international partnerships to scale up training required for the hydrogen economy	DIRCO with DHET	DSI, DTIC	GESI: Women, youth participation in international partnerships	<ul style="list-style-type: none"> International partnerships established Number of women and youth participating in international partnerships
12. Establish international partnerships to support electrolyser research	DSI with DIRCO	universities, Science Councils, private sector	GESI: Consider women, youth in recruitment RDI: Research aimed at improving performance and cost of electrolysers	<ul style="list-style-type: none"> Partnerships established Number of women and youth participating in partnerships
13. Finalise the Just Energy Transition Framework	DMRE	PCCC	GESI: Consider GESI in Just Energy Transition RDI: Research aimed at supporting Just Energy Transition	<ul style="list-style-type: none"> Just Energy Transition framework finalised
14. Establish an overarching body to coordinate relevant players in the quadruple helix around the hydrogen economy	DSI with DTIC	DMRE	GESI: Consider women and youth participation in overarching body	<ul style="list-style-type: none"> Overarching body established Number of women and youth employed by overarching body

Table 4.6: Action plan for hydrogen generation, storage and distribution (continued)

ACTION	CHAMPION	SUPPORTING INSTITUTIONS OR ORGANISATIONS	HOW WILL GESI/JUST TRANSITION AND RDI BE INCLUDED?	HOW WILL WE MONITOR PROGRESS?
15. Complete feasibility studies on water resource availability and desalination to support green H2 production	DWS	Water Research Commission (WRC)	RDI: Centre of Excellence on techno-economic analysis on the cost of GH2 in South Africa	<ul style="list-style-type: none"> Feasibility study completed
16. Complete feasibility studies on new H2 corridors and valleys in South Africa to support the scale-up of demand	DTIC with DMRE		GESI: Consider GESI in hydrogen valleys and corridors	<ul style="list-style-type: none"> Feasibility study completed Number of hydrogen valleys and corridors identified
17. Revise the NDCs taking into account GH2 to support a net-zero carbon economy especially in hard-to-abate sectors	DFFE with DTIC		GESI: Consider GESI in revising the NDCs	<ul style="list-style-type: none"> NDCs revised
18. Call for proposals on improving the cost and efficiency of hydrogen solutions	DSI with SANEDI		GESI: Consider GESI in reviewing of submitted proposals RDI: Research on improving cost and efficiency of hydrogen technologies	<ul style="list-style-type: none"> Number of proposals approved
2025-2030 Grey, blue, green				
19. Pilot CCU on a national scale	DSI with DMRE	DPE, SOEs	GESI: Consider participation of women and youth in technology demonstration RDI: Research on supporting technology demonstration	<ul style="list-style-type: none"> Pilot demonstration completed
20. Develop a grey H2 phase-out plan if green H2 reaches parity with grey H2	DMRE	private sector	GESI: Consider GESI in phase-out plan RDI: Research on reducing the cost of GH2	<ul style="list-style-type: none"> Grey H2 phase-out plan developed



5. CATALYTIC PROJECTS: INDUSTRIAL CLUSTERS AND DEMONSTRATION ZONES

To kick-start the development of a hydrogen society in South Africa, a number of catalytic projects have been identified. Four of these are discussed here: the Hydrogen Valley or Platinum Valley Initiative, CoalCO₂-X project, Boegoebaai SEZ and the Sustainable Aviation Fuels Project.



5.1 THE PLATINUM VALLEY INITIATIVE – SOUTH AFRICA’S HYDROGEN VALLEY

So-called “hydrogen valleys” have been successfully implemented in other countries to promote the scale up of clean, emerging technologies and reduce emissions.⁶⁶ Figure 5.1 illustrates the broader concept of a Hydrogen Valley

and the associated benefits that it offers to kick-starting the development of hydrogen projects.

DEVELOPING A HYDROGEN VALLEY THROUGH A HUB-BASED APPROACH: BENEFITS

FUTURE-PROOFING INVESTMENTS

In a hub-based analysis, a techno-economic assessment of the viability of the community is conducted, taking into account future evolutions of technology costs and regulations as well as the actual demand from players already existing in the Valley. The techno-economic assessment acts as a business viability assessment to ensure that hydrogen projects are viable in the hub.



ENSURING LONG-TERM COMMITMENT ACROSS STAKEHOLDERS

Working at a hub-level allows for dialogue with possible project sponsors and off-takers, establishing a shared vision for the community with hub members. A long-term commitment also allows for investments in skills development within the community and sets a foundation for developing local supply chains and unlocking enabling policy frameworks.



DE-RISKING INVESTMENTS

The hub-based approach could help in de-risking investments by identifying a diversified set of off-takers in the hub across many sectors. De-risking could also be enabled through shared infrastructure investments between off-takers and producers.



BUILDING ON EXISTING FUNDING OPPORTUNITIES

Several opportunities exist for hydrogen development in South Africa, especially from international donors. Organising communities into hubs with a clear business case for the development of hydrogen projects, creates a framework for applying for project funding and strengthens applications through proven viable projects.



Figure 5.1: The Hydrogen Valley concept and benefits

66. “First details on South Africa’s new platinum industrial zone – stretching from Limpopo to KZN”, *BusinessTech*, 19 October 2020, businesstech.co.za/news/energy/441802/first-details-on-south-africas-new-platinum-industrial-zone-stretching-from-limpopo-to-kzn/.

5. CATALYTIC PROJECTS: INDUSTRIAL CLUSTERS AND DEMONSTRATION ZONES (CONTINUED)

The development of such a valley in South Africa presents a significant opportunity for sustainable economic and social development, including job creation and GHG emissions reductions.

To realise this intervention by 2030, South Africa's platinum production will be leveraged to kick-start the hydrogen economy. This could lead to cost savings through shared infrastructure investments, improving the cost competitiveness of hydrogen production through economies of scale, enabling a rapid ramp-up of production within a given territory, socioeconomic development, and the creation of an incubator for new hydrogen pilot projects.⁶⁷

The DSI has partnered with SANEDI, Anglo-American Platinum, Bambili Energy and ENGIE on the Hydrogen Valley Feasibility Study focused on developing catalytic green hydrogen hubs. These hubs will form South Africa's hydrogen valley, through the Platinum Valley Initiative (PVI). These hubs have

been identified based on their potential for a high concentration of future hydrogen demand, their capacity to produce hydrogen (through access to sun, wind and water infrastructure), and their potential contribution to a just transition – an economic development plan that brings positive social impact, particularly to more vulnerable communities.⁶⁸ The hubs (Figures 5.2a and 5.2b) – in Johannesburg, Durban/Richards Bay and Mogalakwena/Limpopo – will host 16 pilot projects and contribute to launching the hydrogen economy in the hydrogen valley.

The PVI will establish a "Hydrogen Corridor" from Limpopo, through Johannesburg to Durban as a strategic intervention that will assist in opening the status quo (heavy-duty diesel trucks) to a technological niche (heavy-duty fuel-cell trucks), while supporting the upscaling of hydrogen consumption in the transport sector.

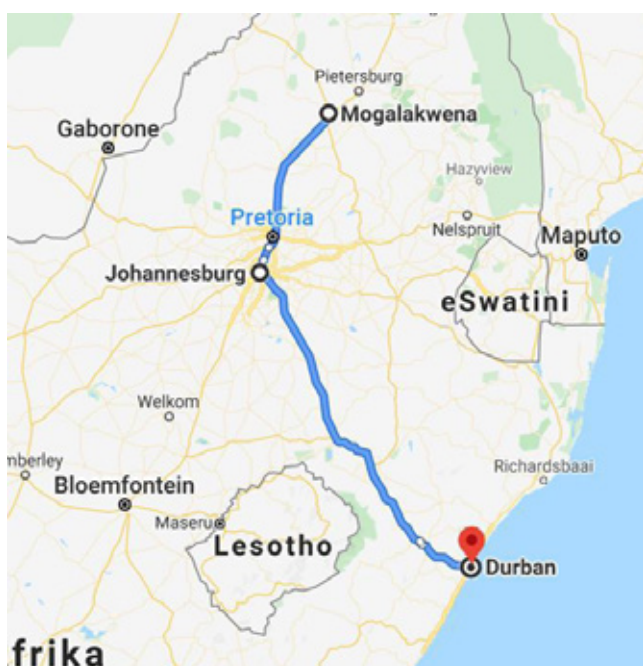


Figure 5.2(a): Geographical representation of the Platinum Valley
Source: Hydrogen Valley Report, October 2021

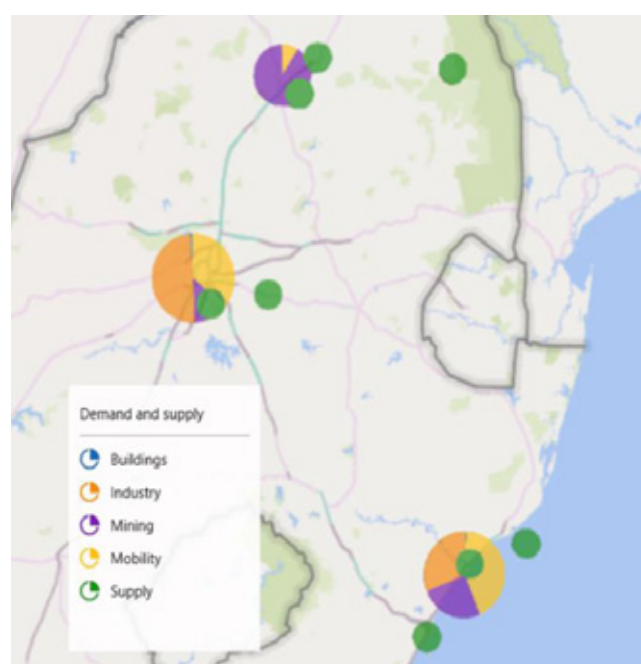


Figure 5.2(b): Indicative hydrogen demand sectors in the hubs

67. Department of Science and Innovation, South Africa Hydrogen Valley Final Report, October 2021. https://www.dst.gov.za/images/2021/Hydrogen_Valley_Feasibility_Study_Report_Final_Version.pdf.

68. *Ibid.*

5. CATALYTIC PROJECTS: INDUSTRIAL CLUSTERS AND DEMONSTRATION ZONES (CONTINUED)



As part of the first phase of the PVI implementation, the DSI commissioned a study aimed at driving the planning, designing, construction and commissioning of projects related to the development of hydrogen-related technologies in the PVI.⁶⁹

The study identified three key areas, spanning the industrial, mobility and building sector, forming the backbone of the PVI as follows:

- **Johannesburg:** The industrial and building hub will drive the switch from grey hydrogen to green hydrogen. Green hydrogen will substitute grey hydrogen in the production of ethylene and fuel, act as catalyst during iron and steel production, and be the fuel for diamond-mining trucks. There is also great potential for it to be used in stationary power in buildings, and in public transport.
- **Durban/Richards Bay:** The mobility sector will drive the switch from grey hydrogen to green hydrogen as the fuel used by heavy- and medium-duty trucks on the N3 freight corridor. Green hydrogen will be used as fuel for port activities, including handling equipment and electricity, oil refining, and medium-grade heating.
- **Mogalakwena/Limpopo:** The mining sector will switch to green hydrogen for mining-truck fuel.

The implementation of the PVI project is expected to have the following significant positive impacts for South Africa:

- By 2030, the PVI is expected to lead to cost savings through shared infrastructure investment, improve the cost competitiveness of hydrogen production through economies of scale and be used as an incubator for new pilot projects.
- The hydrogen demand in these hubs could increase by 80%, to 185 000 tonnes of hydrogen by 2030.
- The levelised cost of green hydrogen is expected to be approximately USD4 per kg H₂ across hubs. While this is still more expensive than grey hydrogen, trends have shown that, with the continued adoption of green hydrogen, this cost gap is likely to decrease.

- The PVI has a strong potential to contribute to a just transition, and could potentially add USD3.9-8.8 billion to South Africa's GDP (including indirect contributions) by 2050, while also creating 14 000 to 30 000 jobs per year.

Promising pilot projects in the industrial (ammonia, chemicals), mobility (mining trucks, buses) and buildings (fuel-cell power) sectors have been identified as key next steps to kick-start the implementation of the PVI.⁷⁰ In the industrial sector, many pilot projects earmarked for the PVI are:

- Sasol has committed to developing ethylene and ammonia from green hydrogen.
- Green steel is a national priority, and there could be an opportunity to pilot green steel production with Arcelor Mittal at one of its sites near Johannesburg.
- The government is interested in reducing emissions in the paper and pulp sector, presenting an opportunity for Durban-based paper mills to switch from natural gas fuel to hydrogen.
- The mobility sector has a number of potential opportunities, including deployment of mining trucks and heavy-duty trucks along the N3 corridor. There are mobility applications using fuel cells in the Durban and Richards Bay port environment (such as in forklifts), in public buses in metropolises and in berthing activities in the port of Durban. Marine bunkering for ammonia may be deployed in the longer term; hydrogen in the maritime sector is a strategic priority, though not yet cost competitive. There is also potential for a fuel-cell train between Durban and Richards Bay, once the technology is further developed.
- In the building sector, there are plans to install fuel cells for power in the Limpopo Science and Technology Park, as well as in the Anglo American corporate office buildings in Rustenburg. Other pilot opportunities might be identified in public office buildings in metropolises, and in buildings at OR Tambo and King Shaka airports.
- Finally, data centres, corporate headquarters and private office buildings see rising interest in hydrogen fuel cells for stationary power, with potential for rapidly growing demand in the near future.

69. Ibid.

70. Ibid.

5. CATALYTIC PROJECTS: INDUSTRIAL CLUSTERS AND DEMONSTRATION ZONES (CONTINUED)

5.2 COALCO₂-X PROJECT

South Africa is the world's 14th largest emitter of GHGs, particularly CO₂ emissions due to its heavy reliance on coal. South Africa's commitment to the PA on climate change requires collaboration between government and business to achieve its stated carbon reduction goals. In this regard, the CoalCO₂-X Project (Figure 5-3) aims to use green hydrogen and pollutants (CO₂, SOx, NOx, etc.) contained in the flue gas from coal-fired boilers to

make value-added products that can support the transition to a decarbonised energy system and assist the country to meet its emission reduction goals while also ensuring a just energy transition. In addition, such an initiative would provide a platform to scale up the domestic demand for hydrogen and create capabilities for the export market. To date, the DSI has provided ZAR50 million to kick-start the CoalCO₂-X RDI Project.

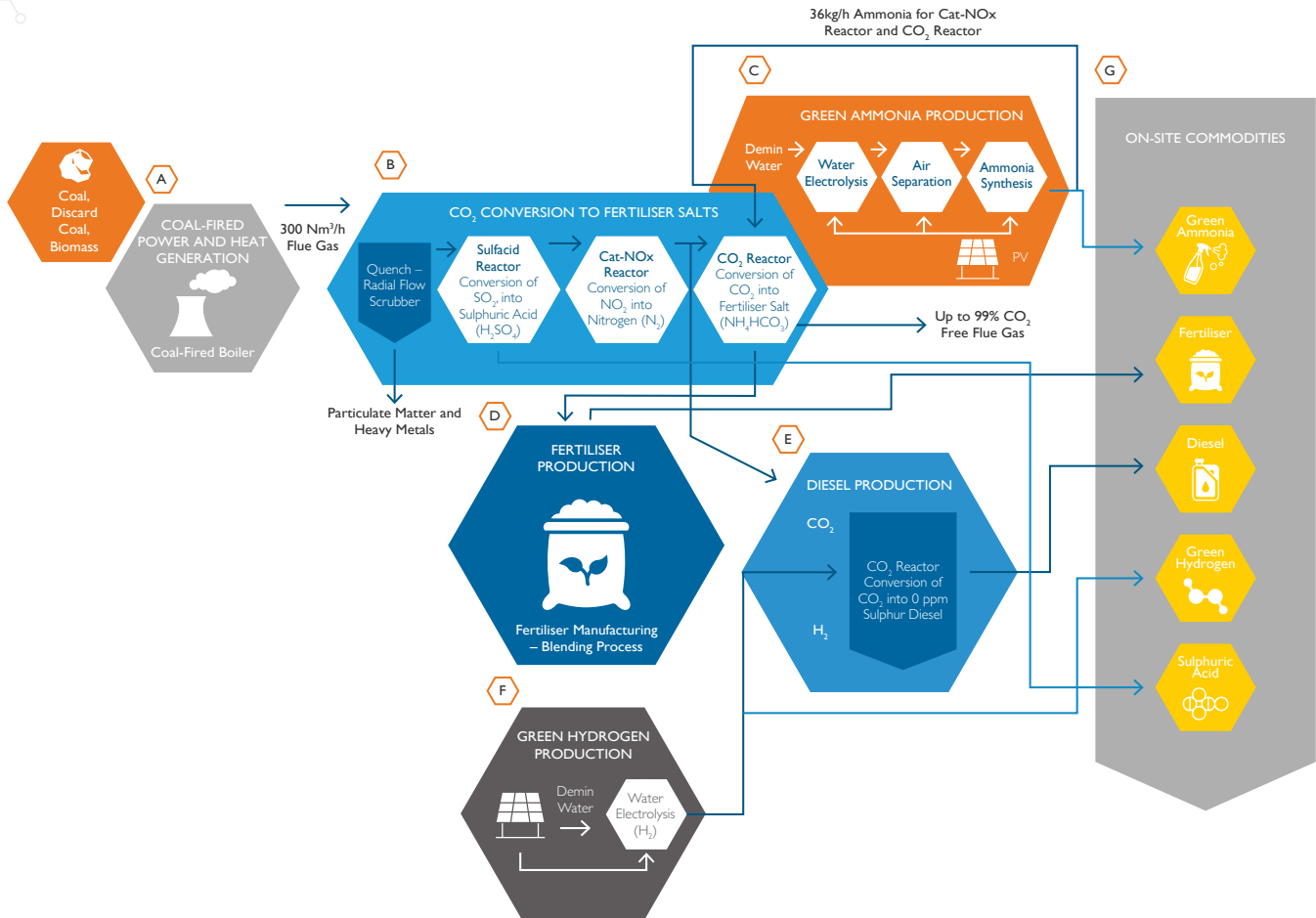
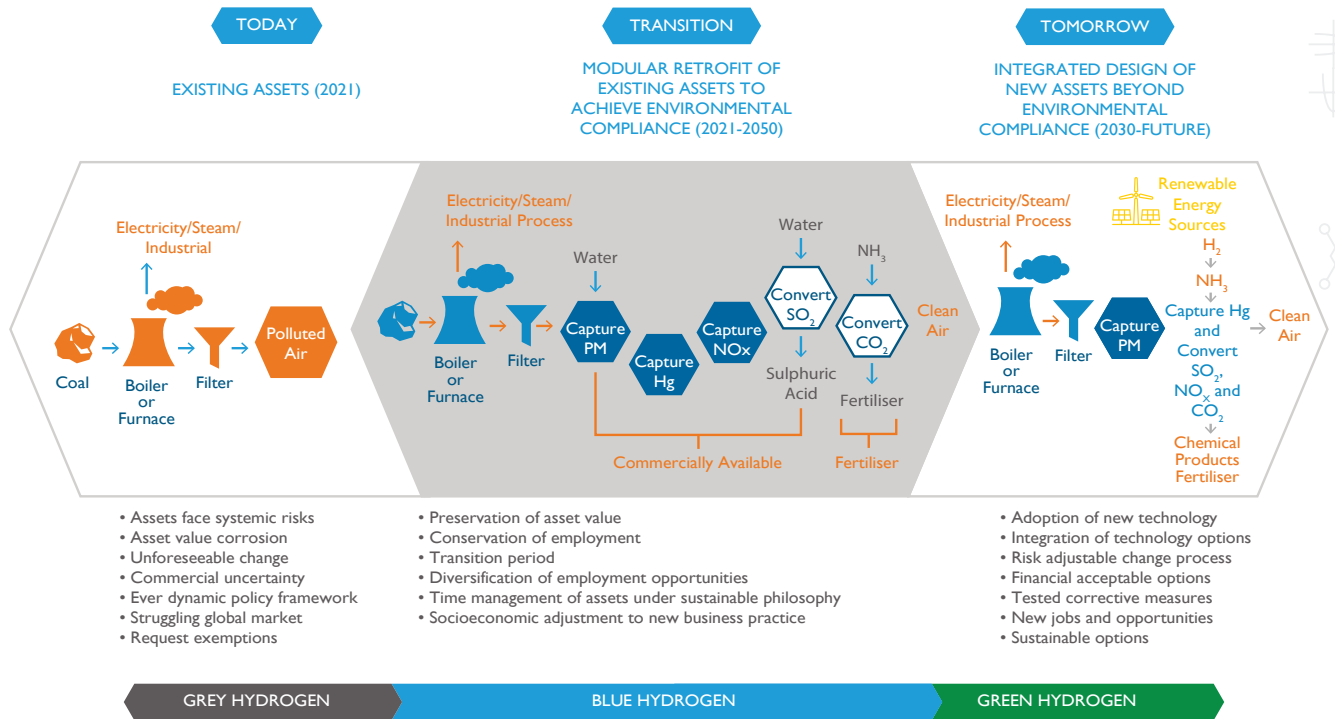


Figure 5.3: Flue gas conversion into value-added green products

5. CATALYTIC PROJECTS: INDUSTRIAL CLUSTERS AND DEMONSTRATION ZONES (CONTINUED)



- Assets face systemic risks
- Asset value corrosion
- Unforeseeable change
- Commercial uncertainty
- Ever dynamic policy framework
- Struggling global market
- Request exemptions

- Preservation of asset value
- Conservation of employment
- Transition period
- Diversification of employment opportunities
- Time management of assets under sustainable philosophy
- Socioeconomic adjustment to new business practice

- Adoption of new technology
- Integration of technology options
- Risk adjustable change process
- Financial acceptable options
- Tested corrective measures
- New jobs and opportunities
- Sustainable options

Figure 5.4: The CoalCO₂-X Project and its role in the Just Transition

Figure 5.4 shows how innovative carbon capture and utilisation technologies combined with green hydrogen and green ammonia can be an integral part of South Africa's just energy transition.

In terms of addressing the needs at societal, economic and individual levels, the CoalCO₂-X programme has been structured to consider the beneficial impact for society.

The programme incorporates and leverages the advantages of the triple helix linkages through which the needs-based CoalCO₂-X technology innovation will deliver value-added impact.

Acting as a technology enabler, the CoalCO₂-X programme is leveraging outputs from higher education and research institutions in South Africa and Europe, including research papers and patents, technology, qualified people and expertise, see Figure 5.5. The programme is positioned to assist government policy and strategy by supplying technologies that will enable or enhance the delivery of government services to individuals and businesses.

5. CATALYTIC PROJECTS: INDUSTRIAL CLUSTERS AND DEMONSTRATION ZONES (CONTINUED)

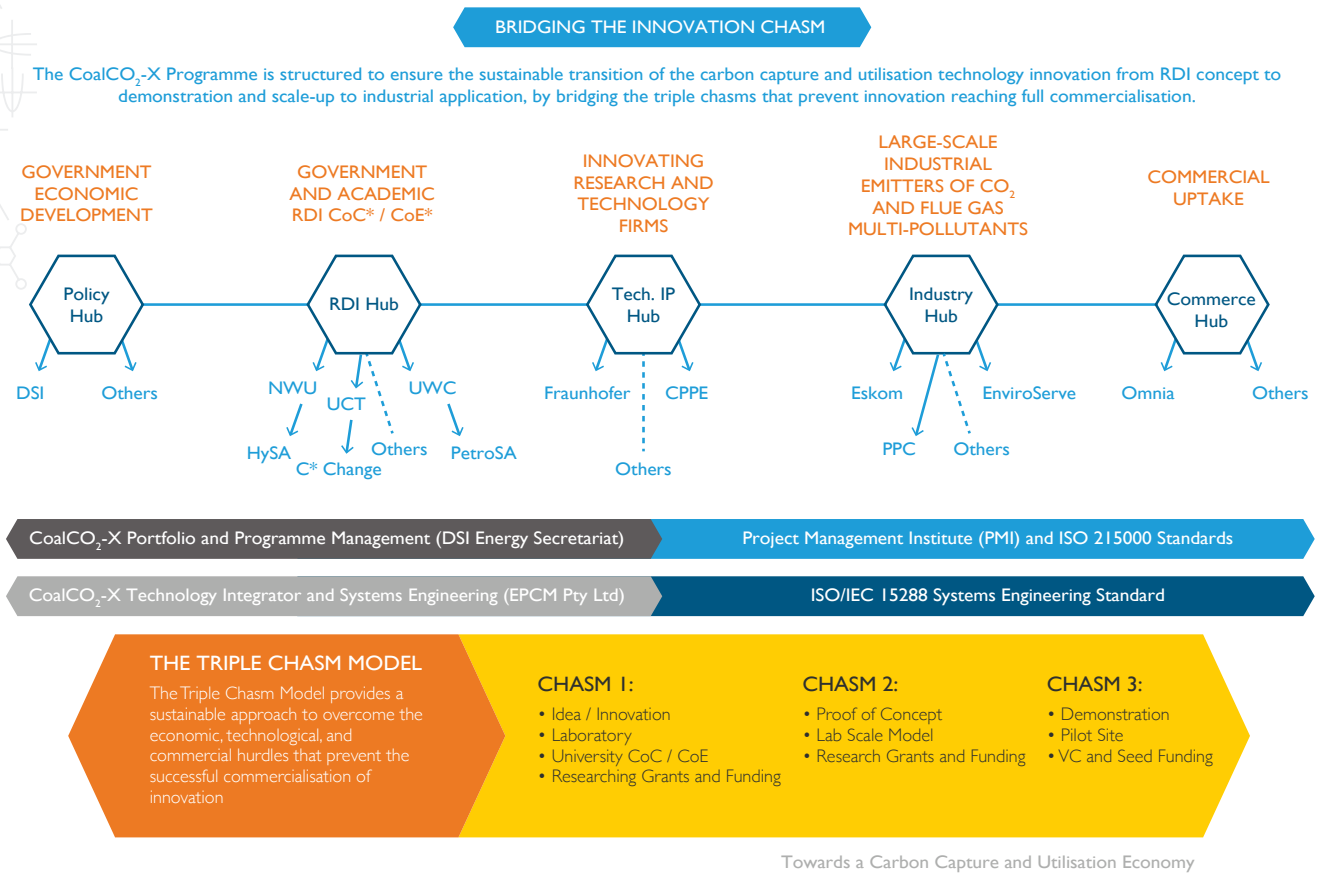


Figure 5.5: Schematic diagram showing the CoalCO₂-X programme Research, Development and Innovation (RDI) hubs

Figure 5.5 illustrates how RDI CoalCO₂-X programme hubs give access to a network of expertise to help and support the expansion of the programme through gaining access to a trusted network of investors, mentors, funders, technical experts and research partners with the know-how needed to help build a better ecosystem. Each hub is expected to have a niche area chair or research-focused areas, and these hubs will connect to each other through collaboration.

The short-, medium- and long-term opportunities for the programme are indicated in Figure 5.6. The near-term achievable commodities are sulphuric acid and fertiliser production for 2020 to 2024 while the longer-term opportunities are to export these commodities in the subsequent five years from 2024.

5. CATALYTIC PROJECTS: INDUSTRIAL CLUSTERS AND DEMONSTRATION ZONES (CONTINUED)

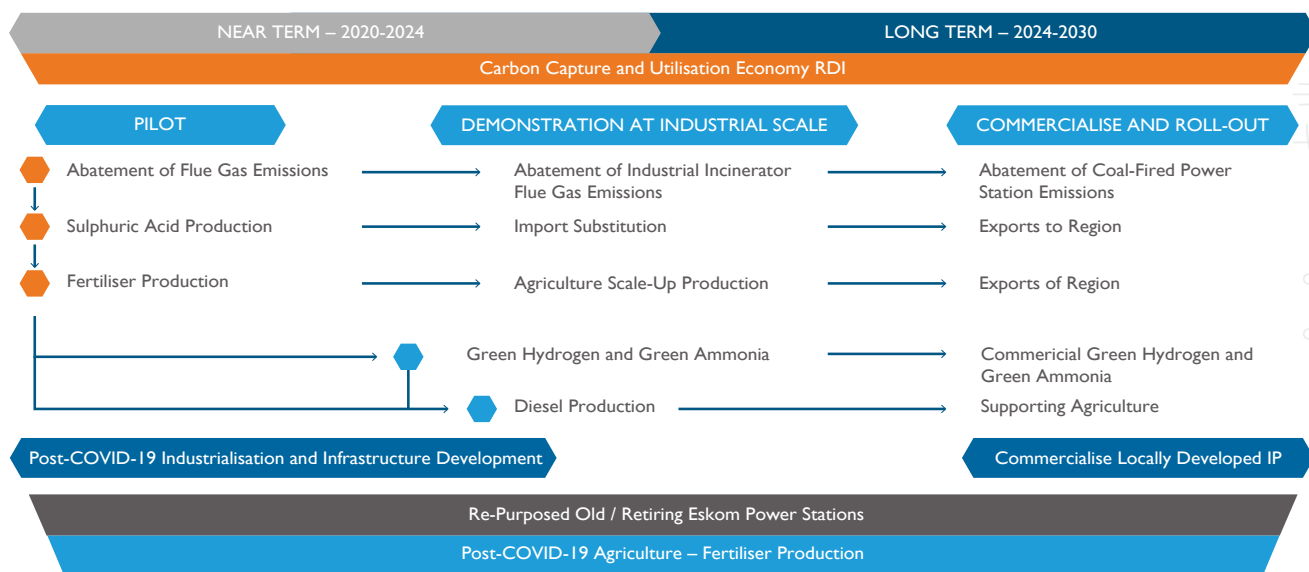


Figure 5.6: Schematic diagram showing near- and long-term opportunities of the CoalCO₂-X programme

5.3 BOEGOEBAAI: A GLOBAL HUB FOR FUTURE FUEL

With a global move towards lowering carbon emissions, hydrogen, which only emits water vapour at the point of use, is often considered the green “fuel of the future”. However, large-scale use of hydrogen has been hampered by the need to burn fossil fuels in its production.

Lowering the carbon footprint of the hydrogen production process, and establishing a fully developed green-hydrogen economy in South Africa, will result in significant benefits, from national GHG emissions abatement to a range of socioeconomic benefits.

Working towards this goal, the South African government has designated Boegoebaai, a port on the Northern Cape coast, as a Strategic Integrated Project (SIP) in the South African NDP. Sasol has committed to leading this project, with the aim of ascertaining whether a global export hub for green hydrogen and ammonia is feasible at Boegoebaai.⁷¹

Boegoebaai is located in the Namakwa SEZ and already has an established hydrogen production plant. The existing plant, the project's strategic location and its classification as an SIP are key elements of its potential as a site for the project. The development will occupy 60 000 hectares of well-irradiated land adjacent to the SEZ plant. Enhancements entail constructing green hydrogen and green ammonia production sites. The facility would also support a 30 GW solar and wind farm – six times South Africa's current installed RE capacity – and 5 GW of electrolysis.⁷²

The feasibility study should take 24 months, from June 2021. However, as this study unfolds, it is becoming clearer that the overall business case needs strengthening through further project preparation.

As the lead project integrator, Sasol will bring together strategic partners along the value chain, along with other roleplayers, to drive industrialisation of the Northern Cape and South Africa as a whole. These include potential customers, funders, investors, technology suppliers and South African green-energy providers.⁷³ Sasol's deep expertise in FT technology will be deployed at the facility. The FT process synthesises carbon monoxide and hydrogen into gas, which is converted to longer-chain hydrocarbons to produce green fuels.

The structure will consist of seven key facilities:⁷⁴

1. **Electrolyser park:** A range of anchor investors with appropriate electrolyser technologies will bid for inclusion, and the successful bidder will construct facilities at the port.
2. **Desalination plant:** The production of green hydrogen requires significant amounts of water. Given the water-scarce nature of the Northern Cape, this will most likely require the desalination of sea water.
3. **Green ammonia production plant:** This would house the additional infrastructure and facilities required to produce green ammonia as a renewable fuel, linked to the green hydrogen production process.
4. **Storage facility:** A bespoke liquid-storage facility for both green hydrogen and green ammonia, will offer tailored loading capacity for export vessels carrying the liquid volumes, and fuelling capability for vessels transitioning to green ammonia as a fuel.
5. **Solar, wind and battery park:** This will upscale the generation of renewables (specifically wind and solar), ensuring 100% RE for the green hydrogen and green ammonia produced. Potential also exists to produce manganese-based precursor materials for the production of lithium-ion batteries, leveraging on the manganese mines located in the Northern Cape.
6. **Supplier park for key common components:** Suppliers to anchor investors can be accommodated in a dedicated, efficient configuration for flowthrough purposes.
7. **Gigafactory:** This will be a dedicated, advanced manufacturing site to ramp up production of electrolysers, leveraging on locally produced intellectual property and expertise.

Sasol has partnered with both national and local government to finalise the location and development of the Boegoebaai facility, signing a memorandum of agreement with the Gauteng Provincial Government and the Northern Cape Economic Development, Trade and Promotion Agency.

As of June 2021, joint funding for the feasibility study had been secured from Sasol and the Industrial Development Corporation (IDC), with the hope that more private- and public-sector investment in the future will be leveraged.⁷⁵

5. CATALYTIC PROJECTS: INDUSTRIAL CLUSTERS AND DEMONSTRATION ZONES (CONTINUED)

The feasibility study is expected to be completed in 2022. In the meantime, the Northern Cape is considering the following commitments to position itself as a production and distribution hub servicing the export market:⁷⁶

- Mobilising and supporting investment to ensure 10 GW of electrolyser capacity is under construction at the Boegoebaai SEZ by 2025-2026, and fully deployed by 2030;
- Packaging 240 000 hectares of well-irradiated, well-positioned, community-owned land to be deployed for RE use to support the electrolyser power supply;
- Consolidating the supply generated across the Northern Cape solar belt for export via a network anchored at the Boegoebaai SEZ;
- Partnering with the private sector to build a green hydrogen pipeline system, connecting projects across the Northern Cape solar belt into Boegoebaai SEZ by 2030; and
- Partnering with Transnet and the private sector to deploy dedicated, specialist rail infrastructure linking green hydrogen producers to both Boegoebaai and to the wider national port system by 2030.

There are significant socioeconomic benefits to a project of this magnitude. In addition to infrastructure investment and skills development, Boegoebaai has the potential to provide a significant number of long-term, sustainable jobs: an estimated 6 000 direct jobs will be created, as well as further indirect employment across the ecosystem.⁷⁷

The development also has the potential to create up to 400 000 tonnes of green hydrogen each year. It will require 9 GW of RE to do so – about 20% of South Africa’s current installed capacity. However, the installation of the 30 GW wind farm should help the project reach this target.⁷⁸

One of the most important outcomes will be to allow South Africa to produce clean hydrogen for mass export, without the need to burn unsustainable hydrocarbons. This would position the country as a global leader in the green-hydrogen economy, with immense opportunities to benefit financially and environmentally. The project would also contribute to a “just transition” for the country.⁷⁹

Figure 5.7: Illustrates the synergies between the Boegoebaai project and the CoalCO₂-X project.

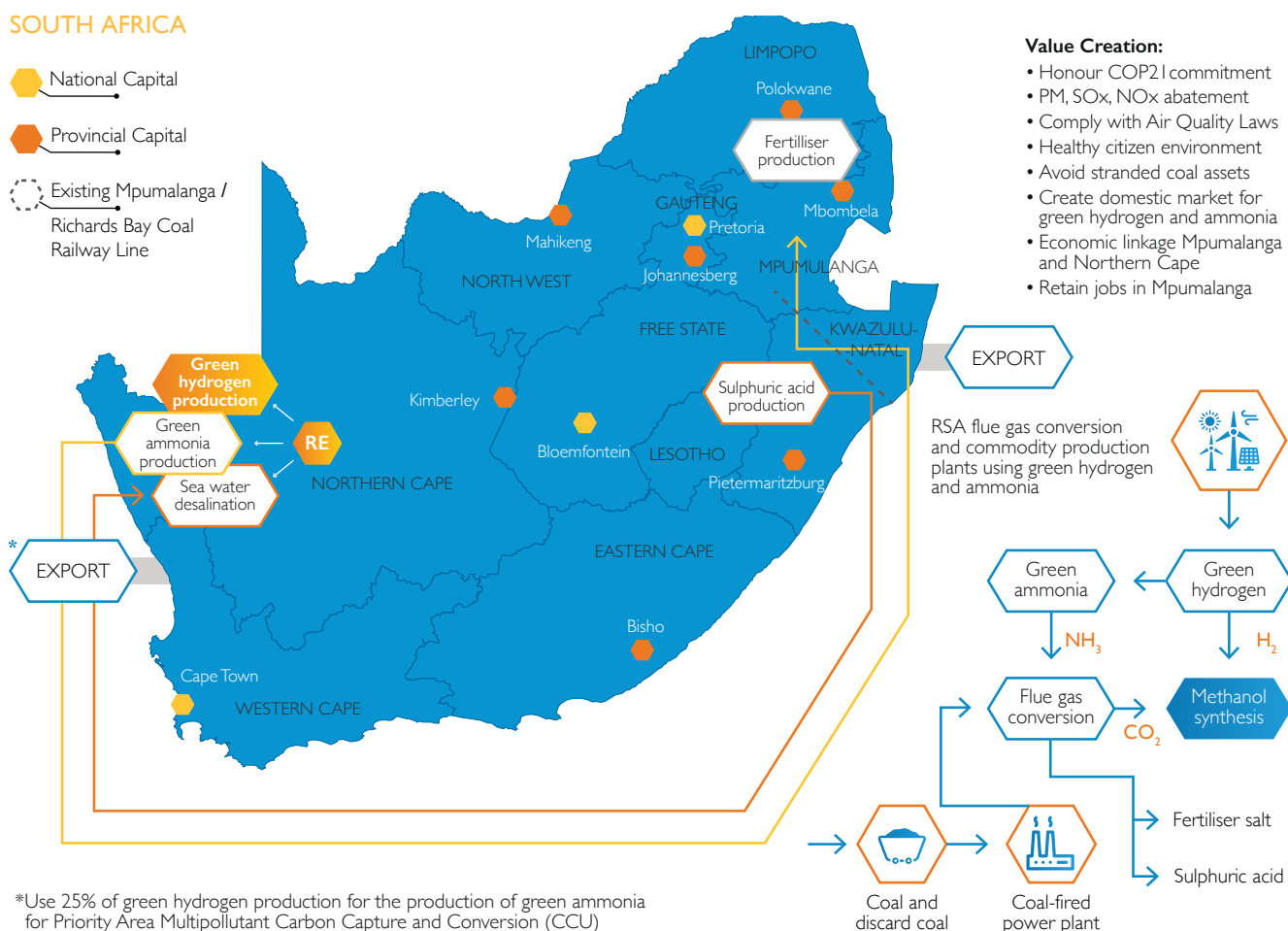


Figure 5.7: Synergies between the Boegoebaai and CoalCO₂-X programmes

71. 'Sasol takes lead role in feasibility study for Boegoebaai green hydrogen project', Engineering News, 6 October 2021, engineeringnews.co.za.
 72. Presidency presentation to Champions: Investment & infrastructure office/infrastructure green hydrogen (H2) South Africa.
 73. Ibid.
 74. Ibid.
 75. 'Sasol announces lead role in feasibility study for the Boegoebaai green hydrogen project', Sasol, 6 October 2021, sasol.com/media-centre/media-releases/sasol-announces-lead-role-feasibility-study-boegoebaai-green-hydrogen.
 76. Ibid.
 77. Ibid.
 78. 'South Africa's Sasol firm plans for large hydrogen plant', Construction Review Online, 8 October 2021, constructionreviewonline.com/news/south-africas-sasol-firm-plans-for-large-hydrogen-plant/; 'Sasol looking at massive Green Hydrogen project in South Africa – creating 6 000 new jobs', Businesstech, 7 October 2021, businesstech.co.za/news/energy/527194/sasol-looking-at-massive-green-hydrogen-project-in-south-africa-creating-6000-new-jobs/.
 79. Ed Reed, 'Sasol signs up green hydrogen study in northwest', Energy Voice, 6 October 2021, energyvoice.com/renewables-energy-transition/hydrogen/africa-hydrogen/354588/sasol-study-hydrogen-boegoebaai/; See the Just Transition Centre, ituc-csi.org/just-transition-centre.

5.4 SUSTAINABLE AVIATION FUELS PROJECT

Globally, aviation is viewed as one of the most challenging areas in which to reduce GHG emissions.⁸⁰ In South Africa, the implementation of SAF, low-carbon alternatives to conventional aviation fuels, is key to decarbonising the sector.

Potential feedstock for SAF production includes biomass crops and wastes, residues and end-of-life products. Benefits of SAF include GHG emission reductions, improved local air quality, improved fuel efficiency, increased energy security, reduction in exposure to the volatility of jet-fuel supply and price, recovery of value from wastes (where used) and socioeconomic development through new investments and job creation. The latter is realised particularly in rural areas, where biomass is farmed for feedstock.⁸¹

However, while the benefits of SAF have been proven, three major challenges to its implementation and usage remain:

- The production of feedstock needs to be upscaled to reach the levels required for production of SAF;
- No policy framework has been implemented. Policy regulations should elevate aviation biofuels as a priority, as is happening in the automotive sector; and
- SAF is still seen as an expensive niche product. This will only change if demand is stimulated, allowing the fuel to become more affordable for airlines.⁸²

To help overcome these challenges, on 14 April 2021, the South African government announced a feasibility study into the upscaling of SAF, utilising Sasol's world-leading FT technology.⁸³ Sasol has partnered with Linde PLC, ENERTRAG AG and Navitas Holdings (Pty) Ltd to form the LEN Consortium, with each company leveraging their strengths to rapidly increase the production of SAF. The consortium aims to bid for the production of SAF under Germany's H2Global platform, using a double-auction mechanism. Through licensing and operations, Sasol and the newly formed consortium are exploring SAF production at the Secunda Synfuels plant in Mpumalanga.

The feasibility study is likely to determine the availability of biomass for feedstock, its cultivation and integration into Secunda's operation, and arrangements to meet the final H2Global mandatory requirements.⁸⁴ This study also aims to present policymakers with strategic opportunities to decarbonise the aviation sector, and to enable the travel and tourism sectors to meet the changing profile of international, and increasingly domestic, travellers – all while seizing the industrialisation opportunity in this emerging green sector.

The LEN Consortium hopes to lower production cost by leveraging Sasol's existing facilities, deep technical knowledge of the FT process, and downstream processing capabilities. The FT process synthesises carbon monoxide and hydrogen into gas, which is converted to longer-chain hydrocarbons for the production of SAF. An important requirement for SAF production is Sasol's proprietary technology, the Power to Liquid (PTL) process. PTL uses the newly synthesised, sustainable carbon feedstock and the production of green hydrogen through electrolysis.

While SAF has been used before and was found to be as efficient an energy source as conventional aviation fuel for commercial flights, its deployment was limited to demonstration or sponsored commercial flights due to the cost.

South African Airways and its subsidiary, Mango, made history in 2016 as the first two airlines in Africa to operate commercial flights powered by SAF, produced from a nicotine-free tobacco plant. The trial demonstrated that it

is possible to use a locally produced feedstock to manufacture bio-jet fuel for commercial aviation. While these flights are an excellent example of both the performance and potential of SAF, until this technology can be incorporated into an airline's "business as usual" plans, the potential for CO₂ reductions from SAF will not be realised.

A study conducted by the International Air Transport Association, showed that a 4.5% SAF penetration into South Africa's current fuel market will contribute to energy security and socioeconomic development, and drive policy implementation. This project could create 55 000 jobs in rural farming, and contribute to economic growth that will see ZAR2 billion (USD180 million) per annum added to the GDP.⁸⁵

Developing a domestic SAF industry also presents South Africa with an opportunity to realise at least five strategic goals:

- Proactive preparation for the international aviation emission mitigation framework under the Carbon Offset Reduction Scheme for International Aviation, which becomes mandatory from 2027;
- Allowing SAF to become a mitigation option available to domestic airlines under South Africa's Carbon Tax Bill;
- Safeguarding South Africa's global connectivity in an increasingly carbon-constrained world;
- Enabling continued growth of the travel and tourism sector and its contribution to economic development by giving the country an edge over other aviation hubs; and
- Leveraging the country's comparative advantages to become a competitive SAF producer – an industrialisation opportunity.

In the LEN Consortium, each company will leverage their strengths to rapidly increase the production of feedstock for SAF:

- Linde PLC will provide access to electrolysis technology via their partnership with ITM to produce the green hydrogen needed for SAF;
- ENERTRAG AG, a German RE company with a strong presence in South Africa, owns close to 1 GW generation capacity and operates more than 6 GW of renewable assets – allowing for the ramp-up of carbon- biomass feedstock needed for SAF production; and
- Navitas Holdings (Pty) Ltd is a South African development, construction and investment company with a strong focus on solar photovoltaic technology and sectors related to the just energy transition,

With the feasibility study underway, next steps and outcomes from the study will only become clear towards the end of 2021. However, Sasol and the LEN Consortium are jointly engaging with the German government to inform the H2Global platform of their intention to bid via the double-auction mechanism. The H2Global carbon auction rounds are expected to launch towards the end of 2021, with the conclusion of the feasibility study. Once SAF production at the Secunda Synfuels plant has been determined as feasible, the obvious next step is engagement between policymakers and the commercial aviation industry. Policy implementation could help realise SAF as an inexpensive, viable product to encourage demand – enabling SAF to become affordable for airlines.⁸⁶

80. 'Sasol to explore potential of cleaner aviation fuels with world class partners', Sasol, April 2021. [sasol.com/media-centre/media-releases/sasol-explore-potential-cleaner-aviation-fuels-world-class-partners](https://www.sasol.com/media-centre/media-releases/sasol-explore-potential-cleaner-aviation-fuels-world-class-partners).

81. 'WP4 Policy brief: Policy support options for promoting Sustainable Aviation Fuels (SAF) in South Africa', WastetoWing, February 2020. dnac4dfluyw8.cloudfront.net/downloads/200228_w2w_wp4_saf_policy_brief_final.pdf.

82. IATA Sustainable Aviation Fuel Roadmap, IATA, 2015. [iata.org/contentassets/d13875e9ed784f75bac90f000760e998/saf-r-1-2015.pdf](https://www.iata.org/contentassets/d13875e9ed784f75bac90f000760e998/saf-r-1-2015.pdf).

83. 'South Africa's Sasol forms consortium to produce sustainable aviation fuel', Reuters, April 14 2021. [reuters.com/world/africa/south-africa-sasol-forms-consortium-produce-sustainable-aviation-fuel-2021-04-14/](https://www.reuters.com/world/africa/south-africa-sasol-forms-consortium-produce-sustainable-aviation-fuel-2021-04-14/).

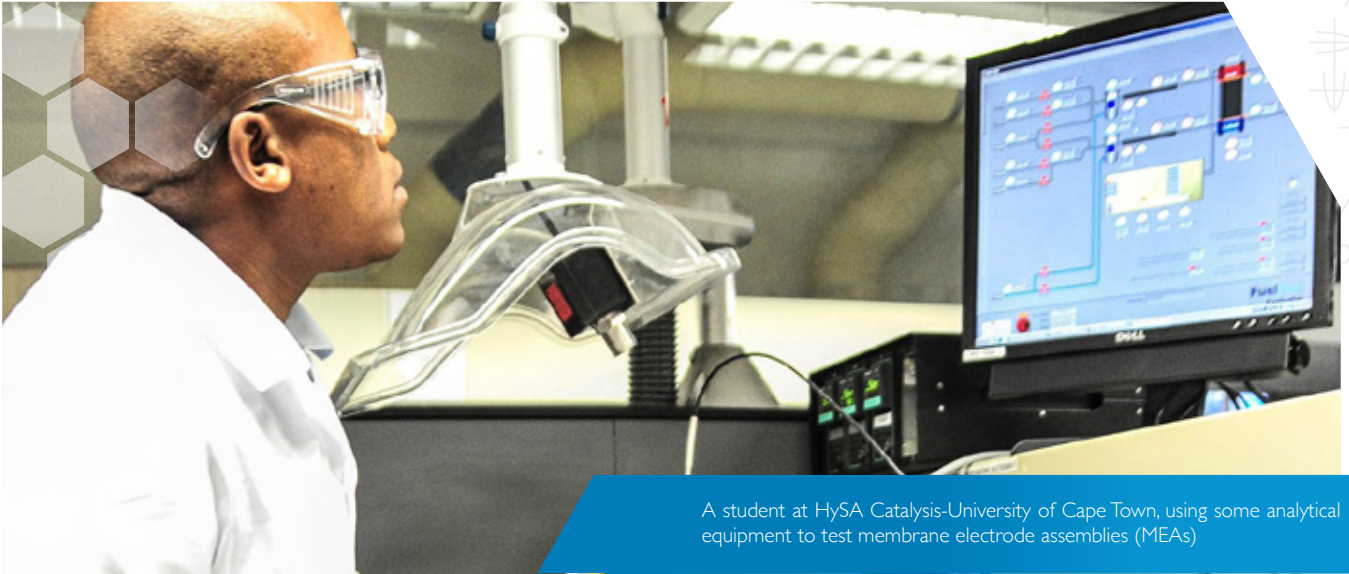
84. 'Sasol to explore potential of cleaner aviation fuels', 2021. <https://www.sasol.com/media-centre/media-releases/sasol-explore-potential-cleaner-aviation-fuels-world-class-partners>.

85. IATA Sustainable Aviation Fuel Roadmap, 2015. [iata.org/contentassets/d13875e9ed784f75bac90f000760e998/saf-r-1-2015.pdf](https://www.iata.org/contentassets/d13875e9ed784f75bac90f000760e998/saf-r-1-2015.pdf).

86. *Ibid.*



6. RESEARCH, DEVELOPMENT AND INNOVATION: THE KEY TO GROWTH OF THE HYDROGEN SOCIETY



A student at HySA Catalysis-University of Cape Town, using some analytical equipment to test membrane electrode assemblies (MEAs)

According to a discussion paper launched by the Mission Innovation and the Clean Hydrogen Mission⁸⁷ during COP26 in Glasgow, there has been a significant increase in hydrogen-related publications in the period 2010-2020 (Figure 6.1) as well as patent filing trends over the period 2010-2019 (Figure 6.2). Growth has been particularly rapid in hydrogen production, followed closely by publications on utilisation. Patent filing exhibits a relatively even distribution across the three areas. The increase in publications and patent filing is attributed to the increase in investments in hydrogen technologies

by both government and the private sector. The increase in investment and publications in hydrogen production technology is testimony to its potential impact on the overall cost competitiveness of hydrogen technology. Once this has been realised, it is expected that there will be a shift towards the storage and distribution as well as the utilisation technologies to further optimise costs along the hydrogen value chain.

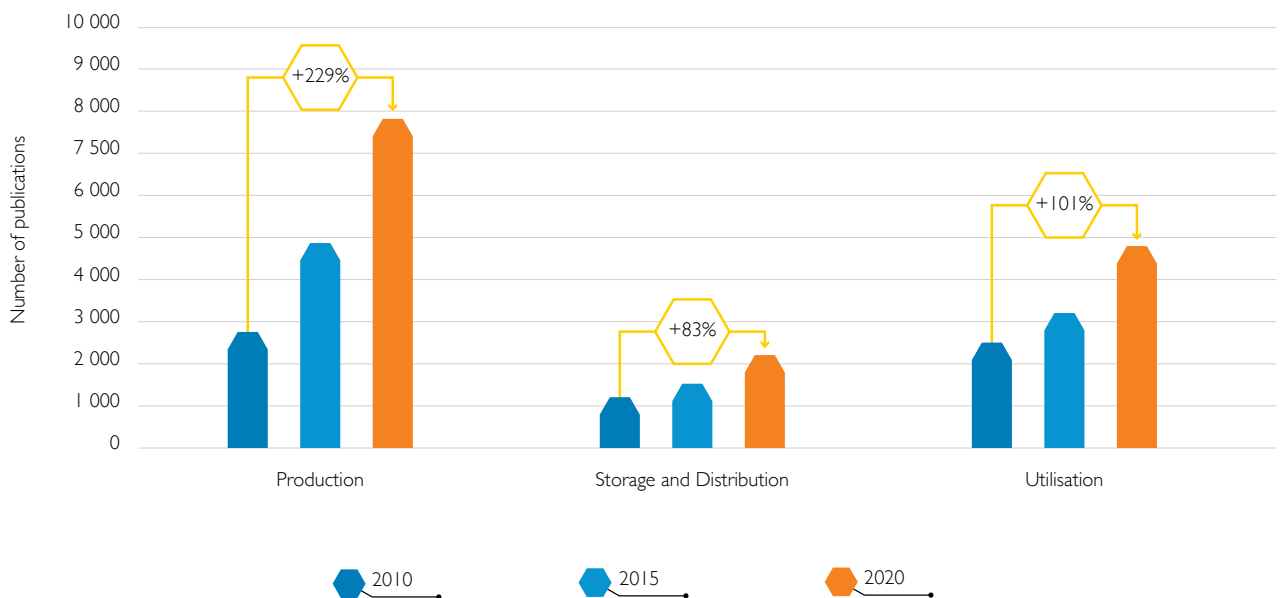


Figure 6.1: Global hydrogen publications output by supply chain area
Source: Mission Innovation Discussion Paper, November 2021

87. Mission Innovation Discussion Paper launched at COP26, November 2021.

6. RESEARCH, DEVELOPMENT AND INNOVATION: THE KEY TO GROWTH OF THE HYDROGEN SOCIETY (CONTINUED)

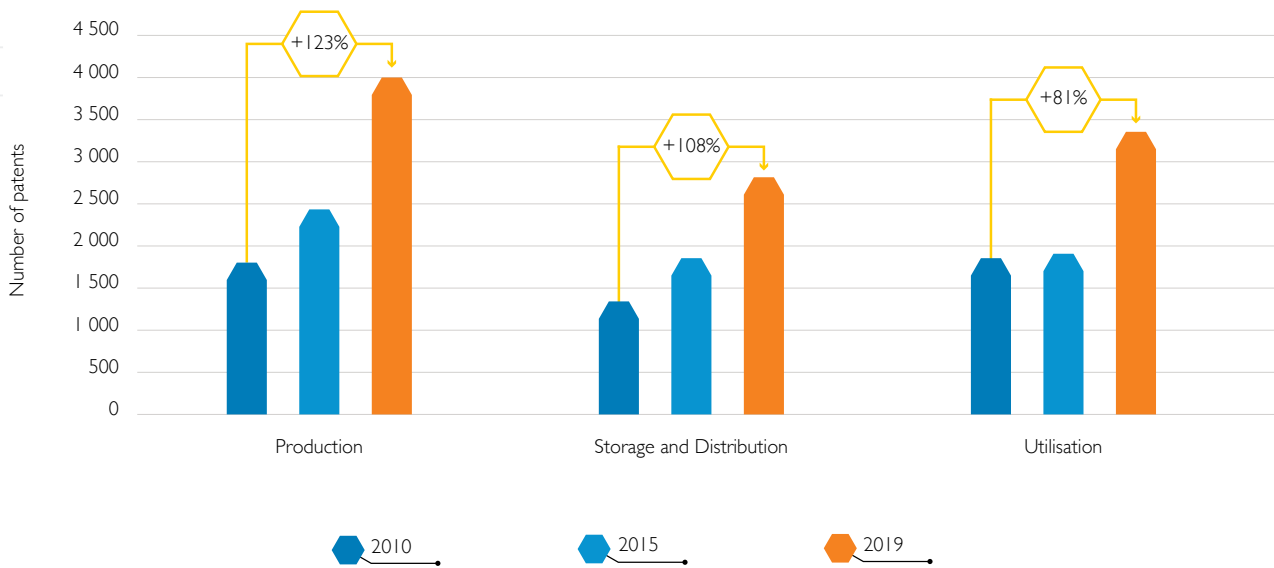


Figure 6.2: Global hydrogen technology patent filing over time
Source: Mission Innovation Discussion Paper; November 2021

The HSRM will support South Africa's vision of moving towards a just and inclusive net-zero carbon economy by 2050, which will require the country to embark on a just energy transition. Government has an important role to play in supporting the transition towards a low-carbon economy driven by innovation. Hence there is a need for scale, investment and collaboration as well as coordination of RDI efforts across industry, science councils and academia. To support the development of a sustainable hydrogen society in South Africa, it will be critical to build on the RDI achievements and technical expertise developed through the HySA Programme. In this regard, Cabinet on 14 September 2021 approved the continued support for the programme for an additional 10 years, beyond the initial 15-year period which ends on 31 March 2023. This will ensure a continuous pipeline of RDI outputs that contribute to the following tenets of the HSRM:

- The necessary human capital to conduct relevant hydrogen RDI;
- The creation of new knowledge, focused on improved material performance and cost reduction; and
- The physical infrastructure to optimally produce, distribute and utilise hydrogen to benefit South African communities and the environment.

Independent reviews conducted after every five years of implementation of the HySA Programme have validated the programme's contribution in creating local capabilities through good technical and knowledge-generation outputs, publications, students and patents. In some cases, international benchmark performance levels had been achieved, which bodes well for the commercialisation of technologies that are traditionally dominated by global value chains.

The development of the HSRM, as recommended by the 2019 independent review, overlaps with phase 3 of implementation of the HySA Programme, which focuses on commercialising locally developed technologies, contributing to international innovation and competing successfully on the world market of the catalysis value chain in hydrogen and fuel cells. The review highlighted the importance of establishing an overarching country plan or roadmap for HFCT to support the RDI and commercial efforts of the HySA Programme. Accordingly, the DSI initiated the development of the HSRM.

The implementation of the HSRM can therefore leverage the technology portfolio of the HySA Programme, and foster engagements with relevant industry players for improved mobilisation of private- and public-sector partnerships that will:

- Expand the RDI community beyond the universities and science councils;
- Increase the delivery of products, incorporating HySA IP to pilot markets;
- Assist in funding further development and commercialisation of RDI outputs; and
- Increase participation of entrepreneurs, SMMEs and global OEMs within the HySA Programme to facilitate the deployment of locally developed IP.

The following RDI areas are considered critical to the implementation of the HSRM:

- Technologies focused on cost effective hydrogen production, storage and distribution. This includes catalyst-coated membrane technology, stack technology for water electrolysis, electrochemical hydrogen compression, liquid organic-hydrogen carrier storage, and Power-to-X;
- Fuel-cell stack and related catalysts and MEAs focused on both the mobility and stationary applications; and
- Cross-cutting research that supports the creation of an enabling environment will be critical especially in the short term. This would include modelling (techno-economic analysis), environment, safety, policy and regulatory barriers, and just transition across the entire hydrogen value chain.

In addressing some of the research areas above, it is important that researchers keep in mind the need to leverage the country's PGM resource endowment. Alloying techniques that exploit the best properties of all the PGMs in various combinations will be critical in order to develop better performing catalysts while taking advantage of the price variations in the raw materials.

7. HUMAN CAPITAL DEVELOPMENT

Human capital development is crucial for delivering a sustainable hydrogen society in South Africa. The focus of the DSI-supported Energy RDI Flagship Programmes, including the HySA Programme, over the past decade has been to support MSc and PhD students, which has been critical to the development of new knowledge. To date, 635 students (137 supported through the HySA Programme), comprising 436 MSc (83 from HySA) and 199 PhD (54 from HySA) students have been supported. The Energy RDI Flagship Programmes also produced 961 publications (277 from HySA) in Institute for Scientific Information journals, and 72 patents (31 from HySA) were filed or granted, which is an indication of the vibrancy of the research ecosystem that exists to support knowledge generation. To support the objectives of the HSRM, the master's and doctoral students should continue to be funded through the four Energy RDI Flagship Programmes, the bursary schemes of the National Research Foundation, and the energy-related South African Research Chairs.

A 2019 study by the CSIR and the German-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 2050.⁸⁸ However, the majority of these new jobs are expected to be categorised as skilled, requiring either university education or vocational training. Given the estimation that one-third of Technical and Vocational Education and Training (TVET) graduates in South Africa are unemployed, there is a need to address the critical skills gap between industry demands and the public college offering. One of the challenges identified by the Department of Labour is limited skill acquisition, which continues to contribute to the high unemployment rate among the youth in South Africa. This results in inadequate preparation of youth for entry into a rapidly changing labour market characterised by increasing digitisation and automation.

The implementation of the HSRM is therefore expected to contribute to an increase in the market demand for hydrogen and fuel-cell, renewable power, and battery technologies across various sectors of the economy, with an increasing need for trained and experienced personnel as well as accompanying services, such as qualified maintenance technicians, installers, and manufacturing professionals. In a future sustainable hydrogen society in South Africa, sectoral job opportunities for skilled graduates are expected to range from operations and maintenance, to management of PGM mining, refining and beneficiation, transportation and construction, and industrial manufacturing. These job opportunities will require artisanal, technical, digital and other skills related to the relevant stages of the value chain.

The implementation of the HSRM is expected to set the pace for the country's creation of a sustainable workforce that is inclusive and green-growth oriented. Aligning the country's TVET college system with real industry needs, and creating opportunities to improve labour absorption in the implementation of the HSRM, are therefore critical. A sectoral alignment with industry-specific requirements will facilitate a just labour transition, where potential job losses in the traditional coal-mining industry, for example, are mitigated through the upskilling, retraining and on boarding of workers in the implementation of the HSRM.

The following established or envisaged strategic interventions, aimed at supporting the role of South Africa's TVET system in ensuring both a sustainable energy and labour transition, will contribute effectively to the implementation of the HSRM:

7.1 TECHNICAL AND VOCATIONAL EDUCATION AND TRAINING (TVET) FUEL-CELL TRAINING

In 2020, the DSI, in collaboration with the Energy and Water Sector Education Training Authority (EWSETA), Bambili Energy and the University of Pretoria, launched a course to train unemployed TVET graduates on the installation, operation and maintenance of hydrogen and fuel cells. To date, 25 unemployed graduates have undergone the six-week training. Partnerships are being sought to extend the training to more graduates as part of creating skills to support the hydrogen economy. Before creating the pipeline for scaling up the number of artisans and technicians that can be absorbed through the hydrogen economy, it is critical that a comprehensive study is undertaken to understand the required pipeline. In February 2021, the DSI in partnership with EWSETA and the private sector (local SMMEs, global fuel cell OEMs) commenced a research study to analyse the role of the TVET college system in the establishment of a hydrogen economy in South Africa, with the aim of boosting the capacity of TVET colleges to train a green-hydrogen economy workforce.

7.2 TVET SKILLS GAP

The TVET college system does not cater for skills that are specifically relevant to the hydrogen economy. Some level of training involving hydrogen currently happens in local TVETs located close to SASOL facilities in the form of chemical technical training and for maintenance, fitting and other mechanical technical requirements. Studies are being conducted on how the TVET system could be leveraged to develop skills for the hydrogen economy, while addressing the high unemployment rate among the TVET graduates. This would also mean a shift in focus from steam methane reforming (SMR) to electrolyser-based production, resulting in the production of green hydrogen and green ammonia.

7.3 JUST ENERGY TRANSITION CENTRE

While the transition to a net-zero carbon economy is expected to support a net increase in jobs, it is expected that there will be some job losses in the transition. The envisaged establishment of the Just Energy Transition Centre will focus on re-skilling marginalised communities to take up opportunities in new and emerging energy areas, such as hydrogen and fuel cells, batteries, carbon capture and use, and RE technologies. The Just Energy Transition Centre will be expected to conduct studies with relevant research chairs to predict market demand for the skills and inform policy to respond with appropriate interventions.

7.4 PUBLIC AWARENESS AND ENGAGEMENT

To promote awareness of the technology and the benefits of integrating hydrogen in the energy mix, a comprehensive public awareness and engagement platform will be created. Such a platform would be designed to facilitate national discourse on hydrogen and related technologies, showcase deployments as well as conduct outreach events aimed at disseminating evidence-based information. The public engagement initiative will require strong partnerships across the public and private sectors, civil society and academia.

88. "Future skills and job creation through renewable energy in South Africa: Assessing the co-benefits of decarbonising the power sector", cobenefits.info/resources/cobenefits-south-africa-jobs-skills.

8. GENDER EQUALITY AND SOCIAL INCLUSION (GESI)



The implementation of the HSRM will contribute to a growth of green industries that are sustainable, resource- and energy-efficient, low-carbon, low-waste, non-polluting and safe. In order to realise the goal of a “just and inclusive net-zero carbon economic growth for societal wellbeing by 2050”, the implementation of the HSRM needs to integrate the element of gender equality. Women’s potential in green industry needs to be realised,

and women need to be empowered to take leadership roles in green industries as entrepreneurs or industry professionals. A United Nations (UN) report published in February 2021 addressed the barriers most women entrepreneurs are likely to encounter when starting a green business (Table 8.1).⁸⁹ Figure 8:1 gives a conceptualisation of the economic and social barriers in general.

Table 8.1: Barriers to women’s economic empowerment in green industry

BARRIERS TO ADVANCEMENT

- Lack of awareness about policies and programmes
- Lack of access to technology, market, capital, collateral and credit resources, networks, mentoring
- Lack of necessary skills

BARRIERS TO TRANSFORMATION

- Restricted mobility
- Unpaid care work
- Intersectional inequalities
- Discriminatory hiring practices
- Lack of self-confidence
- Lack of access to information

8. GENDER EQUALITY AND SOCIAL INCLUSION (GESI) (CONTINUED)

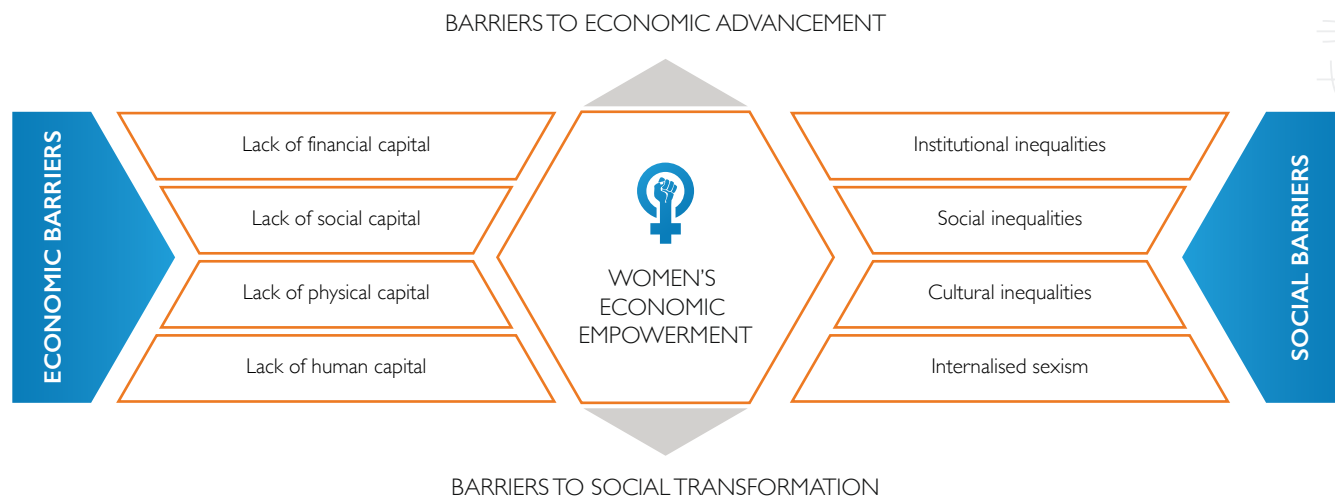


Figure 8.1: Conceptualisation of Women's Economic Empowerment

Source: UNIDO Report, February 2021

Green industries have a high potential to act as a catalyst for enhanced gender equality and the empowerment of women in wider society. The following recommendations, extracted from the UN report, will therefore be considered in the implementation of the HSRM, with the aim of encouraging more women to become green-industry professionals and entrepreneurs:

- Generating visibility and rolemodels: for example, the South African Women in Science Awards, which profile female scientists and researchers as role models for young women and girls;
- Strengthening opportunities for women in sectors such as RE and green industry;
- Providing mentoring and networking opportunities;
- Raising awareness of opportunities for women in the green industry, for example, green-energy business campaigns focused on women, increased access to TVET and public information, targeted support for small-scale female entrepreneurs, women-only information sessions introducing the concept of "green industry";
- Rolling out capacity-building initiatives at local government level on the design, planning and execution of green initiatives to enhance understanding of "green" laws;
- Investing in training and capacity-building initiatives for female green-industry professionals to encourage equal access to promotions, management and leadership roles;
- Developing a pipeline of female talent with the technical skills and knowledge required to secure green-industry jobs and advance to senior levels;
- Developing targeted leadership and management training programmes for female green-industry professionals that will support their career advancement;
- Hiring women-owned businesses as vendors along the hydrogen and fuel cell value chain; and
- Reviewing and developing specific monitoring and evaluation frameworks that collect baseline sex-disaggregated data with indicators for gender equality in the implementation of the HSRM.

89. United Nations, "Policy Assessment for the Economic Empowerment of Women in Green Industry: Synthesis Report of the Country Assessments in Cambodia, Peru, Senegal and South Africa", unido.org/sites/default/files/files/2021-06/Synthesis_Report_Final.pdf.

9. MONITORING, EVALUATION AND LEARNING FRAMEWORK



Parliamentary Portfolio Committee on Science and Technology conduct an oversight visit to HySA Systems at University of the Western Cape

9.1 MONITORING OF THE HSRM OBJECTIVES

Monitoring is a continuing function that uses systematic collection of qualitative or quantitative data on specified indicators (Figure 9.1). These indicators provide management and the main stakeholders of an ongoing development

intervention with indications of progress, achievement of objectives, and how allocated funds are used. Monitoring of the HSRM is broken down according to each level of the Theory of Change: each objective, outcome, lever and output is identified separately.

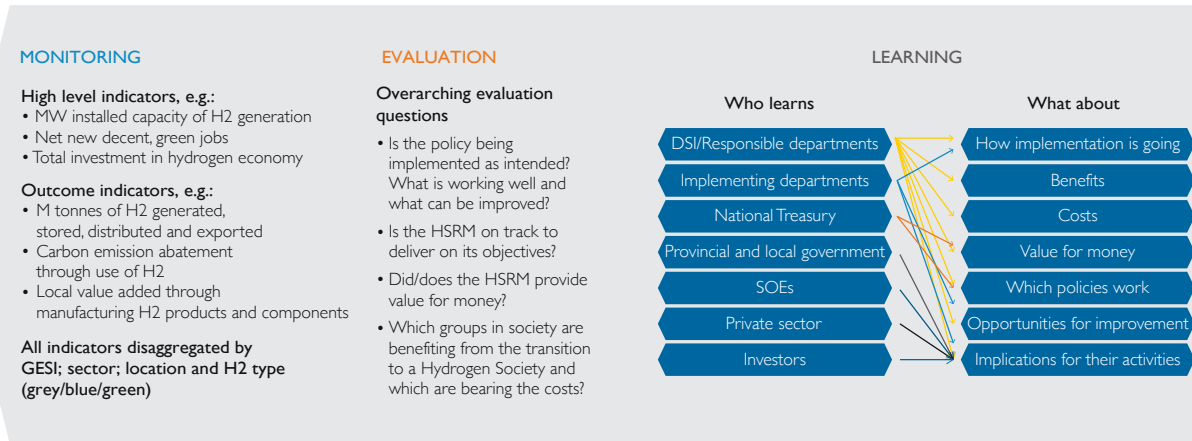


Figure 9.1: Schematic of the Monitoring, Evaluation and Learning (MEL) framework

9. MONITORING, EVALUATION AND LEARNING FRAMEWORK



The HSRM will contribute to the goal of just and inclusive net-zero carbon economic growth for societal wellbeing by 2050 through supporting interlinked objectives. These include supporting the just labour transition through:

- Providing new, high-quality green jobs in the generation and storage of hydrogen;
- Manufacturing hydrogen-related products such as fuel cells and electrolyzers;
- The beneficiation of minerals through the supply of value-added components in the hydrogen value chain;
- The export of green hydrogen; and
- Creating jobs in the local manufacture of hydrogen-related products and construction of infrastructure, and preserving them in the transport and industry sectors.

Other objectives of the HSRM include:

- Reducing GHG emissions by replacing fossil fuels in energy-intensive industry, road and rail transport, and shipping and aviation;
- Enabling the greening of the power sector by providing RE storage to the grid, and reliable zero-carbon electric and thermal energy for off-grid applications; and
- Enabling energy security by providing zero-carbon solutions to the national electrification plan, and back-up energy to the electricity grid for critical applications.

Developing domestic manufacturing of hydrogen products and components, along with the greening of the economy and growing hydrogen exports, will encourage inward investment. Together with reduced oil imports, these changes will also support improvements in the balance of payments.

Realising these objectives will improve South Africa's access to clean energy and reduce inequality and poverty.

9.2 EVALUATION

Evaluation is the systematic and objective assessment of an ongoing or completed project, programme or policy, its design, implementation and results. The aim is to determine the relevance and fulfilment of HSRM objectives, development efficiency, effectiveness, impact and sustainability (Figure 9.1). This evaluation should provide information that is credible and useful, enabling the incorporation of lessons learned into the decision-making process of stakeholders.

9.3 THE LEARNING FRAMEWORK

The learning framework will provide an opportunity for stakeholders to draw on lessons learned during the implementation of the HSRM. The overarching structure will indicate the stakeholders who are expected to learn, as well as what they learn. Further details will be provided in the sectoral learning plans (Figure 9.1).

10. CONCLUSION



The NDP 2030 envisions a country that, over the long term, can manage the transition to a low-carbon economy at a pace consistent with Government's public pledges, without impacting negatively on jobs or competitiveness. It is crucial to consider key guiding principles to ensure hydrogen can be harnessed to benefit all parts of society, now and in the future. To this end, the South African HSRM seeks to achieve the following outcomes:

- A clear understanding and acknowledgment of the societal benefits of hydrogen as an energy carrier;
- A vision for the role of hydrogen in building South Africa, shared by Government, business and civil society;
- A commitment to producing clean hydrogen in a way that is socially just and sensitive to the potential impacts on jobs and local economies;
- The necessary human capital to develop relevant hydrogen research, development and innovation;

- The physical infrastructure to optimally produce, distribute and utilise hydrogen to benefit South African communities and our environment;
- Industries that have invested in and are actively using hydrogen and hydrogen-related technologies across a variety of applications;
- A supportive policy and regulatory environment that incentivises the investment in and use of hydrogen; and
- A strong inflow of foreign direct investment, and an outflow of hydrogen exports that will add meaningful value to South Africa and assist in the economic recovery of the country.

If these outcomes can be achieved, South Africa, with its wealth of natural resources, can take its place at the forefront of the global transition to clean, affordable and sustainable energy, powering a more just and carbon-neutral society.

GLOSSARY



ACRONYM	DEFINITION
ASCCI	Automotive Supply Chain Competitiveness Initiative
BCF	Billion Cubic Feet
BH2	Blue Hydrogen
CCUS	Carbon Capture, Utilisation and Storage
CEF	Central Energy Fund
CO₂	Carbon Dioxide
COGTA	Cooperative Governance and Traditional Affairs
CTL	Coal to Liquids
CSIR	Council for Scientific and Industrial Research
DBSA	Development Bank of Southern Africa
DFFE	Department of Forestry, Fisheries and the Environment
DFI	Development Finance Institution
DIRCO	Department of International Relations and Cooperation
DHET	Department of Higher Education and Training
DMRE	Department of Mineral Resources and Energy
DOD	Department of Defence
DoL	Department of Labour
DOT	Department of Transport
DPE	Department of Public Enterprises
DPWI	Department of Public Works and Infrastructure

ACRONYM	DEFINITION
DSI	Department of Science and Innovation
DTIC	Department of Trade, Industry and Competition
EHC	Electrochemical Hydrogen Compressor
EU	European Union
EWSETA	Energy and Water Sector Education and Training Authority
FT	Fischer-Tropsch
FCEV	Fuel-Cell Electric Vehicle
GDP	Gross Domestic Product
GH2	Green Hydrogen
GHG	Greenhouse Gas
GESI	Gender, Equality and Social Inclusion
GTL	Gas to Liquids
GTS	Green Transport Strategy
H2	Hydrogen
HFCT	Hydrogen and Fuel Cell Technologies
HSRM	The Hydrogen Society Roadmap
HySA	Hydrogen South Africa
ICE	Internal Combustion Engine
IDC	Industrial Development Corporation
IEA	International Energy Agency
IEP	Integrated Energy Plan

ACRONYM	DEFINITION
INDC	Intended Nationally Determined Contribution
IP	Intellectual Property
IPCC	Intergovernmental Panel on Climate Change
IPAP	Industrial Policy Action Plan
IPHE	International Partnership for Hydrogen and Fuel Cells in the Economy
IPR	Intellectual Property Rights
IRP	Integrated Resources Plan
MEA	Membrane Electrode Assembly
MEL	Monitoring, Evaluation and Learning
MINTEK	South African Minerals Research Council
Mt	Million Tonnes
NBI	National Business Initiative
NCCRP	National Climate Change Response White Paper
NDC	Nationally Determined Contributions
NDP	National Development Plan
NEM: AQA	National Environmental Management: Air Quality Act, 2004
NERSA	National Energy Regulator of South Africa
NIPF	National Industrial Policy Framework
NO_x	Nitrogen Oxide
NT	National Treasury
NWU	North-West University

ACRONYM	DEFINITION
PA	Paris Agreement
PGMs	Platinum Group Metals
PetroSA	Petroleum, Oil and Gas Corporation of South Africa
PPD	Peak, Plateau and Decline
PTL	Power to Liquid
PVI	Platinum Valley Initiative
R&D	Research and Development
RDI	Research, Development and Innovation
RE	Renewable Energy
REIPPPP	Renewable Energy Independent Power Producer Procurement Programme
SABS	South African Bureau of Standards
SADC	Southern African Development Community
SAF	Sustainable Aviation Fuel
SAISI	South African Iron and Steel Institute
SALGA	South African Local Government Association
SANEDI	South Africa National Energy Development Institute
SARChI	South African Research Chair Initiative
SAREM	South African Renewable Energy Masterplan
SDG	Sustainable Development Goal
SEZ	Special Economic Zone
SIP	Strategic Integrated Project

ACRONYM	DEFINITION
SMME	Small, Medium and Micro Enterprise
SOEs	State Owned Entities
STI	Science, Technology and Innovation
t	Tonne
TCO	Total Cost of Ownership
TVET	Technical and Vocational Education and Training
UAV	Unmanned Aerial Vehicle
UCT	University of Cape Town
UK	United Kingdom
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
USA	United States of America
USD	United States Dollar
UWC	University of the Western Cape
WHO	World Health Organisation
ZAR	South African Rand

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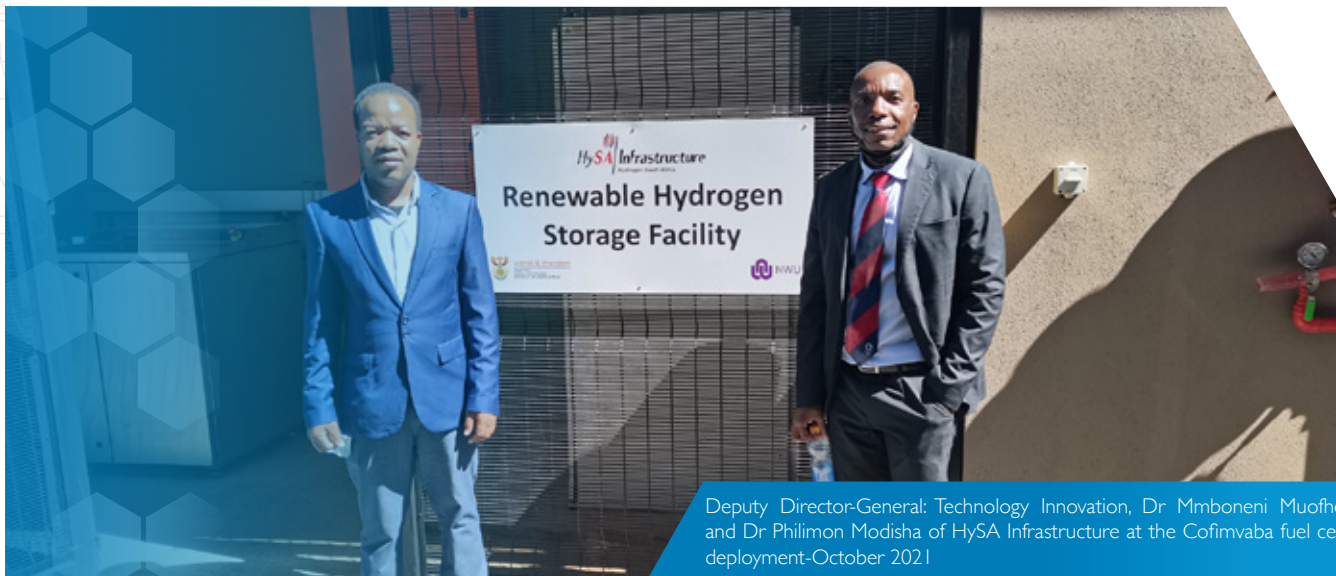
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APPENDICES



APPENDIX A: APPROACH AND METHODOLOGY



Deputy Director-General: Technology Innovation, Dr Mmboneni Muofhe and Dr Philimon Modisha of HySA Infrastructure at the Cofimvaba fuel cell deployment-October 2021

The purpose of this high-level roadmap is to develop a shared vision for the hydrogen society of South Africa and translate it into actionable goals and actions. The roadmap enables multiple stakeholders to collaborate and develop a common path towards achieving a preferred future for South Africa's hydrogen society. A three-pronged approach was adopted towards developing the high-level roadmap, which integrates the use of a futures framework foresight method, a roadmap-development process, and a hydrogen-sector development model. Each component of the methodology is outlined below.

THE FRAMEWORK FORESIGHT METHOD

The emergence and exploration of novel technologies for adoption in the future presents a multiplicity of contexts which are not predictable with any measure of accuracy. This is a key principle of developing this roadmap, as the future of hydrogen in energy is fraught with varying measures of ambiguity, turbulence, uncertainty, novelty and unpredictability. These ever-pervasive dynamic environmental conditions prescribe an open-minded approach

to developing a roadmap to the future of hydrogen. A futures framework has been adopted to guide the development of foresight into the future of hydrogen. It offers a systematic study of possible, probable and preferable futures, including the world views and myths that underlie each future. The framework is grounded on the following key assumptions about the future to help frame the approach to developing the roadmap (Figure 12-1):

- There are multiple futures of a hydrogen energy system over the long term; and
- The future is not predictable with any measure of accuracy.

Therefore:

- Adopt an approach based on plausibility as opposed to probability when studying the future;
- Develop scenarios and reach consensus on a preferred future; and
- Draw from hindsight, and insights from the baseline assessment, to develop strategic foresights for several plausible scenarios for the future of hydrogen.

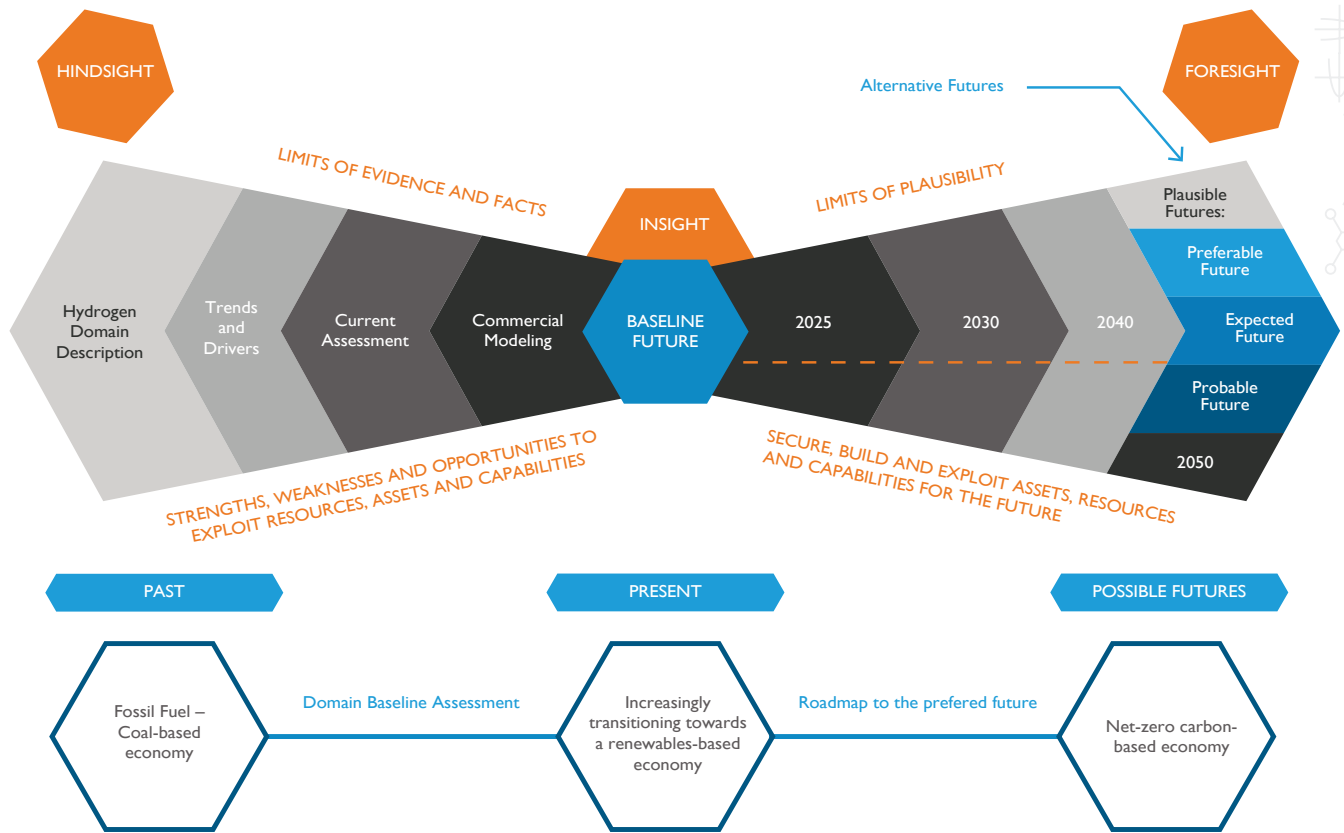


Figure 12.1: The Framework Foresight Illustration

THE SOUTH AFRICA HYDROGEN DEVELOPMENT MODEL

The core team established a hydrogen-development model to enable the identification of strategic impacts and outcomes needed to deliver benefits of a material and strategic nature to the South African people, while addressing global challenges. Secondly, the model had to consider high-priority sectors for hydrogen application in South Africa. The process of identifying the sectors took into consideration unemployment, energy poverty, facilitating a just transition, the addition of socioeconomic value, and sustainable environmental outcomes and impacts. Thirdly, the framework also considered enablers of hydrogen growth and development such as infrastructure, research, knowledge and innovation, human capital and technological capability. The hydrogen-development model formed the basis for identifying the ambitions, aspirations and strategic actions required to achieve the identified outcomes and impacts.

The following elements form the core of the hydrogen-development model:

- **Purpose:** The reasons and rationale for unlocking South Africa's hydrogen potential and developing a high-level roadmap.
- **Stakeholder benefits:** The key **impacts and outcomes** that South Africa can achieve in leveraging its hydrogen opportunity.
- **Growth areas:** The critical sectors of the economy **where hydrogen can most** benefit South Africa.
- **Growth enablers:** The **critical success factors** that will enable South Africa to effectively benefit from the hydrogen opportunity.

APPENDIX B: STAKEHOLDER ENGAGEMENT

Stakeholders are both beneficiaries and actors, whose perspectives and desires are critical to developing a deep understanding of the issues, gaps and opportunities that can be addressed by the roadmap. A collaborative, multi-stakeholder and multi-disciplinary approach was integrated into the roadmap-development process, with the objective of directing all information, perspectives and efforts towards unlocking the country's full hydrogen potential. The team deployed tools and events to solicit insights from a prioritised list of stakeholders across essential parts of the sector. To this end, a phased stakeholder-engagement process was applied, as outlined below as well as in Figure 13.1.

STAKEHOLDER QUESTIONNAIRES

The stakeholder-engagement processes started off with questionnaires sent to stakeholders targeted by the project, based on initial research and consultation with the DSI and the NWU, to solicit hydrogen insights and foresight. The questionnaires were used to assess the level of engagement of individual stakeholders and groups, identifying growth-area champions to engage in the expert working-group sessions.

INTERVIEWS

Like the questionnaires, individual stakeholders were interviewed to solicit their insights on how hydrogen could benefit their respective sectors. The outcomes of the interviews were also used to draft hypotheses presented in the expert working-group sessions.

EXPERT WORKING GROUPS

The expert working-group sessions were conducted with stakeholders from the chosen sectors (namely energy, mining, transport, export, industry, buildings, and RDI), to discuss the questionnaire and interviews, test hypotheses relevant to their respective sectors, and address gaps identified in the baseline assessment and interviews. The sessions were also geared at building consensus among stakeholders, and co-developing aspirations for the South African Hydrogen Society.

INDUSTRY REFERENCE GROUPS

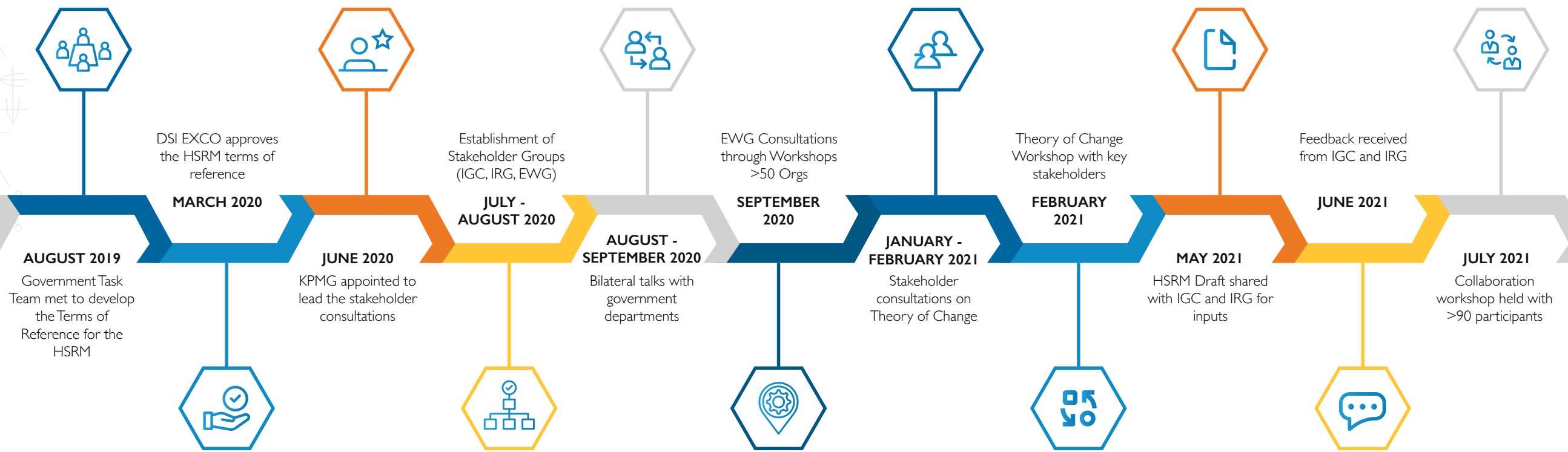
The draft roadmap was distributed to key stakeholders to solicit their input. These stakeholders were selected based on their intimate knowledge of the sectors in which they operate, that were deemed to be relevant to the development of the hydrogen economy.

COLLABORATION WORKSHOPS

Post-workshop stakeholder engagement culminated in a collaboration workshop. The purpose of the workshop was to present the outcome of the stakeholder consultation process and confirm the action plan in the draft roadmap. The session also aimed to inform the stakeholders about the shared aspirations and secure buy-in for the hydrogen society roadmap, and the proposed action plan in particular.

HYDROGEN SOCIETY ROADMAP — STAKEHOLDER ENGAGEMENT

MILESTONES



ACADEMIA/COUNCILS/ R&I



GOVERNMENT/PARASTATAL



INDUSTRIAL REFERENCE GROUP



Figure 13.1: HSRM stakeholder agreement





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