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 2013 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 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, Boegoebaa 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.
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

UNDERSTANDING SOUTH AFRICA’S HYDROGEN OPPORTUNITY
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 2030\(^1\) 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.

\section{South Africa’s Current Energy Landscape}

Figure 1.1 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.\(^4\)

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1.2 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 turbines and less than 1 GW of non-dispatchable RE.

Figure 1.1: South African energy flow in 2017
Source: UCT 2020

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.
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 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. 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.8 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.

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

Figure 1.4: Generation and transmission capacity expected in 2030
Source: Eskom 2021

- 2098 MW of Battery Storage across the network
- 6400 MW of PV generation
- 3000 MW of Gas potentially at Dedisa, Athene and Saldanha
- 14 400 MW of Wind generation Potentially across the W Cape And E Cape
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. Natural gas is primarily imported from Mozambique. Domestic production, offshore in the Eastern Cape, is estimated at 1.7% of domestic demand (26 PJ), with the remainder sourced from the ROMPCO pipeline via Sasol, the country’s largest integrated fuels-and-chemicals producer.

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. 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. 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. Figure 1.6 shows these in relation to the major liquid fuel and gas pipelines.

References:
13. The Engen refinery located in eThekwini (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-liv-ville-as-an-import-terminal-2021-04-23; the National Petroleum Company of South Africa (PetroSA) 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.
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.\(^\text{15}\) 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.\(^\text{16}\)

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).\(^\text{17}\)

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.\(^\text{18}\) 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.

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\(^{16}\) Ibid.

\(^{17}\) Ibid.

I.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. 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. 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.

The instrument that provides detailed information to guide planning of the overall energy mix for the country is the IEP. 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. 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. 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.

The Minerals Beneficiation Strategy focuses on the need for downstream beneficiation of South Africa’s mineral resources, noting the potential for fuel-cell production. 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.
### 1.4 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

<table>
<thead>
<tr>
<th>ROLE PLAYER</th>
<th>MANDATE RELEVANT TO THE HSRM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GOVERNMENT DEPARTMENTS AND REGULATORS</strong></td>
<td></td>
</tr>
<tr>
<td>Department of Mineral Resources and Energy (DMRE)</td>
<td>Custodian of policy and planning for the energy sector, focusing on energy security through diversifying the country’s energy mix to include RE sources.</td>
</tr>
<tr>
<td>National Energy Regulator of South Africa (NERSA)</td>
<td>Regulates the energy sector in the context of national policy and planning, licenses new energy infrastructure and regulates electricity and hydrocarbons-infrastructure tariffs.</td>
</tr>
<tr>
<td>National Treasury</td>
<td>Governs fiscal and procurement policies.</td>
</tr>
<tr>
<td>Department of Transport (DoT)</td>
<td>Leads the implementation of the Green Transport Strategy 2018.</td>
</tr>
<tr>
<td>Department of Trade, Industry and Competition (DTIC)</td>
<td>Develops local industries and trade with particular focus on green industries and job creation; works to attract foreign investment.</td>
</tr>
<tr>
<td>Department of Public Enterprises (DPE)</td>
<td>As the main shareholder, the DPE provides oversight to Eskom, the sole power off-taker.</td>
</tr>
<tr>
<td>Department of Public Works and Infrastructure (DPWI)</td>
<td>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.</td>
</tr>
<tr>
<td>Department of Forestry, Fisheries and the Environment (DFFE)</td>
<td>Sustainable development and environmental integrity; grants environmental authorisations in terms of the National Environmental Management Act (NEMA).</td>
</tr>
</tbody>
</table>
### ROLE PLAYER | MANDATE RELEVANT TO THE HSRM
---|---
**STATE-OWNED ENTITIES**

<table>
<thead>
<tr>
<th>Role Player</th>
<th>Mandate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eskom</td>
<td>National electricity-supply utility and single buyer for renewables from the REIPPPP.</td>
</tr>
<tr>
<td>Central Energy Fund (CEF)</td>
<td>Contributes to the security of energy supply of South Africa through exploration, acquisition, development, marketing and strategic partnership.</td>
</tr>
<tr>
<td>South African National Energy Development Institute (SANEDI)</td>
<td>Promotes energy research and technology innovation, supports green energy and energy-efficiency uptake.</td>
</tr>
<tr>
<td>Industrial Development Corporation (IDC)</td>
<td>Development finance institution (DFI) providing finance for industrialisation projects.</td>
</tr>
<tr>
<td>PetroSA (now incorporated into the South African National Petroleum Company)</td>
<td>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.</td>
</tr>
</tbody>
</table>

**PRIVATE COMPANIES**

<table>
<thead>
<tr>
<th>Role Player</th>
<th>Mandate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engen, BP, Shell, Astron Energy</td>
<td>Owners of crude-oil refineries and distribution channels for refined product.</td>
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</tbody>
</table>

**OTHER**

<table>
<thead>
<tr>
<th>Role Player</th>
<th>Mandate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Academic institutions and science councils</td>
<td>RDI linked to all stages of the hydrogen value chain.</td>
</tr>
</tbody>
</table>
South Africa is the world’s 14th largest emitter of GHGs, particularly CO$_2$ 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. 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.

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". 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 (CO$_2$) 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 CO$_2$ emissions by 2050.

South Africa is the world’s 14th largest emitter of GHGs, particularly CO$_2$ emissions. The National Climate Change Response Policy (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 CO$_2$ intensity.

### Table 1.2: Key climate change policy documents

<table>
<thead>
<tr>
<th>POLICY/PLAN</th>
<th>KEY ASPECTS</th>
</tr>
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</table>
| White Paper on National Climate Change Response 2011 | • 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                             | • 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          | • Revision of original submission for a 2030 mitigation target range, from 398-614 Mt CO$_2$e to a range of 350-420 Mt CO$_2$e (reviewed every five years).  
• 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. |
| Climate Change Bill 2021                         | • Levy administered by Eskom for electricity generated from fossil fuels.  
• Currently an offset against the carbon-tax liability is applicable. |
| Electricity environmental levy                   | • Levy administered by the South African Revenue Service on new-vehicle purchases; based on the CO$_2$ emissions intensity of the vehicle. |
| New-vehicle emissions levy                       |                                                                            |

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29. Intergovernmental Panel on Climate Change (IPCC), Global Warming of 1.5°C: An IPCC Special Report, 2018, ppcc.cryeel.3.
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, unfccc.int/sites/ndcstaging/PublishedDocuments/South%20Africa%20First/South%20Africa%20Updated%20NDC%20September%202021.pdf.
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 398.5-510 Mt CO\(_2\)e, and between 350-420 Mt CO\(_2\)e 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 CO\(_2\)e, or 80% of the official GHG inventory of 512.7 Mt CO\(_2\)e (excluding natural land sinks).\(^34\) Within the energy sector, power generation constitutes the major share at 216.5 Mt CO\(_2\)e (42%), followed by transport at 54.7 Mt CO\(_2\)e (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 CO\(_2\)e in 2017 (6.3%), with ferroalloys and iron and steel, the predominant sectors, emitting 11.3 Mt CO\(_2\)e and 7.7 Mt CO\(_2\)e 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 CO\(_2\)e per USD GDP, is currently more than double the G20 and global average\(^37\), 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.

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\(^{34}\) The national inventory for 2017 amounts to 482,016 GgCO\(_2\)e when land sinks are included.


\(^{36}\) 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.1691950.


\(^{38}\) BRICS is the term to describe the group of major emerging markets comprising Brazil, India, China and South Africa.
1.6 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 PM2.5 (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

<table>
<thead>
<tr>
<th>CATEGORIES</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grey hydrogen</td>
<td>• Produced from fossil fuels (coal, natural gas). Emits carbon through coal gasification with a carbon-capture system or via electrolysis.</td>
</tr>
<tr>
<td></td>
<td>• Considered dirty, even though this hydrogen produces zero emissions at point of use.</td>
</tr>
<tr>
<td>Blue hydrogen</td>
<td>• 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.</td>
</tr>
<tr>
<td></td>
<td>• Lower greenhouse gas emissions than grey hydrogen.</td>
</tr>
<tr>
<td>Pink/Purple hydrogen</td>
<td>• Produced using nuclear energy.</td>
</tr>
<tr>
<td></td>
<td>• Lower emissions than both grey and blue hydrogen.</td>
</tr>
<tr>
<td>Turquoise hydrogen</td>
<td>• 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.</td>
</tr>
<tr>
<td>Green hydrogen</td>
<td>• Produced using RE sources with zero emissions, such as by water electrolysis.</td>
</tr>
<tr>
<td></td>
<td>• Seen as holding the most significant promise for decarbonisation.</td>
</tr>
</tbody>
</table>

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.\(^ {42}\)

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.\(^ {46}\) 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.

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


\(^ {47}\) Ibid.

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.

<table>
<thead>
<tr>
<th>Power Fuels</th>
<th>Applications examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen</td>
<td>- Heavy road transport</td>
</tr>
<tr>
<td>Methane</td>
<td>- Public transport</td>
</tr>
<tr>
<td>Propane</td>
<td>- Crude oil refineries</td>
</tr>
<tr>
<td>Diesel</td>
<td>- Steel production</td>
</tr>
<tr>
<td>Kerosene (jet-fuel)</td>
<td>- Industrial process heat</td>
</tr>
<tr>
<td>Petrol</td>
<td>- Buildings</td>
</tr>
<tr>
<td>Methanol</td>
<td>- Public transport</td>
</tr>
<tr>
<td>Propylene</td>
<td>- Industrial process heat</td>
</tr>
<tr>
<td>Ethylene</td>
<td>- Buildings</td>
</tr>
<tr>
<td>Ammonia</td>
<td>- Air transport</td>
</tr>
<tr>
<td>Methanisation</td>
<td>- Chemical industries</td>
</tr>
</tbody>
</table>
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 electrolyser 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.


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.\(^{50}\)

\(^{50}\) Strategy and pwc.com, Green Hydrogen Production Potential in South Africa, June 2020.
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.\(^5\) The EU has identified Africa as a region with high RE potential and as a possible supplier of green hydrogen.

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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). 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

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. 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. 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 Institute 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.

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**Table 2.2: Current HySA Centres of Competence and focus areas**

<table>
<thead>
<tr>
<th>CENTRE NAME</th>
<th>RESEARCH FOCUS</th>
<th>HOST INSTITUTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>HySA Catalysis</td>
<td>• Catalysts and catalytic devices for fuel cells and hydrogen production.</td>
<td>• University of Cape Town (UCT)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• South African Minerals Research Council (MINTEK)</td>
</tr>
<tr>
<td>HySA Infrastructure</td>
<td>• Technologies for hydrogen, production, storage and distribution.</td>
<td>• North-West University (NWU)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Council for Scientific and Industrial Research (CSIR)</td>
</tr>
<tr>
<td>HySA Systems</td>
<td>• Systems integration and technology validation.</td>
<td>• University of the Western Cape (UWC)</td>
</tr>
</tbody>
</table>

---

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

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.

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>Cabinet approves the National Hydrogen South Africa (HySA) R&amp;D Strategy</td>
</tr>
<tr>
<td>2008</td>
<td>Formal launch of the HySA Programme by Minister of Science and Technology</td>
</tr>
<tr>
<td>2009</td>
<td>Launch of the Ahlfambeni incorporating the metal hydride H2 storage material</td>
</tr>
<tr>
<td>2010</td>
<td>Hosting of the 17th IPHE Meeting by South Africa</td>
</tr>
<tr>
<td>2011</td>
<td>Development of a fuel cell powered golf cart prototype</td>
</tr>
<tr>
<td>2012</td>
<td>Dr. Phil Mjwara launches a fuel cell unit at the University of the Western Cape Nature Reserve</td>
</tr>
<tr>
<td>2013</td>
<td>Launch of fuel cells for off-grid rural electrification in Naledi Trust Village in the Free State</td>
</tr>
</tbody>
</table>

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

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

- Hosting of the 30th IPHE Meeting in South Africa
- Launch of the HySA developed fuel cell unit at Poelano Secondary School in North West
- HySA MEAs and catalyst successfully qualified within a commercial system
- HySA Competitive Fund introduced to facilitate collaboration with industry
- Fuel cell powered scooters deployed at SAPO Offices in Cape Town
- Fuel cell training for TVET graduates and students launched
- IDC is mandated to develop the Green Hydrogen Commercialisation Strategy
- Cabinet approves the Hydrogen Society Roadmap


- Fuel cell launch at the Chamber of Mines building in Johannesburg
- Launch of the fuel cell forklift and refueling station at Impala Platinum Refineries
- Launch of fuel cell at Windsor East Clinic in Randburg
- Launch of fuel cell at Cofimvaba Schools in Eastern Cape


- Launch of fuel cell at Cofimvaba Schools in Eastern Cape
- Fuel cell launch at Wits University in Johannesburg
- Launch of fuel cell at the Chamber of Mines building in Johannesburg
- Fuel cell launch at the Chamber of Mines building in Johannesburg

**SOUTH AFRICA’S HYDROGEN ECONOMY JOURNEY (CONTINUED)**

- Second HySA Five Year Review conducted
- Fuel cell launch at the Chamber of Mines building in Johannesburg
- Fuel cell launch at the Chamber of Mines building in Johannesburg
- Fuel cell launch at the Chamber of Mines building in Johannesburg

**HYDROGEN SOCIETY ROADMAP FOR SOUTH AFRICA**

DEPARTMENT OF SCIENCE AND INNOVATION
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

<table>
<thead>
<tr>
<th>POLICY</th>
<th>LINK TO THE HYDROGEN SOCIETY</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Climate Change Response White Paper (2011)</td>
<td>South Africa has committed to reduce emissions via a peak, plateau and decline trajectory, to which hydrogen could make a contribution.</td>
</tr>
<tr>
<td>Beneficiation strategy for minerals industry of South Africa (2011)</td>
<td>Supports the development of technologies that benefit the country’s mineral resources locally for increased revenue.</td>
</tr>
<tr>
<td>Department of Public Works and Infrastructure Green Building Policy (2018)</td>
<td>Given their low-carbon footprint, hydrogen fuel cells are a viable option for deployment in public buildings and to power critical infrastructure.</td>
</tr>
<tr>
<td>National Development Plan 2030</td>
<td>Advocates for the transition to a low-carbon and diversified energy system.</td>
</tr>
</tbody>
</table>
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). 
### Table 2.4: Tax and incentive mechanisms that could support hydrogen-related technologies

<table>
<thead>
<tr>
<th>TAX/INCENTIVE MECHANISM</th>
<th>APPLICATION TO THE HYDROGEN SOCIETY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Section 11D of the Income Tax Act No 58 of 1962 (R&amp;D tax deduction)</td>
<td>Section 11D does not restrict the type of R&amp;D undertaken and may therefore be used as a tax incentive to advance R&amp;D specifically within the hydrogen landscape.</td>
</tr>
<tr>
<td>Section 12L of the Income Tax Act No 58 of 1962 (Energy Efficiency Allowance)</td>
<td>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.</td>
</tr>
<tr>
<td>Special Economic Zones (SEZ)</td>
<td>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.</td>
</tr>
<tr>
<td>Critical Infrastructure Programme (CIP)</td>
<td>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).</td>
</tr>
<tr>
<td>Capital Projects Feasibility Programme (CPFP)</td>
<td>The CPFP incentive may be used to reduce the cost of feasibility studies for hydrogen-related manufacturing projects in South Africa.</td>
</tr>
<tr>
<td>Support Programme for Industrial Innovation (SPII)</td>
<td>R&amp;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.</td>
</tr>
<tr>
<td>Technology and Human Resources for Industry Programme (THRIP)</td>
<td>This incentive may be used to increase the number of people with the appropriate skills in hydrogen applications and technologies.</td>
</tr>
<tr>
<td>South African Automotive Masterplan (SAAM)</td>
<td>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.</td>
</tr>
</tbody>
</table>
THE POTENTIAL FUTURE OF HYDROGEN IN SOUTH AFRICA
3. BUILDING BLOCKS FOR A SOUTH AFRICAN HYDROGEN SOCIETY

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 socio-economic 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.

**WHAT IS A THEORY OF CHANGE?**

- Explains how a policy is expected to lead a chain of results
- Enables policymakers to think through policy development
- Informs what should be monitored and how the policy should be evaluated

**THE THEORY OF CHANGE FOR THE HYDROGEN SOCIETY ROADMAP**

Just and inclusive net-zero carbon economic growth for societal wellbeing by 2050

<table>
<thead>
<tr>
<th>Partners</th>
<th>Outputs</th>
<th>Levers of change</th>
<th>Hydrogen Society Roadmap Outcomes</th>
<th>Objectives</th>
<th>Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decarbonisation of transport sectors</td>
<td>Reduced GHG emissions</td>
<td>Decarbonisation of energy intensive industry</td>
<td>Creation of export market for SA H2</td>
<td>Centre of Excellence in Manufacturing for H2 products and fuel cell components</td>
<td>Green and enhanced power sector and buildings</td>
</tr>
<tr>
<td>Just labour transition</td>
<td>Energy security</td>
<td>Investment</td>
<td>Reduced inequality and poverty</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Levers of Change, e.g. Infrastructure, skills, cost competitiveness, regulation

<table>
<thead>
<tr>
<th>Integrated policy environment</th>
<th>Financial framework</th>
<th>Industrial clusters</th>
<th>Infrastructure</th>
<th>Research, development and innovation</th>
<th>Skills development</th>
</tr>
</thead>
</table>

**Figure 3.1: Theory of change for the HSRM**
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.
3.1.4 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.

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.
Source: HySA Infrastructure CoC.
HYDROGEN SOCIETY ROADMAP FOR SOUTH AFRICA

DEPARTMENT OF SCIENCE AND INNOVATION

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

DEPARTMENTS IN CHARGE FOR POLICIES

HYDROGEN SOCIETY ROADMAP FOR SOUTH AFRICA

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

Figure 3.3: Overarching theory of change

Objectives

- Investment (inward/domestic)* (MTSF)
  - DTIC
- Reduced GHG emissions (NDC, IPP 2019, NOCP, LEED, GTS, AMR, IPP, PAC)
  - DTIC, DMRE, NPC, DoT, DTC
- Just labour transition (job quality, green jobs)* (MTSF)
  - All departments
- Balance of payments improvement (NDP)
  - DTIC, NT, NPC
- Energy security* (affordability, availability, accessibility) (NDP, SARB)
  - DMRE, DTIC
- Reduced inequality and poverty* (MTSF, NDP)
  - All departments, NPC

Lever of Change

- Decarbonisation of transport sectors: heavy-duty vehicles, shipping, aviation, rail*
  - Local and international demand (GH2, green products)
  - Compliance and regulation
  - Cost competitiveness (LCOE of GH2)
- Decarbonisation of energy intensive industry (steel, chemicals, mining, refineries, cement)*
  - Manufacturing sector for H2 products and excellence
  - Green and enhanced power sector and buildings (includes grid stability)*
  - International commitments
  - Innovative culture and skilled workforce

Outputs

- Demonstration and pilot projects including industrial clusters
  - Market development/business cases
  - Financial framework (access to capital markets)
  - National and international partnerships
  - Research, development and innovation
  - Skills development*
- Creation of export market for SA H2*
  - Raw materials available (water, PGMs)
  - National and international partnerships
  - Research, development and innovation

Partners

- DTC, DoS, DoD, DSI, DoS, DMRE, NT, DoS, SA Bureau of Standards, SA National Energy Regulator,
  - Platinum Valley and Limpopo Science and Technology Park, CEF
  - Green Hydrogen Economy: Just labour transition through TVET College
  - DSI, DMRE, DME, private sector: SAOC, SA regions, SOEs
  - Green Hydrogen Economy: Just labour transition through TVET College
  - Platinum Valley and Limpopo Science and Technology Park, CEF
  - DSI, DMRE, DME, private sector: SAOC, SA regions, SOEs

HYDROGEN SOCIETY ROADMAP FOR SOUTH AFRICA

DEPARTMENT OF SCIENCE AND INNOVATION
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.64 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 clean-production technologies across the economy. Portfolios should be established that set minimum targets for utilisation in priority sectors, in sync with emissions and employment targets, to incubate clean-production technologies across the economy. These pillars outline measures to promote domestic use and create export opportunities via the establishment of new global markets for carbon-neutral commodities:

3.2.3 Mitigate investment risks

In the face of several identified opportunities that lack clear timetables 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 electrolyser). 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.65

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.

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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)

- **ESTABLISH TARGETS AND POLICY SIGNALS**
  - Finalise Green Hydrogen Commercialisation Strategy to support HSRM
  - Review NDCs taking into account GH2 to support a move towards a low-carbon 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

- **CREATION OF EXPORT MARKET FOR SA GREEN HYDROGEN**
  - Develop hydrogen export strategy to support business case for green H2 (including derivatives) export

- **DECARBONISATION OF INDUSTRY**
  - 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

- **DECARBONISATION OF TRANSPORT SECTORS**
  - Create an enabling environment for investment in refuelling infrastructure
  - Classification of hydrogen as a transport fuel

- **MITIGATE INVESTMENT RISK**
  - 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)

- **HARMONISE STANDARDS AND REMOVE BARRIERS**
  - Conduct feasibility studies to develop demand-driven business cases for municipal transport, heavy goods vehicles, buses and taxis
  - Scale up conversion of government fleets and municipal vehicles to use hydrogen as a fuel

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

- **STRATEGIC DEMONSTRATION AND DEPLOYMENT PROJECTS**
  - Pilot fuel cells in informal settlements
  - Test hydrogen as a fuel for mining into hydrogen fuel cell powered vehicles as part of showing hydrogen as a fuel
  - Implement refuelling station pilots for buses, heavy goods vehicles and taxis

- **SUPPORT DEMAND CREATION**
  - Implement catalytic projects such as Boegoeblou SEZ, Platinum Valley Initiative (SA’s Hydrogen Valley) CosmoC, X
  - Demonstration and SAF project

- **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 subdivisions (buildings, micro-grids)

- **ENHANCED AND GREEN POWER SECTOR**
  - 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 subdivisions (buildings, micro-grids)

- **CENTRE OF EXCELLENCE IN MANUFACTURING**
  - Develop a policy framework that incentivises the use of locally manufactured components in various applications (FC vehicles, stationary FCs, electrolyzers)

- **PROMOTE RDI**
  - Develop an RDI Strategy to support HSRM
  - Establish international partnerships to support hydrogen fuels in vehicle manufacturing sectors
  - Implement manufacturing strategy in collaboration with global OEMs

- **HARMONISE STANDARDS AND REMOVE BARRIERS**
  - Adopt and implement regulatory framework including establishing independent H2 product and component testing and verification facilities

- **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**

**Figure 3.5: Summary of key actions**
Figure 3.6: Some high-level numbers on the catalytic projects and some key actions and milestones

### PRODUCTION

<table>
<thead>
<tr>
<th>2021-2024</th>
<th>2025-2030</th>
<th>2030-2040</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PRODUCTION</strong></td>
<td><strong>PRODUCTION</strong></td>
<td><strong>PRODUCTION</strong></td>
</tr>
<tr>
<td>• Small scale electrolysis production</td>
<td>• 5GW electrolysis capacity under construction in NC</td>
<td>• Increase electrolysis capacity to at least 15GW by 2040</td>
</tr>
<tr>
<td>• At least 1MW GH2 production piloted</td>
<td>• 10GW electrolysis capacity deployed in NC by 2030</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• 1.7GW electrolyser capacity deployed in H2 Valley by 2030</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• At least 500kt H2 produced annually by 2030</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>USE</strong></td>
<td><strong>USE</strong></td>
<td><strong>USE</strong></td>
</tr>
<tr>
<td>• At least 100 buses and trucks powered by H2 by 2025</td>
<td>• At least 500 buses and trucks powered by H2 by 2030</td>
<td>• Sector coupling and full use in transport, industry and power</td>
</tr>
<tr>
<td>• At least 20 forklifts converted to fuel cell power by 2025</td>
<td>• Power generation in turbines using H2 and ammonia</td>
<td></td>
</tr>
<tr>
<td>• At least 5 refueling stations deployed by 2025</td>
<td>• Sector coupling and use in transport, industry</td>
<td></td>
</tr>
<tr>
<td>• Demonstration in power generation and stationary fuel cells in public buildings</td>
<td>• Industry demonstration including SAFs</td>
<td></td>
</tr>
<tr>
<td>• Industry demonstration including SAFs</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>JOBS</strong></td>
<td><strong>JOBS</strong></td>
<td><strong>JOBS</strong></td>
</tr>
<tr>
<td>• Upscaling of training and reskilling for new jobs</td>
<td>• At least 20 000 jobs created annually by 2030</td>
<td>• At least 30 000 jobs created annually by 2040</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Establish targets and policy signals
Support demand creation
Mitigate investment risk
Harmonize standards and remove barriers
Promote Research, Development and Innovation
Strategic demonstration and deployment projects
Skills development and public awareness

Figure 3.6: Some high-level numbers on the catalytic projects and some key actions and milestones
4. SOUTH AFRICAN HYDROGEN-SOCIETY OUTCOMES

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

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. 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%. 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).

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.

59. GTS 2018.
Figure 4.1: Theory of change for decarbonisation of heavy vehicles, shipping, aviation and rail

PHASE 1

- Regulatory framework that:
  - Shows a clear pathway to zero emissions transport
  - Requires just transition
  - Removes regulatory barriers

- Fiscal framework that incentivises zero emissions transport

- Establish procurement requirement for zero carbon transport

- Facilitate investment in green vehicles and infrastructure

- Establish competitive local supply of zero carbon vehicles

- Regulator review
  - Identify and consult on new regulations, codes and standards
  - Publish framework
  - Implement policy, regulations, codes and standards

- Evaluate, select and implement incentives for the purchase of H2 vehicles (tax relief, subsidy)
  - Remove subsidy on fossil-fuelled transport

- Central and local government set policy to buy H2 vehicles/specified zero carbon shipping/travel
  - Encourage major corporate buyers to follow suit

- Finance available for purchase of H2 vehicles on competitive terms
  - Finance for investment in fuelling infrastructure

- Encourage local manufacture of H2 vehicles through SEZ, tax relief, R&D support and subsidy
  - Discourage imports through tariffs

- Knowledge and technical capacity in place

- Identify skills needed
  - Develop skills development strategy
  - Implement skills development strategy

- R&D strategy to support and pilot H2 vehicle manufacture and infrastructure for fuelling

Department of Transport, DMRE

DSI identifies and assesses then negotiates with other departments

Department of Transport supported by DSI

DSI and DoT engage donors and DFIs to establish blended finance facility

DTIC

PHASE 2

- Development of skills for manufacture, maintenance and operation of vehicles

- Identify skills needed
  - Develop skills development strategy
  - Implement skills development strategy

- Knowledge and technical capacity in place

- R&D strategy to support and pilot H2 vehicle manufacture and infrastructure for fuelling

Department of Science and Innovation

Department of Transport, DMRE

Department of Science and Innovation

Department of Trade, Industry and Competition

Department of Science and Innovation
An aerial view of the Solar PV plant for on-site hydrogen production at the Mogalakwena Platinum Mine.

Source: Anglo American Platinum
### SECTOR: ROAD TRANSPORT

<table>
<thead>
<tr>
<th>ACTION</th>
<th>CHAMPION</th>
<th>SUPPORTING INSTITUTIONS OR ORGANISATIONS</th>
<th>HOW WILL GES/JUST TRANSITION AND RDI BE INCLUDED?</th>
<th>HOW WILL WE MONITOR PROGRESS?</th>
</tr>
</thead>
<tbody>
<tr>
<td>2021-2024</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Develop policy and regulatory framework that incentivises or rewards transport users that use hydrogen as a fuel to help generate scale</td>
<td>DoT</td>
<td>DMRE, DTIC, National Treasury</td>
<td>GESI: Engage women and youth in developing framework and implications to address any job losses</td>
<td>• Policy and regulatory framework developed • Number of vehicles using GH2 as a fuel</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>RDI: Centre of Excellence on techno-economic analysis on the cost of GH2 as a fuel</td>
<td></td>
</tr>
<tr>
<td>2. Conduct feasibility studies to develop demand-driven business cases for municipal transport, heavy goods vehicles, buses and taxis</td>
<td>DoT</td>
<td>COGTA, National Treasury, metro municipalities, taxi associations</td>
<td>RDI: Centre of Excellence on techno-economic analysis on technology and market readiness</td>
<td>• Feasibility studies completed</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>GESI: Engage women and youth in developing framework and implications to address any job losses</td>
<td></td>
</tr>
<tr>
<td>3. Develop regulations, codes and standards (RCS) for hydrogen refuelling</td>
<td>DMRE</td>
<td>DTIC, SABS</td>
<td>RDI: Research on high pressure storage</td>
<td>• Regulations developed and in use</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>GESI: Engage women and youth in developing framework and implications to address any job losses</td>
<td></td>
</tr>
<tr>
<td>4. Implement refuelling station pilots for buses, heavy goods vehicles and taxis</td>
<td>DMRE</td>
<td>Government, private sector/PetroSA/CEF</td>
<td>RDI: Research on high pressure storage</td>
<td>• Number of refuelling stations in operation • % women- and youth-led SMMEs involved</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>GESI: Engage women and youth in developing framework and implications to address any job losses</td>
<td></td>
</tr>
<tr>
<td>5. Develop a regulatory framework to support a zero emission transport across all modes (road, rail, ship)</td>
<td>DoT</td>
<td>DMRE, Transnet</td>
<td>RDI: SARChI on legislative and regulatory frameworks</td>
<td>• Regulatory framework developed</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>GESI: Engage women and youth in developing framework and implications to address any job losses</td>
<td></td>
</tr>
<tr>
<td>6. Classification of hydrogen as a transport fuel</td>
<td>DMRE</td>
<td>CEF, private sector</td>
<td>Not necessarily</td>
<td>• Share of hydrogen used as transport fuel</td>
</tr>
<tr>
<td>2025-2030</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Scale up the conversion of government fleets and municipal vehicles to use hydrogen as a fuel through public procurement</td>
<td>DoT</td>
<td>DMRE, DTIC, COGTA, National Treasury, metros, municipalities</td>
<td>GESI: Consider participation of women-led SMMEs in the supply chains</td>
<td>• Number of hydrogen-fuelled vehicles • Jobs generated • Number of women-led SMMEs involved</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>RDI: Research on conversion technology with a focus on performance of locally developed components</td>
<td></td>
</tr>
<tr>
<td>8. Create an enabling environment for investment in refuelling infrastructure</td>
<td>CEF</td>
<td>SASOL/petrochemical sector/PetroSA, operator/fuel providers</td>
<td>GESI: Consider role of SMMEs in the establishment, ownership and operation of the infrastructure</td>
<td>• Number of SMMEs involved in the supply chain</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>RDI: Centre of Excellence on techno-economic analysis on the cost of GH2 as a fuel</td>
<td></td>
</tr>
<tr>
<td>9. Implement incentives and compliance programmes.</td>
<td>DTIC</td>
<td>DMRE/National Treasury, DOT, private sector</td>
<td>GESI: Consider participation of women- and youth-led SMMEs in the incentive schemes</td>
<td>• Uptake of the incentives • % women- and youth-led SMMEs involved</td>
</tr>
</tbody>
</table>
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 Sector 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. If 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.

![Figure 4.2: Volumes of South Africa’s exports to leading partners in 2018 (ZAR billion)](source: NBI Report 2021)


### Other relevant policies:
- Industry Masterplans
- Renewable Energy Masterplan
- National Development Plan
- Economic Reconstruction and Recovery Plan

### Links to other HSRM outcomes:
- Centre of Excellence in Manufacturing for H2 products and fuel cell components
- Green H2 generation industry
- Just transition

---

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

<table>
<thead>
<tr>
<th>DTIC, DMRE</th>
<th>DTIC, DMRE</th>
<th>DSI, Platinum Valley, Limpopo</th>
<th>DSI and DTIC engage donors, DFIs and private investors</th>
<th>DSI, DTIC, TVET, etc., DSI, DTIC</th>
<th>DTIC, DMRE, Infrastructure SA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regulatory framework that:</td>
<td>Fiscal framework that incentivises investment in decarbonising-intensive industry</td>
<td>Build confidence in and ability to deploy innovation</td>
<td>Establish skills and knowledge base to ensure transition to H2 industry</td>
<td>Industry commitment to decarbonisation</td>
<td>Infrastructure in place to supply H2 to industry</td>
</tr>
<tr>
<td>• Shows a clear pathway to zero emissions industry</td>
<td>• Requires just transition</td>
<td>• Removes regulatory barriers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Regulatory review</td>
<td>• Evaluate, select and implement incentives for investment in H2 technology (tax relief, subsidy)</td>
<td>• Remove subsidy on fossil fuels</td>
<td>• Work with donors and DFIs to establish financing mechanisms</td>
<td>• Encourage private investment with favourable policies</td>
<td>• Facilitate investment in generation/transmission/storage to provide sufficient H2 for industry’s needs</td>
</tr>
<tr>
<td>• Identify and consult on new policy, regulations, codes and standards</td>
<td>• Research, development and demonstration through industrial clusters</td>
<td></td>
<td>• Identify skills needed and develop a skills development strategy</td>
<td>• Policy measures, e.g. carbon tax, fossil fuel levies</td>
<td></td>
</tr>
<tr>
<td>• Publish framework</td>
<td></td>
<td></td>
<td></td>
<td>• Work with industry and industry bodies to support commitment to decarbonisation</td>
<td></td>
</tr>
<tr>
<td>• Implement policy, regulations, codes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

**4. SOUTH AFRICAN HYDROGEN-SOCIETY OUTCOMES (CONTINUED)**

**SECTION B: THE POTENTIAL FUTURE OF HYDROGEN IN SOUTH AFRICA**

**Other relevant policies:**
- Industry Masterplans
- Renewable Energy Masterplan
- National Development Plan
- Economic Reconstruction and Recovery Plan

**Links to other HSRM outcomes:**
- Centre of Excellence in Manufacturing for H2 products and fuel cell components
- Green H2 generation industry
- Just transition

---

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

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**HYDROGEN SOCIETY ROADMAP FOR SOUTH AFRICA**

**DEPARTMENT OF SCIENCE AND INNOVATION**

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

<table>
<thead>
<tr>
<th>ACTION</th>
<th>CHAMPION</th>
<th>SUPPORTING INSTITUTIONS OR ORGANISATIONS</th>
<th>HOW WILL GESI/JUST TRANSITION AND RDI BE INCLUDED?</th>
<th>HOW WILL WE MONITOR PROGRESS?</th>
</tr>
</thead>
<tbody>
<tr>
<td>2021-2024</td>
<td>DTIC/NBI</td>
<td>PIC/DMRE, Private sector</td>
<td>GESI: Membership of women- and youth-led SMMEs paid by the DTIC</td>
<td>% of membership which is women and youth</td>
</tr>
<tr>
<td>1. Establish a national Hydrogen industry association tasked with advocacy for hydrogen and stimulating investment in the industrial sector</td>
<td>DTIC/DC</td>
<td>DSI, Private sector</td>
<td>Not necessarily</td>
<td>Study completed hydrogen industrial hubs identified</td>
</tr>
<tr>
<td>2. Conduct feasibility studies on developing hydrogen industrial hubs at South African ports that link with shipping, truck and aviation routes</td>
<td>DTIC</td>
<td>SAISI</td>
<td>Not necessarily</td>
<td>Policy revised and approved</td>
</tr>
<tr>
<td>3. Align Steel Masterplan to the HSRM</td>
<td>DMRE, DTIC</td>
<td>DSI, Private sector</td>
<td>Not necessarily</td>
<td>Policies developed and approved</td>
</tr>
<tr>
<td>4. Develop policies and regulations that will stimulate demand for hydrogen-related applications in the energy-intensive industries (mining, cement, steel, refineries)</td>
<td>National Treasury, DTIC</td>
<td>DMRE, DTIC, private sector</td>
<td>Not necessarily</td>
<td>Policies developed and approved</td>
</tr>
<tr>
<td>5. Develop the local market framework with incentives that support domestic consumption of green hydrogen and ammonia</td>
<td>National Treasury, DTIC</td>
<td>DMRE, private sector</td>
<td>GESI: Set aside opportunities for youth- and women-led businesses</td>
<td>% women- and youth-led businesses involved in the value chain</td>
</tr>
<tr>
<td>6. Reduce the administrative timeframes required for approval for self-generation projects</td>
<td>National Treasury, DMRE</td>
<td>National Treasury, Minerals Council SA</td>
<td>GESI: Consider role of women-led SMMEs in approved projects</td>
<td>MWh of electricity generated</td>
</tr>
<tr>
<td>7. Provide incentives for mining companies to start using hydrogen for power generation to create domestic demand</td>
<td>National Treasury, DMRE</td>
<td>National Treasury, Minerals Council SA</td>
<td>GESI: Participation of women and youth in incentive schemes</td>
<td>Number of incentives in place</td>
</tr>
<tr>
<td>8. Convert the heavy goods vehicle for mining into hydrogen and fuel-cell-powered vehicles as part of showing proof of concept</td>
<td>DoT</td>
<td>Minerals Council SA</td>
<td>GESI: Participation of women- and youth-led SMMEs in the supply chains</td>
<td>Number of HGVs converted</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>% women-led SMMEs involved</td>
</tr>
<tr>
<td>2025-2030</td>
<td>DMRE</td>
<td>National Treasury, Minerals Council SA</td>
<td>GESI: Participation of women and youth in incentive schemes</td>
<td>Number of incentives in place</td>
</tr>
<tr>
<td>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</td>
<td>DoT</td>
<td>DMRE</td>
<td>GESI: Participation of women- and youth-led SMMEs in the supply chains</td>
<td>Number of HGVs converted</td>
</tr>
<tr>
<td>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</td>
<td>DoT</td>
<td>DMRE</td>
<td>GESI: Participation of women- and youth-led SMMEs in the supply chains</td>
<td>% women-led SMMEs involved</td>
</tr>
<tr>
<td>2030-2040</td>
<td>DMRE</td>
<td>National Treasury, Minerals Council SA</td>
<td>GESI: Participation of women and youth in incentive schemes</td>
<td>Number of incentives in place</td>
</tr>
<tr>
<td>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</td>
<td>DoT</td>
<td>DMRE, NAAMS: ABC</td>
<td>GESI: Participation of women- and youth-led SMMEs in the supply chains</td>
<td>Number of HGVs converted</td>
</tr>
<tr>
<td>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</td>
<td>DoT</td>
<td>DMRE, NAAMS: ABC</td>
<td>GESI: Participation of women- and youth-led SMMEs in the supply chains</td>
<td>% women-led SMMEs involved</td>
</tr>
<tr>
<td>2040-2050</td>
<td>DMRE</td>
<td>National Treasury, Minerals Council SA</td>
<td>GESI: Participation of women and youth in incentive schemes</td>
<td>Number of incentives in place</td>
</tr>
<tr>
<td>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</td>
<td></td>
<td></td>
<td></td>
<td>Number of HGVs converted</td>
</tr>
</tbody>
</table>
4.3 CREATION OF AN EXPORT MARKET FOR SOUTH AFRICAN HYDROGEN

The IEA Net-zero study 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 report 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.

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.

**International commitments**

- DTIC lead
- Private sector

**International demand**

- DTIC lead with SABS, DFFE, DMRE, NERSA

**Confidence in SA market and green H2**

- DTIC lead with SOEs, ISA, Transnet

**Enabling export infrastructure**

- DSI lead with HySA, private sector, SOEs, SANEDI

**Cost competitiveness (LCOE of GH2)**

- H2 generation, storage and distribution industry established
- Green and enhanced power sector and buildings

**Note:** Dedicated GH2 generation capacity may be required for the export market if the availability of GH2 is constrained.

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**Relevant policies guiding:**

- Renewable Energy Masterplan
- Economic Reconstruction and Recovery Plan
- Minerals Beneficiation

**Creation of export market for SA Hydrogen**

- Million tonnes green H2 exported (disaggregated by product)
- Rand (bn) export earnings

**Other HSRM outcomes:**

- H2 generation, storage and distribution industry established
- Green and enhanced power sector and buildings

**Market analysis**

- Identify export obstacles - tariffs, standards
- Export strategy for green H2
- Business case established
- Negotiate purchasing commitments
- Partnerships established/maintained

**H2 infrastructure investment in:**

- Domestic H2 generation, storage and distribution
- Export H2 storage and port infrastructure

**R&D into most efficient generation, storage and shipping methods at scale - confirm that SA green H2 cost competitive with LNG (e.g. increase efficiency and durability of water electrolysis, reduce cost)**

**Review of supply barriers by 2023 (e.g. tariffs on components, land use controls)**

**Propose adjustments to fiscal and policy environment**

**Implement by 2025**

**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

<table>
<thead>
<tr>
<th>SECTOR: HYDROGEN EXPORT</th>
<th>ACTION</th>
<th>CHAMPION</th>
<th>SUPPORTING INSTITUTIONS OR ORGANISATIONS</th>
<th>HOW WILL GESI/JUST TRANSITION AND RDI BE INCLUDED?</th>
<th>HOW WILL WE MONITOR PROGRESS?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2021-2024</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| 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 | • International commitments  
• International demand  
• Number of potential partners and investors engaged  
• Number of secured partnerships  
• % women- and youth-led SMMEs involved  
• Investment made in support of regional integration  
• Tonnes of GH2 traded across the region |
| 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 |                               |
| 3.                      | Expand regional cooperation/partnerships on GH2 | DIRCO | DSI, SADC | GESI: Consider GESI in partnerships and supply chains |                               |
| 4.                      | Develop a hydrogen export strategy to inform the business case for green GH2 (including derivatives) export | DTIC lead | DIRCO, National Treasury, DPE, private sector | GESI: Targets for women- and youth-led SMMEs considered in export strategy | • 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 | • International codes and standards adopted for use in South Africa  
• Locally produced GH2 products traded on the global market |
| 6.                      | Review, develop and publish harmonised policy, regulations, codes and standards, and legislation to ensure green GH2 as export opportunity by 2024 | DTIC lead with SABS | DFFE | Not necessarily  
RDI: Centre of Excellence on legislative and regulatory frameworks | • 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 | • Cost competitiveness (LCOE of GH2)  
• Number of facilities earmarked for or dedicated to GH2 export |
| 8.                      | Integrate hydrogen exports into existing national port and rail strategies | DTIC lead with Transnet, CEF, ISA | GESI: Address job losses/negative effects) | • Number of facilities earmarked for or dedicated to GH2 export |                               |
|                         | 2025-2030 |          |                                           |                                          |                               |
| 9.                      | Implement export strategy including negotiation of purchasing commitments, establishing partnerships, and commerce exports | DTIC lead | DIRCO, National Treasury, DPE, SOEs (Transnet, CEF) | GESI: Targets for women- and youth-led SMMEs in supply chain | • Number of partnerships established  
• Strategy implemented  
• Purchasing commitments made  
• Tonnes of GH2 exported  
• Investments made in GH2-related projects  
• Tonnes of GH2 produced  
• Enabling export infrastructure  
• Dedicated green hydrogen generation capacity  
• Cost competitive GH2  
• Intellectual property rights filed/granted |
| 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 | • Number of partnerships established  
• Strategy implemented  
• Purchasing commitments made  
• Tonnes of GH2 exported  
• Investments made in GH2-related projects  
• Tonnes of GH2 produced  
• Enabling export infrastructure  
• Dedicated green hydrogen generation capacity  
• Cost competitive GH2  
• Intellectual property rights filed/granted |
| 11.                     | Invest in rail and port infrastructure to support GH2 export | DTIC lead ISA | DIFE, DBSA, SOEs (CEF,Transnet) | GESI: Action plans to address job losses/negative effects) and in supply chains |                               |
| 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 | • Number of partnerships established  
• Strategy implemented  
• Purchasing commitments made  
• Tonnes of GH2 exported  
• Investments made in GH2-related projects  
• Tonnes of GH2 produced  
• Enabling export infrastructure  
• Dedicated green hydrogen generation capacity  
• 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 | • Number of partnerships established  
• Strategy implemented  
• Purchasing commitments made  
• Tonnes of GH2 exported  
• Investments made in GH2-related projects  
• Tonnes of GH2 produced  
• Enabling export infrastructure  
• Dedicated green hydrogen generation capacity  
• Cost competitive GH2  
• Intellectual property rights filed/granted |
| 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 | • % of global GH2, market  
• 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, electrolyzers, membrane-electrode assemblies (MEA) 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.
Figure 4.6: Theory of change for Centre of Excellence in Manufacturing for hydrogen products and fuel cell components
<table>
<thead>
<tr>
<th>ACTION</th>
<th>CHAMPION</th>
<th>SUPPORTING INSTITUTIONS OR ORGANISATIONS</th>
<th>HOW WILL GESI/JUST TRANSITION AND RDI BE INCLUDED?</th>
<th>HOW WILL WE MONITOR PROGRESS?</th>
</tr>
</thead>
<tbody>
<tr>
<td>2021-2024</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Develop a GH2 product and component manufacturing strategy and business case aligned with Automotive Masterplan and Minerals Beneficiation Masterplan</td>
<td>DTIC, DSI</td>
<td>HySA, ASCCI, OEMs, and Minerals Council</td>
<td>GESI: Include plans to increase % of jobs for women and disabled Consider location of facilities in disadvantaged areas</td>
<td>• Approved Commercialisation/Manufacturing Strategy</td>
</tr>
<tr>
<td>2. Conduct study and develop export strategy for H2 products and fuel cell components</td>
<td>DTIC</td>
<td>with private sector, ASCCI</td>
<td>RDI: Centre of Excellence on techno-economic analysis</td>
<td>• International demand for H2 products established • Number of purchasing commitments in place</td>
</tr>
<tr>
<td>3. Develop a policy framework that incentivises the use of locally manufactured components in various applications (FC vehicles, stationary FCs, electrolyzers)</td>
<td>DTIC with DoT</td>
<td>DMR, DPW, DoD, NT, ASCCI</td>
<td>GESI: Participation of women- and youth-led SMME incentives developed and in procurement</td>
<td>• Domestic demand established for H2 products • Targets for integrating hydrogen-related products in the domestic market in place</td>
</tr>
<tr>
<td>4. Develop and implement RDI strategy to support H2 product and component manufacture (electrolysers, fuel cells, MEA, subcomponents)</td>
<td>DTIC with DSI</td>
<td>SANEDI, HySA, ASCCI and Minerals Council</td>
<td>GESI/Just Transition: Consider just Transition in support for local manufacturing</td>
<td>• Innovative culture developing H2 products and processes • Number of H2 products and components manufactured locally</td>
</tr>
<tr>
<td>5. Identify skills needed to support the implementation of the manufacturing strategy and develop a skills development roadmap</td>
<td>DHET with DSI</td>
<td>SANEDI, HySA, private sector</td>
<td>GESI: Consider GESI in plans Include plans to encourage women to train and enter market</td>
<td>• Skills development roadmap developed • % women in skilled workforce for local manufacturing</td>
</tr>
<tr>
<td>6. Develop strategy for attracting FDI in vehicle manufacturing sectors</td>
<td>DTIC with National Treasury</td>
<td>NAAMSA, ABC</td>
<td>GESI/Just Transition: Participation of women- and youth-led SMMEs in sector</td>
<td>• FDI investment in the manufacturing sector</td>
</tr>
<tr>
<td>7. Finalise Minerals Beneficiation Masterplan</td>
<td>DMRE</td>
<td>Minerals Council</td>
<td>GESI/Just Transition: Participation of women- and youth-led SMMEs in sector</td>
<td>• Masterplan approved for implementation</td>
</tr>
<tr>
<td>2025-2030</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Adopt and implement regulatory framework including establishing independent H2 product and component testing and verification facilities</td>
<td>DTIC with SABS</td>
<td>DSI, ASCCI</td>
<td>GESI/Just Transition: Participation of women- and youth-led SMMEs in product and component testing</td>
<td>• Establishment of testing facility • Number of H2-related products and components tested and certified</td>
</tr>
<tr>
<td>9. Implement targeted manufacturing incentives (to include allowances, special economic zones, subsidies, tax relief, rebates, infrastructure availability)</td>
<td>DTIC with National Treasury</td>
<td>private sector</td>
<td>GESI: Consider GESI and role of SMMEs in the supply chains</td>
<td>• Fiscal framework incentivises manufacture of H2 products • Industry awareness of policy awareness of benefits</td>
</tr>
<tr>
<td>10. Implement manufacturing strategy in collaboration with global OEMs</td>
<td>DSI with DTIC</td>
<td>OEMs, ASCCI and Minerals Council</td>
<td>GESI/Just Transition: Participation of women- and youth-led SMMEs in manufacturing</td>
<td>• Number of H2-related products and components manufactured locally</td>
</tr>
<tr>
<td>11. Implement skills development roadmap and embed in existing TVET and higher education sectors</td>
<td>DHET</td>
<td>DSI</td>
<td>GESI/Just Transition: Target women in recruitment of trainees</td>
<td>• Number of engineers/scientists/artisans trained (disaggregated)</td>
</tr>
<tr>
<td>12. Conduct RDI to support H2 product and component manufacture (electrolysers, fuel cells, MEA, subcomponents)</td>
<td>DSI with SANEDI</td>
<td>HySA, ASCCI and Minerals Council</td>
<td>GESI: Consider GESI in recruitment of knowledge workers</td>
<td>• IP generated on components and system level performance</td>
</tr>
</tbody>
</table>
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 networks 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.4 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.

64. Decarbonising South Africa’s Power System, NBI report Chapter 1, 2021.
Figure 4.7: Theory of change for a green and enhanced power sector

GREEN AND ENHANCED POWER SECTOR

- Energy
- Availability
- Accessibility
- Affordability

MAIN GRID
- FCs and H2 storage (grid stability)
- MW of FCs installed; tonnes of H2 produced to store RE (includes PtG)
- MW of energy produced from H2 energy (FCs, turbines)

MICRO/ISLAND GRID
- Back-up power (Number of power outages; MW of FCs installed)
- ICT applications (MW of FCs installed)
- Remote areas/islands (MW of FCs installed)
- Buildings (commercial, public, residential, includes CHP and H2 boilers) (MW of FCs/H2 power installed in buildings, electric and thermal)

National and international partnerships are developed

IRP, SAREM

Attractive investment environment (de-risking H2 investments)

Cost competitiveness (LCOE of GH2)

Enabling infrastructure and policy supports H2 and disincentivises CO2 intensive alternatives

Compliance and Regulation

Local demand for GH2, green products (synfuels, ammonia)

International commitments (H2 production scale-up)

IRP, SAREM

Financial framework:
- Access to finance
- Specific H2 financial schemes in place

Policy
- H2 specific favourable and integrated policy is set (subsidies for GH2), fiscal measures are in place
- Renewable energy surplus is available and geographically distributed, Diesel Gensets replacement

Regulatory environment:
- H2 regulation, codes and standards in place for power grids (main and micro/island)
- Demonstration and pilot projects for market development; includes industrial clusters, informal settlements, PMVs
- Power and heating

Skills development

Raw materials available: water, PGMs, etc.

Demonstration and pilot projects for market development; includes industrial clusters, informal settlements, PMVs

National and international partnerships are developed

Skills development

Financial framework:
- Access to finance
- Specific H2 financial schemes in place

Policy
- H2 specific favourable and integrated policy is set (subsidies for GH2), fiscal measures are in place
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Regulatory environment:
- H2 regulation, codes and standards in place for power grids (main and micro/island)
- Demonstration and pilot projects for market development; includes industrial clusters, informal settlements, PMVs
- Power and heating

Skills development

Raw materials available: water, PGMs, etc.

DTIC, DSI, DMRE, NT, DoT, DBSA, IDC, PIC, financial institutions, CEF, Infrastructure SA

DTIC, DFF, DSI, DMRE, NT, DoT, SA Bureau of Standards, SADC, National Energy Regulator

DSI, DMRE, DHET, H2SA, private sector, SOEs, SADC, SANEDI

PI Valley and Limpopo S&T Park, CEF

TVET

DTIC, DFFE, DIRCO, private sector, SADC, SA regions, SOEs

DSI to lead, DMRE, DHET, HySA, private sector, SOEs, SADC, SANEDI, TVET
### SECTOR: GREEN AND ENHANCED POWER SECTOR

#### 2021-2024

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<tbody>
<tr>
<td>1.</td>
<td>National electrification plan/target to be divided into main and micro-grids</td>
<td>DMRE</td>
<td>Eskom</td>
<td>GESI: Incorporate GESI into the electrification plans</td>
</tr>
<tr>
<td>2.</td>
<td>Finalise South African Renewable Energy Masterplan (SAREM)</td>
<td>DMRE with DTIC</td>
<td>DSI</td>
<td>GESI: Participation of women and youth in SAREM</td>
</tr>
<tr>
<td>3.</td>
<td>Align SAREM and Steel Masterplan with HSRM targets</td>
<td>DMRE</td>
<td>DSI, DTIC</td>
<td>GESI: Targets for women- and youth-led SMMEs</td>
</tr>
<tr>
<td>4.</td>
<td>Update NDCs to align with HSRM with a specific focus on the power generation sector</td>
<td>DFFE</td>
<td>DSI, Science Councils</td>
<td>GESI: Support for remote education due to COVID-19</td>
</tr>
<tr>
<td>5.</td>
<td>Subsidies to telco applications for FC deployment to scale up</td>
<td>National Treasury with DCTS</td>
<td>Telcos, DSI</td>
<td>GESI: Participation of women and youth in SAREM</td>
</tr>
<tr>
<td>6.</td>
<td>Pilot FCs in data centres for proof of concept</td>
<td>DCTS with DSI</td>
<td>RDI: E2 back-up application featuring long-term storage</td>
<td>• Number of data centres powered by FCs</td>
</tr>
<tr>
<td>7.</td>
<td>Pilot FCs in informal settlements keeping the same standard as main grid</td>
<td>DMRE with DSI</td>
<td>DSI</td>
<td>GESI: Targets for women- and youth-led SMMEs involved in deployments</td>
</tr>
<tr>
<td>8.</td>
<td>Develop a national set of standards on energy within the built environment to enable use of H2 in buildings</td>
<td>DPWI with DMRE</td>
<td>Eskom, Green Building Council (GBC)</td>
<td>RDI: Centre of Excellence on Legislation and Policy in hydrogen</td>
</tr>
<tr>
<td>9.</td>
<td>Create awareness of hydrogen economy through different building-related bodies around H2 and HCT in buildings</td>
<td>DPWI with GBC</td>
<td>DSI, real estate entities</td>
<td>RDI: RE integration in built environment</td>
</tr>
<tr>
<td>10.</td>
<td>Use public procurement to stimulate H2 and fuel cell demand in public building sector</td>
<td>DPWI with DMRE</td>
<td>SANEDI, private sector</td>
<td>RDI: Centre of Excellence on techno-economic analysis</td>
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<td>11.</td>
<td>Adopt H2 and FCs to power critical infrastructure</td>
<td>DoD with DPWI</td>
<td>DSI, private sector</td>
<td>GESI: Consider youth and women in procurement</td>
</tr>
<tr>
<td>12.</td>
<td>Create a marketing and advocacy plan for H2 use in the electricity sector (main, micro-grid)</td>
<td>GCIS with DMRE</td>
<td>DSI, DHET</td>
<td>GESI: Consider GESI in procurement</td>
</tr>
<tr>
<td>13.</td>
<td>Incorporate and couple H2 production into existing PPA</td>
<td>DMRE with IPP office</td>
<td>NT</td>
<td>GESI: Consider GESI in procurement</td>
</tr>
<tr>
<td>14.</td>
<td>Facilitate the approval of the Solar Research Facility (SRF) plan for funding</td>
<td>DMRE with DSI</td>
<td>private sector</td>
<td>GESI: Consider GESI in staffing and training</td>
</tr>
<tr>
<td>15.</td>
<td>Prepare a position paper to specifically fund H2 use in sub-sectors (buildings, micro-grids)</td>
<td>National with DMRE</td>
<td>DSI</td>
<td>RDI: Centre of Excellence on techno-economic analysis</td>
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#### 2025-2030

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<td>16.</td>
<td>Complete establishment of the SRF</td>
<td>DSI</td>
<td>private sector</td>
<td>RDI: H2 production from solar energy</td>
</tr>
<tr>
<td>17.</td>
<td>Connect households to either main or micro-grids using FCs</td>
<td>DMRE</td>
<td>local municipalities</td>
<td>GESI: Targets for women and youth in staff</td>
</tr>
<tr>
<td>18.</td>
<td>Revise the IRP to include hydrogen gas for generation</td>
<td>DMRE</td>
<td></td>
<td>GESI: Targets for women and youth led SMMEs</td>
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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. 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.

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.

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Figure 4.9: Theory of change for hydrogen generation, storage and distribution
Table 4.6: Action plan for hydrogen generation, storage and distribution

<table>
<thead>
<tr>
<th>ACTION</th>
<th>CHAMPION</th>
<th>SUPPORTING INSTITUTIONS OR ORGANISATIONS</th>
<th>HOW WILL GESI/JUST TRANSITION AND RDI BE INCLUDED?</th>
<th>HOW WILL WE MONITOR PROGRESS?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Infrastructure SA</td>
<td>Sasol, PetroSA, NCP Chloro-Chem, NERSA, DMRE, DSI</td>
<td>GESI: Have targets for the participation of women and youth in market deployment plan</td>
<td>• Market deployment plan to be in place</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>RDI: Research, development and demonstration of MW scale electrolyser focused on cost reduction of GH2</td>
<td>• Number of MW electrolyzers deployed in SA</td>
</tr>
<tr>
<td>2.</td>
<td>DTIC</td>
<td>DMRE, DSI, private sector, SOEs</td>
<td>GESI: Have targets for the participation of women and youth in GH2 supply chains</td>
<td>• Cost of GH2 per kg</td>
</tr>
<tr>
<td>3.</td>
<td>Infrastructure SA</td>
<td>GESI: Have targets for the participation of women and youth in SIP</td>
<td>• GH2 commercialisation strategy developed</td>
<td>• Number of women and youth involved in SIP</td>
</tr>
<tr>
<td>4.</td>
<td>Infrastructure SA with NCEDA</td>
<td>DSI, SANEDI, Sasol</td>
<td>GESI: Have targets for the participation of women and youth in catalytic projects</td>
<td>• Number of women and youth involved in catalytic projects</td>
</tr>
<tr>
<td>5.</td>
<td>GCIS with DMRE</td>
<td>DSI, DTIC</td>
<td>GESI: Women, youth framework in place including skills development, social acceptance</td>
<td>• Number of women involved in the Communication Plan</td>
</tr>
<tr>
<td>6.</td>
<td>DTIC</td>
<td>GESI: Framework for women, youth participation in deployment of infrastructure</td>
<td>• Number of women and youth trained</td>
<td>• Critical infrastructure programme revised</td>
</tr>
<tr>
<td>7.</td>
<td>DSI</td>
<td>private sector, academia</td>
<td>GESI: Participation of women and youth in RDI Strategy</td>
<td>• RDI strategy developed</td>
</tr>
<tr>
<td>8.</td>
<td>DSI with DMRE</td>
<td>DFFE, private sector, academia, SOEs, Provincial Government</td>
<td>GESI: Women, youth participation in CCU</td>
<td>• CCU technology piloted</td>
</tr>
<tr>
<td>9.</td>
<td>DHET with DoL</td>
<td>DTIC, DSI</td>
<td>GESI: Women, youth participation in skills development</td>
<td>• Skills development roadmap developed</td>
</tr>
<tr>
<td>10.</td>
<td>DHET</td>
<td>DMRE, DFFE, DTIC, DSI</td>
<td>GESI: Women, youth considered for reskilling</td>
<td>• Number of women and youth trained</td>
</tr>
<tr>
<td>11.</td>
<td>DIRCO with DHET</td>
<td>DSI, DTIC</td>
<td>GESI: Women, youth participation in international partnerships</td>
<td>• Framework for job preservation through reskilling developed</td>
</tr>
<tr>
<td>12.</td>
<td>DIRCO with DSI</td>
<td>universities, Science Councils, private sector</td>
<td>GESI: Consider women, youth in recruitment</td>
<td>• International partnerships established</td>
</tr>
<tr>
<td>13.</td>
<td>DMRE</td>
<td>PCCC</td>
<td>GESI: Consider GESI in Just Energy Transition</td>
<td>• Number of women and youth participating in international partnerships</td>
</tr>
<tr>
<td>14.</td>
<td>DSI with DTIC</td>
<td>DMRE</td>
<td>GESI: Research aimed at supporting Just Energy Transition</td>
<td>• Partnerships established</td>
</tr>
</tbody>
</table>

2021-2024 Grey, blue, green

**SECTION B: THE POTENTIAL FUTURE OF HYDROGEN IN SOUTH AFRICA**

4. SOUTH AFRICAN HYDROGEN-SOCIETY OUTCOMES (CONTINUED)
<table>
<thead>
<tr>
<th>ACTION</th>
<th>CHAMPION</th>
<th>SUPPORTING INSTITUTIONS OR ORGANISATIONS</th>
<th>HOW WILL GESI/JUST TRANSITION AND RDI BE INCLUDED?</th>
<th>HOW WILL WE MONITOR PROGRESS?</th>
</tr>
</thead>
<tbody>
<tr>
<td>15. Complete feasibility studies on water resource availability and desalination to support green H2 production</td>
<td>DWS</td>
<td>Water Research Commission (WRC)</td>
<td>RDI: Centre of Excellence on techno-economic analysis on the cost of GH2 in South Africa</td>
<td>Feasibility study completed</td>
</tr>
<tr>
<td>16. Complete feasibility studies on new H2 corridors and valleys in South Africa to support the scale-up of demand</td>
<td>DTIC with DMRE</td>
<td></td>
<td>GESI: Consider GESI in hydrogen valleys and corridors</td>
<td>Feasibility study completed</td>
</tr>
<tr>
<td>17. Revise the NDCs taking into account GH2 to support a net-zero carbon economy especially in hard-to-abate sectors</td>
<td>DFFE with DTIC</td>
<td></td>
<td>GESI: Consider GESI in revising the NDCs</td>
<td>Number of hydrogen valleys and corridors identified</td>
</tr>
<tr>
<td>18. Call for proposals on improving the cost and efficiency of hydrogen solutions</td>
<td>DSI with SANEDI</td>
<td></td>
<td>GESI: Consider GESI in reviewing of submitted proposals</td>
<td>Number of proposals approved</td>
</tr>
<tr>
<td><strong>2025-2030 Grey, blue, green</strong></td>
<td></td>
<td></td>
<td>RDI: Research on improving cost and efficiency of hydrogen technologies</td>
<td></td>
</tr>
<tr>
<td>19. Pilot CCU on a national scale</td>
<td>DSI with DMRE</td>
<td>DPE, SOEs</td>
<td>GESI: Consider participation of women and youth in technology demonstration</td>
<td>Pilot demonstration completed</td>
</tr>
<tr>
<td>20. Develop a grey H2 phase-out plan if green H2 reaches parity with grey H2</td>
<td>DMRE</td>
<td>private sector</td>
<td>GESI: Consider GESI in phase-out plan</td>
<td>Grey H2 phase-out plan developed</td>
</tr>
</tbody>
</table>

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

- **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.

- **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.

- **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*

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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.

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68. Ibid.
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 metros 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 metros and, and 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.
5.2 COALCO$_2$-X PROJECT

South Africa is the world’s 14th largest emitter of GHGs, particularly CO$_2$ 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 CoalCO$_2$-X Project (Figure 5-3) aims to use green hydrogen and pollutants (CO$_2$, 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 ZARS50 million to kick-start the CoalCO$_2$-X RDI Project.

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

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.

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.
The CoalCO2-X Programme is structured to ensure the sustainable transition of the carbon capture and utilisation technology innovation from RDI concept to demonstration and scale-up to industrial application, by bridging the triple chasms that prevent innovation reaching full commercialisation.

**The Triple Chasm Model**

**CHASM 1:**
- Idea / Innovation
- Laboratory
- University CoC / CoE
- Researching Grants and Funding

**CHASM 2:**
- Proof of Concept
- Lab Scale Model
- Research Grants and Funding

**CHASM 3:**
- Demonstration
- Pilot Site
- VC and Seed Funding

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

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.
5.3 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 Boegoebaaai, 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 Boegoebaaai.71

Boegoebaaai 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 production of green hydrogen and ammonia is feasible at Boegoebaaai.71

Boegoebaaai 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 production of green hydrogen and ammonia is feasible at Boegoebaaai.71

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 role-players, 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.72 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 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 Boegoebaaai 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
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:\textsuperscript{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.\textsuperscript{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 would help the project reach this target.\textsuperscript{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.\textsuperscript{79}

Figure 5.7: Illustrates the synergies between the Boegoebaai project and the CoaCo\textsubscript{2}-X project.

**SOUTH AFRICA**

\begin{itemize}
  \item National Capital
  \item Provincial Capital
  \item Existing Mpumalanga / Richards Bay Coal Railway Line

\end{itemize}

*Use 25\% of green hydrogen production for the production of green ammonia for Priority Area Multipollutant Carbon Capture and Conversion (CCU)*

\textsuperscript{71} Sasol takes lead role in feasibility study for Boegoebaai green hydrogen project, Engineering News, 6 October 2021. engineeringnews.co.za.

\textsuperscript{72} Presidency presentation to Champions: Investment & infrastructure office/infrastructure green hydrogen (H2) South Africa.

\textsuperscript{73} Ibid

\textsuperscript{74} Ibid

\textsuperscript{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/.

\textsuperscript{76} Ibid

\textsuperscript{77} Ibid


See the Just Transition Centre, itc-cc.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.84 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.85

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.86

To help overcome these challenges, on 14 April 2021, the South African government announced a feasibility study to upscale the production of SAF, utilising Sasol’s world-leading FT technology.87 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.88 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.89

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 ITH 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.90

87. Ibid.
88. Ibid.
89. Ibid.
6. RESEARCH, DEVELOPMENT AND INNOVATION: THE KEY TO GROWTH OF THE HYDROGEN SOCIETY

According to a discussion paper launched by the Mission Innovation and the Clean Hydrogen Mission 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.

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

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

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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.
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. 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.
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). 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

<table>
<thead>
<tr>
<th>BARRIERS TO ADVANCEMENT</th>
<th>BARRIERS TO TRANSFORMATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of awareness about policies and programmes</td>
<td>Restricted mobility</td>
</tr>
<tr>
<td>Lack of access to technology, market, capital, collateral</td>
<td>Unpaid care work</td>
</tr>
<tr>
<td>and credit resources, networks, mentoring</td>
<td>Intersectional inequalities</td>
</tr>
<tr>
<td>Lack of necessary skills</td>
<td>Discriminatory hiring practices</td>
</tr>
<tr>
<td></td>
<td>Lack of self-confidence</td>
</tr>
<tr>
<td></td>
<td>Lack of access to information</td>
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</table>
SECTION B: THE POTENTIAL FUTURE OF HYDROGEN IN SOUTH AFRICA

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.

9. MONITORING, EVALUATION AND LEARNING FRAMEWORK

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.

<table>
<thead>
<tr>
<th>MONITORING</th>
<th>EVALUATION</th>
<th>LEARNING</th>
</tr>
</thead>
<tbody>
<tr>
<td>High level indicators, e.g.:</td>
<td>Overarching evaluation questions</td>
<td>What about</td>
</tr>
<tr>
<td>• MW installed capacity of H2 generation</td>
<td>• Is the policy being implemented as intended?</td>
<td>How implementation is going</td>
</tr>
<tr>
<td>• Net new decent, green jobs</td>
<td>• What is working well and what can be improved?</td>
<td>Benefits</td>
</tr>
<tr>
<td>• Total investment in hydrogen economy</td>
<td>• Is the HSRM on track to deliver on its objectives?</td>
<td>Costs</td>
</tr>
<tr>
<td>Outcome indicators, e.g.:</td>
<td>• Did/does the HSRM provide value for money?</td>
<td>Value for money</td>
</tr>
<tr>
<td>• M tonnes of H2 generated, stored, distributed and exported</td>
<td>• Which groups in society are benefiting from the transition to a Hydrogen Society and which are bearing the costs?</td>
<td>Which policies work</td>
</tr>
<tr>
<td>• Carbon emission abatement through use of H2</td>
<td></td>
<td>Opportunities for improvement</td>
</tr>
<tr>
<td>• Local value added through manufacturing H2 products and components</td>
<td></td>
<td>Implications for their activities</td>
</tr>
<tr>
<td>All indicators disaggregated by GESI; sector; location and H2 type (grey/blue/green)</td>
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Figure 9.1: Schematic of the Monitoring, Evaluation and Learning (MEL) 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).
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.
<table>
<thead>
<tr>
<th>ACRONYM</th>
<th>DEFINITION</th>
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</thead>
<tbody>
<tr>
<td>ASCCI</td>
<td>Automotive Supply Chain Competitiveness Initiative</td>
</tr>
<tr>
<td>BCF</td>
<td>Billion Cubic Feet</td>
</tr>
<tr>
<td>BH2</td>
<td>Blue Hydrogen</td>
</tr>
<tr>
<td>CCUS</td>
<td>Carbon Capture, Utilisation and Storage</td>
</tr>
<tr>
<td>CEF</td>
<td>Central Energy Fund</td>
</tr>
<tr>
<td>CO₂</td>
<td>Carbon Dioxide</td>
</tr>
<tr>
<td>COGTA</td>
<td>Cooperative Governance and Traditional Affairs</td>
</tr>
<tr>
<td>CTL</td>
<td>Coal to Liquids</td>
</tr>
<tr>
<td>CSIR</td>
<td>Council for Scientific and Industrial Research</td>
</tr>
<tr>
<td>DBSA</td>
<td>Development Bank of Southern Africa</td>
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<tr>
<td>DFFE</td>
<td>Department of Forestry, Fisheries and the Environment</td>
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<tr>
<td>DFI</td>
<td>Development Finance Institution</td>
</tr>
<tr>
<td>DIRCO</td>
<td>Department of International Relations and Cooperation</td>
</tr>
<tr>
<td>DHET</td>
<td>Department of Higher Education and Training</td>
</tr>
<tr>
<td>DMRE</td>
<td>Department of Mineral Resources and Energy</td>
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<tr>
<td>DOD</td>
<td>Department of Defence</td>
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<tr>
<td>DoL</td>
<td>Department of Labour</td>
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<tr>
<td>DOT</td>
<td>Department of Transport</td>
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<tr>
<td>DPE</td>
<td>Department of Public Enterprises</td>
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<tr>
<td>DPWI</td>
<td>Department of Public Works and Infrastructure</td>
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<td>ACRONYM</td>
<td>DEFINITION</td>
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<tr>
<td>DSI</td>
<td>Department of Science and Innovation</td>
</tr>
<tr>
<td>DTIC</td>
<td>Department of Trade, Industry and Competition</td>
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<tr>
<td>EHC</td>
<td>Electrochemical Hydrogen Compressor</td>
</tr>
<tr>
<td>EU</td>
<td>European Union</td>
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<tr>
<td>EWSETA</td>
<td>Energy and Water Sector Education and Training Authority</td>
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<tr>
<td>FT</td>
<td>Fischer-Tropsch</td>
</tr>
<tr>
<td>FCEV</td>
<td>Fuel-Cell Electric Vehicle</td>
</tr>
<tr>
<td>GDP</td>
<td>Gross Domestic Product</td>
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<tr>
<td>GH2</td>
<td>Green Hydrogen</td>
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<tr>
<td>GHG</td>
<td>Greenhouse Gas</td>
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<td>GESI</td>
<td>Gender, Equality and Social Inclusion</td>
</tr>
<tr>
<td>GTL</td>
<td>Gas to Liquids</td>
</tr>
<tr>
<td>GTS</td>
<td>Green Transport Strategy</td>
</tr>
<tr>
<td>H2</td>
<td>Hydrogen</td>
</tr>
<tr>
<td>HFCT</td>
<td>Hydrogen and Fuel Cell Technologies</td>
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<tr>
<td>HSRM</td>
<td>The Hydrogen Society Roadmap</td>
</tr>
<tr>
<td>HySA</td>
<td>Hydrogen South Africa</td>
</tr>
<tr>
<td>ICE</td>
<td>Internal Combustion Engine</td>
</tr>
<tr>
<td>IDC</td>
<td>Industrial Development Corporation</td>
</tr>
<tr>
<td>IEA</td>
<td>International Energy Agency</td>
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<tr>
<td>IEP</td>
<td>Integrated Energy Plan</td>
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## ACRONYM DEFINITION

<table>
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<tr>
<th>ACRONYM</th>
<th>DEFINITION</th>
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<tbody>
<tr>
<td>INDC</td>
<td>Intended Nationally Determined Contribution</td>
</tr>
<tr>
<td>IP</td>
<td>Intellectual Property</td>
</tr>
<tr>
<td>IPCC</td>
<td>Intergovernmental Panel on Climate Change</td>
</tr>
<tr>
<td>IPAP</td>
<td>Industrial Policy Action Plan</td>
</tr>
<tr>
<td>IPHE</td>
<td>International Partnership for Hydrogen and Fuel Cells in the Economy</td>
</tr>
<tr>
<td>IPR</td>
<td>Intellectual Property Rights</td>
</tr>
<tr>
<td>IRP</td>
<td>Integrated Resources Plan</td>
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<tr>
<td>MEA</td>
<td>Membrane Electrode Assembly</td>
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<tr>
<td>MEL</td>
<td>Monitoring, Evaluation and Learning</td>
</tr>
<tr>
<td>MINTEK</td>
<td>South African Minerals Research Council</td>
</tr>
<tr>
<td>Mt</td>
<td>Million Tonnes</td>
</tr>
<tr>
<td>NBI</td>
<td>National Business Initiative</td>
</tr>
<tr>
<td>NCCRP</td>
<td>National Climate Change Response White Paper</td>
</tr>
<tr>
<td>NDC</td>
<td>Nationally Determined Contributions</td>
</tr>
<tr>
<td>NDP</td>
<td>National Development Plan</td>
</tr>
<tr>
<td>NEM: AQA</td>
<td>National Environmental Management: Air Quality Act, 2004</td>
</tr>
<tr>
<td>NERSA</td>
<td>National Energy Regulator of South Africa</td>
</tr>
<tr>
<td>NIPF</td>
<td>National Industrial Policy Framework</td>
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<tr>
<td>NOx</td>
<td>Nitrogen Oxide</td>
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<tr>
<td>NT</td>
<td>National Treasury</td>
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<tr>
<td>NWU</td>
<td>North-West University</td>
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<td>ACRONYM</td>
<td>DEFINITION</td>
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<tr>
<td>PA</td>
<td>Paris Agreement</td>
</tr>
<tr>
<td>PGMs</td>
<td>Platinum Group Metals</td>
</tr>
<tr>
<td>PetroSA</td>
<td>Petroleum, Oil and Gas Corporation of South Africa</td>
</tr>
<tr>
<td>PPD</td>
<td>Peak, Plateau and Decline</td>
</tr>
<tr>
<td>PTL</td>
<td>Power to Liquid</td>
</tr>
<tr>
<td>PVI</td>
<td>Platinum Valley Initiative</td>
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<tr>
<td>R&amp;D</td>
<td>Research and Development</td>
</tr>
<tr>
<td>RDI</td>
<td>Research, Development and Innovation</td>
</tr>
<tr>
<td>RE</td>
<td>Renewable Energy</td>
</tr>
<tr>
<td>REIPPPP</td>
<td>Renewable Energy Independent Power Producer Procurement Programme</td>
</tr>
<tr>
<td>SABS</td>
<td>South African Bureau of Standards</td>
</tr>
<tr>
<td>SADC</td>
<td>Southern African Development Community</td>
</tr>
<tr>
<td>SAF</td>
<td>Sustainable Aviation Fuel</td>
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<td>SAISI</td>
<td>South African Iron and Steel Institute</td>
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<td>SALGA</td>
<td>South African Local Government Association</td>
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<td>SANEDI</td>
<td>South Africa National Energy Development Institute</td>
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<td>SARChI</td>
<td>South African Research Chair Initiative</td>
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<td>SAREM</td>
<td>South African Renewable Energy Masterplan</td>
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<td>SDG</td>
<td>Sustainable Development Goal</td>
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<tr>
<td>SEZ</td>
<td>Special Economic Zone</td>
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<td>SIP</td>
<td>Strategic Integrated Project</td>
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<td>ACRONYM</td>
<td>DEFINITION</td>
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<tr>
<td>SMME</td>
<td>Small, Medium and Micro Enterprise</td>
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<tr>
<td>SOEs</td>
<td>State Owned Entities</td>
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<tr>
<td>STI</td>
<td>Science, Technology and Innovation</td>
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<tr>
<td>t</td>
<td>Tonne</td>
</tr>
<tr>
<td>TCO</td>
<td>Total Cost of Ownership</td>
</tr>
<tr>
<td>TVET</td>
<td>Technical and Vocational Education and Training</td>
</tr>
<tr>
<td>UAV</td>
<td>Unmanned Aerial Vehicle</td>
</tr>
<tr>
<td>UCT</td>
<td>University of Cape Town</td>
</tr>
<tr>
<td>UK</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>UN</td>
<td>United Nations</td>
</tr>
<tr>
<td>UNFCCC</td>
<td>United Nations Framework Convention on Climate Change</td>
</tr>
<tr>
<td>USA</td>
<td>United States of America</td>
</tr>
<tr>
<td>USD</td>
<td>United States Dollar</td>
</tr>
<tr>
<td>UWC</td>
<td>University of the Western Cape</td>
</tr>
<tr>
<td>WHO</td>
<td>World Health Organisation</td>
</tr>
<tr>
<td>ZAR</td>
<td>South African Rand</td>
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REFERENCES (CONTINUED)

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.
13. The Engen refinery located in eThekwini (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.
16. Ibid.
17. Ibid.
20. Ibid.
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 the Environment (DFFE), South Africa’s updated Nationally Determined Contribution (NDC), 2021, unfccc.int/sites/ndcstaging/PublishedDocuments/South%20Africa%20First/South%20Africa%20Updated%20First%20NDC%20September%202021.pdf.
34. The national inventory for 2017 amounts to 482,016 GgCO₂e when land sinks are included.


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.


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


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


47. Ibid.


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


68. Ibid.
69. Ibid.
70. Ibid.
71. ‘Sasol takes lead role in feasibility study for Boegoebaai green hydrogen project’, Engineering News, 6 October 2021, engineeringnews.co.za.
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84. ‘South Africa’s Sasol forms consortium to produce sustainable aviation fuel’, Reuters, April 14 2021.
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APPENDICES
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.
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.

**FIGURE 12.1: THE FRAMEWORK FORESIGHT ILLUSTRATION**
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 Engagements**

- **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

AUGUST 2019
Government Task Team met to develop the Terms of Reference for the HSRM

MARCH 2020
DSI EXCO approves the HSRM terms of reference

JUNE 2020
KPMG appointed to lead the stakeholder consultations

JULY - AUGUST 2020
Establishment of Stakeholder Groups (IGC, IRG, EWG)

AUGUST - SEPTEMBER 2020
EWG Consultations through Workshops >50 Orgs

SEPTEMBER 2020
Bilateral talks with government departments

JULY - AUGUST 2020
Theory of Change Workshop with key stakeholders

AUGUST - SEPTEMBER 2020
Stakeholder consultations on Theory of Change

JULY 2021
Collaboration workshop held with >90 participants

MAY 2021
Feedback received from IGC and IRG

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ACADEMIA/COUNCILS/ R&I

GOVERNMENT/PARASTATAL

INDUSTRIAL REFERENCE GROUP

Figure 13.1: HSRM stakeholder agreement