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South African Industry Demand for Green Hydrogen Technician and Artisan Skills

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Introduction

South Africa is at a pivotal moment in its development trajectory, and has a number of opportunities to transition towards a sustainable and low-carbon pathway. The development of a green hydrogen economy has emerged as a developmental priority and complementary pathway to achieving a sustainable future. A number of public and private sector participants have shown enthusiasm and optimism related to the development of this value chain and interest and investment commitments are anticipated to rise in the coming years. South Africa has a strategic advantage in the hydrogen economy given the country's good renewable energy conditions, access to the platinum catalyst through its platinum resources used in electrolysers and fuel cells, and an existing Fischer–Tropsch[1] skills base.

A number of countries have been developing and enacting policy to support the hydrogen economy in the recent past through the formulation of strategies, setting targets and incentivising hydrogen research and development, pilot projects and infrastructure. By mid-2019, a combined total of 50 targets, mandates and policy incentives were in place globally in support of the hydrogen economy (IEA, 2019). Countries are beginning to place themselves in global hydrogen value chains and signal to the global market their intentions related to the import, production, or export of hydrogen. Countries are driven by the increasing cost-competitiveness of green hydrogen, the search for further decarbonisation options and energy security concerns. Among the Group of Twenty (G20) and the European Union, 11 have such policies in place and 9 have national roadmaps for hydrogen energy. A lot of attention has been devoted to developing mobility solutions with market signaling and development around FCEV passenger cars, refueling stations, and heavy-duty transport such as buses and trucks. Further, policies to stimulate scale in the production of electrolysers for hydrogen production features prominently. Countries have incorporated a range of policy tools to drive the hydrogen economy. They include funding mechanisms, targets for hydrogen applications, subsidy mechanisms, investment funds, and tax credit schemes.

The development of green hydrogen and allied value chains offer numerous benefits for the country. Green hydrogen can feed into a number of existing hydrogen production activities and serve to reduce the carbon intensity of existing production, thus improving the sustainability of historically difficult-to-decarbonise value chains such as petrochemicals production. The petrochemicals industry is currently highly carbon intensive and is one of the highest emitters of greenhouse gases in the national landscape. Decarbonisation is also possible in other value chains such as electricity production and metals refining.

Beyond the climate benefits, the green hydrogen value chain creates new input and downstream markets which, in turn, stimulate the emergence of additional skills and capabilities. Here, input markets, such as those related to fuel cell and electrolyser production, as well as membrane and catalyst production, can create employment in new and sustainable industries and assist in migrating from South Africa's carbon-intensive production landscape. Downstream, automotive markets, for example, have begun to consider

[1] The Fischer-Tropsch process is a feature of South Africa's petrochemical and liquid fuels landscape through Sasol's production processes. Through Sasol, the country has access to the skills and capabilities around using the process and adapting it to augment existing fossil-intensive production with sustainable inputs such as green hydrogen.

hydrogen-fuelled transport. Particularly, investments into heavy duty vehicles which operate on fuel cells are beginning to manifest.

There is an undoubtedly an urgency for South Africa to transition towards a low-carbon industry. Domestic climate change legislation that penalises carbon emissions, such as carbon taxes and budgets, seek to make carbon-intensive firms increasingly absorb the costs of emissions. Further, shareholder activism has put increasing pressure on firms to account for their emissions and transition towards sustainable production. On the international stage, South Africa's large trade partners, such as the EU and the US, are already setting the scene for border carbon tariffs that seek to penalise carbon intensive economies. In addition, carbon-intensive activities, such as the coal value chain, are facing international sanction as major importers of South African coal turn towards domestic decarbonisation of their energy value chains.

In this urgency to transition, there arises an additional developmental concern in the form of what is known as the Just Energy Transition (JET). Like with many other economic transitions, technological advances in methods of production provide advantages and impose costs on certain groups in society. Given South Africa's high reliance on the coal value chain and with historic investments and human capital built to cater to that value chain, a migration away from such fossil-intensive value chains, places costs on the most vulnerable in society. In South Africa, much like in other coal-dependent countries in the world, coal-mining towns are a feature of the economic landscape. The mining towns in Mpumlalanga, such as Emalahleni and Steve Tswhete, are disproportionately reliant on the coal value chain, when compared to the rest of the economy. Mines, power stations and petrochemical plants dominate the economic landscape and employment in these regions is highly dependent on the coal value chain. Once activities related to coal mining, electricity generation and petrochemicals production reduce coal consumption, employees, small businesses and communities stand to be devastated by the impact. The JET then seeks to employ a basket of policy tools to ensure that such vulnerable stakeholders are not forgotten in the energy transition and include them in such a transition. This can take the form of policies that seek to increase economic diversification in these regions, provide opportunities for reskilling and retraining of the workforce, increase social welfare, and provide temporary income support for employees who are being reskilled and retrained, to name a few.

South Africa's current green hydrogen development is in a state of flux with a number of promising policies and investments on the horizon. National level policies such as the Hydrogen Society Roadmap (HSRM) are currently under development, and intend to provide the strategic direction of the hydrogen value chain in South Africa. Further, large and carbon-intensive stakeholders such as Eskom and Sasol have indicated interest in investing in the green hydrogen value chain. Input industries have already begun to form with private sector firms having set up or being in the process of setting up manufacturing activities to supply electrolysers and fuel cells, which are at the heart of green hydrogen production.

While these efforts are notable and positive, for the green hydrogen value chain to materialise in a meaningful way and for ambitions to be realised, South Africa will require the necessary workforce and human capital input to feed into green hydrogen activities. To incorporate and take into account the necessity for a JET, and given that there is a high degree of unemployment in the economy, focus is placed on the technician and artisan level job prospects in the new and emerging green hydrogen economy. By assessing the human capital needs of industry, the institutions that provide support to artisans and technicians, such as the TVET system, can be increased in capacity to cater to the growing needs of the hydrogen economy.

Given the nascent domestic green hydrogen value chain, the analysis takes the approach of combining three key sources of information in order to scope the roles and associated industry skills demand. First literature sources are explored, which offer some insight into the types of artisan and technician roles that are likely to appear in the green hydrogen economy. The second source of information is drawn from job adverts in countries which are more advanced than South Africa in terms of their development of the green hydrogen value chain. These job adverts are sourced from large multinational firms. Finally, the roles were tested with market participants currently involved in the existing hydrogen value chain in South Africa to understand the appropriateness of roles to the South African context based on their understanding of market development.

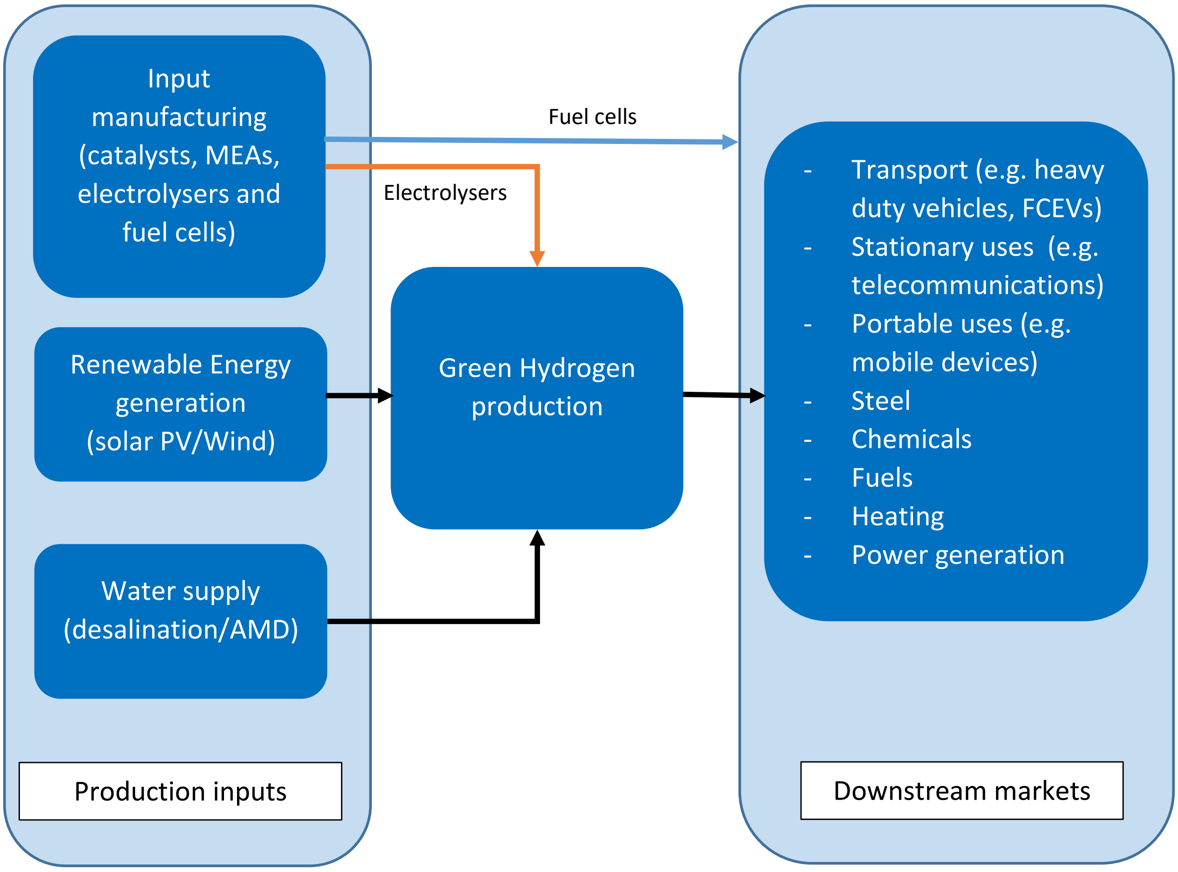
This report is structured as follows. Section 1 unpacks the green hydrogen value chain as it currently exists in South Africa and includes investment and technological dynamics where relevant. Section 2 turns to examining the skills that are anticipated in the green hydrogen value chain, discussing the input, production and downstream stages. Section 3 turns to an analysis of the TVET system and how programmes are structured. Section 4 then turns to a discussion from the analysis and insights on the way forward. Section 6 concludes.

Section 1: Value chain overview and activity

Following a value chain approach, the figure below segments the green hydrogen value chain based on inputs, production and downstream markets. This study focuses on the elements of the value chain that are specific to the green hydrogen production. This includes input manufacturing, production and downstream markets[2].

[2] For the purposes of the analysis the renewable energy input and manufacturing stages, and water inputs and manufacturing stages are not covered and beyond the scope of the paper.

Figure 1. Green hydrogen value chain



Source: TIPS

Notes: 1. Blue arrow indicates sale of fuel cell products and services directly to downstream markets for fuel cell applications. 2. Orange arrow indicates the sale of electrolyser products and services for the production of green hydrogen

Input manufacturing

Input manufacturing refers to the production processes that involve the production of green hydrogen generation systems and the systems which use hydrogen to produce energy. Specifically this refers to membrane electrode assembly, and the production of catalysts, electrolysers and fuel cells.

Box 1. Understanding green hydrogen and fuel cell technology

Green hydrogen refers to hydrogen produced via renewable energy-based electricity and electrolysis. Electrolysis is the process of using electricity to break up water into hydrogen and oxygen (United States DOE, n.d.). The principal inputs into green hydrogen production via electrolysis are electricity and water. Proton Exchange Membranes (PEM) are a newer technology which have superior properties than older electrolysis systems in certain applications. PEM systems, compared to older systems, also occupy less space, are capable of compressing hydrogen to a greater degree, and offer flexible operation (EC, 2018). This flexibility allows the system to operate with variable electricity supply. Despite these advantages, the PEM systems are costlier than older alkaline systems due to expensive electrode catalysts (like platinum and iridium), and by the need for membrane materials. The main cost drivers for PEM systems are the cost of catalysts and membranes. PEM systems nevertheless have seen popularity globally and account for the largest share of recent electrolyser installations since 2015 (IEA, 2019).

Fuel cell technology and hydrogen go hand in hand, since when hydrogen is used in a fuel cell, there are no associate emissions and this provides a sustainable form of energy where hydrogen is used to produce electricity. There are a number of applications where fuel cells are used and these include fuel cell electric vehicles (FCEVs), heavy-duty transport (e.g. trucks, buses), rail, flexible power generation systems, backup power systems (e.g. mobile telecoms towers) and building heating. The classification of fuel cell technologies are determined by the kind of electrolyte used in the system. Different applications have different requirements from the fuel cell, so fuel cell types are typically tied with a given application. Fuel cells include Proton Exchange Membrane Fuel Cells (PEMFC), Direct Methanol Fuel Cells (DMFC), Alkaline Fuel Cells (AFC), Phosphoric Acid Fuel Cells (PAFC), Molten Carbonate Fuel Cells (MCFC), Solid Oxide Fuel Cells (SOFC), and Reversible Fuel Cells.

The current input manufacturing space in South Africa has been developing rapidly recently, with a number of projects underway to increase domestic production of electrolysers and fuel cell systems. Current and emerging firms in the South African landscape are indicated below along with their input products.

Table 1. Input manufacturing firms in South Africa

Firm	Products	Location
HyPlat	Membrane electrode assembly (MEAs) for fuel cells and electrolysers, catalysts	Cape Town and Johannesburg

Firm	Products	Location
Isondo Precious Metals	Membrane electrode assembly (MEAs) for fuel cells and electrolysers, catalysts	Johannesburg
Hydrox Holdings	Alkaline-based water electrolysis systems	Johannesburg
Bambili Energy	Fuel cell systems for transport and stationary uses	Durban
Chem Energy SA	Fuel cell products for backup and continuous (off grid) telecom power solutions	Durban
Mitochondria Energy	PEM fuel cells and Solid Oxide Fuel Cells (SOFC)	Johannesburg

Source: TIPS

PEM-based electrolyser and fuel cell systems have seen popularity recently with a large proportion of new hydrogen production based on PEM electrolysers globally. The PEM-based route is seen as advantageous for South Africa, given South Africa's endowment of platinum resources, and given that the PGM-based catalysts such as platinum are used in PEM systems. There are some input manufacturers which also offer other systems such as alkaline and solid-oxide options.

Firms at this stage of the value chain aim to supply input components and full electrolyser and fuel cell systems to a number of downstream firms that include domestic hydrogen producers, telecommunications firms, electricity producers, automotive firms and serve the export market, where demand for electrolysers and fuel cells are growing.

There is currently a strong link between research and development (R&D) activities and private firms given that the input manufacturing market is fairly new in the South African landscape. HyPlat, for example, was formed as a commercial venture stemming from research activities linked with UCT and the HySA programme[3] in South Africa (UCT, 2020). Many ventures are headed by individuals with a scientific-orientation and strong research and industrial links. Based on engagements with input manufacturers, there is a strong appetite for new skills and capabilities across skills levels at this stage of the value chain.

Box 2. Isondo Precious Metal's investments in the input manufacturing stage

[3] HySA was initiated by the Department of Science and Technology in 2007, as a 15 year programme with the aim of developing the hydrogen and fuel cell economy. HySA has a strong focus on Research, Development, and Innovation (RDI) and aims to increase South African intellectual property, knowledge, human resources, products, components and processes in the hydrogen and fuel cell economy.

Isondo Precious Metals (IPM) has been designing a state-of-the-art facility to be opened in mid-July 2021, with production beginning in 2022 at the OR Tambo Industrial Development Zone. Initial production is anticipated to begin in June 2022 with the production of catalyst coated membranes (CCMs) and MEAs for fuel cells and electrolysers. Isondo was initially privately funded, however in 2016, the dtic provided support for feasibility studies. Isondo is ambitious to work with state partners in developing the domestic hydrogen value chain and works closely with the dtic in developing domestic capabilities.

PGM catalysts are a key input into production, and Isondo is planning on producing catalysts in-house to improve process efficiencies and reduce input costs. A PGM recovery and refining plant is also planned for the facility. Isondo will be a flagship production facility in the input landscape covering the entire spectrum of inputs into the hydrogen economy by 2023.

Isondo regards the domestic landscape as ideal for localisation with reduced reliance on imports to grow the domestic value chain and for the South African hydrogen economy to be competitive. Tertiary education, skills and technology within the country are regarded as ideal to leverage the hydrogen economy. Isondo draws on international networks and experts in the fuel cell, electrolyser, and catalyst space and uses experts to train interns and professionals.

Isondo's first intake of employees have been in highly skilled professions for the development side of the business. These include graduates with degrees in engineering and chemistry. Once operations commence, there will be increased demand for technicians and artisans, who are deployed in manufacturing including those technicians and artisans with mechanical, electrical, automation and robotic skills sets.

Hydrogen production

There is currently no commercial green hydrogen production in South Africa and existing hydrogen production occurs via fossil fuel-based routes. Despite this, a number of industrial players producing fossil fuels-based hydrogen have indicated interest in reducing their carbon emissions and supplementing with green hydrogen production in the short to medium term (5-10 years), with possible full-scale production beyond this time period (approximately beyond 2030). These views, however, are tentative given the rapidly evolving development of green hydrogen, both domestically and internationally. Further, private firms await the Hydrogen Society Roadmap to provide an indication of South Africa's strategic direction and policy intent. Specifically, incumbent firms and potential entrants await policy signals around: the planned targets for downstream markets such as fuel cell electric vehicles; power generation refueling infrastructure; hydrogen transport vectors (products (e.g. LOHC, ammonia) and transportation); export targets and markets; value chain development (upstream and downstream); and industrial policy measures (e.g. localization, industrial development zones, and incentive packages). The policy signals through existing initiatives such as the Hydrogen Society Roadmap (HSRM), and the current initiatives by dtic and the IDC are processes that firms are looking towards for such guidance.

Existing hydrogen production activities are detailed below to provide an indication of the existing production base and the current interest in green hydrogen.

Sasol produces approximately 2,7 million tonnes per annum of grey hydrogen at both its Secunda and Sasolburg plants with bulk of the production being reserved for captive (internal) use, within Sasol's existing production routes to produce chemicals such as ammonia and methanol. Around 2 400 technicians and artisans are employed across the Sasol grey hydrogen production sites, with the Secunda and Sasolburg employment split roughly 67% and 33%, respectively. At the Secunda site, coal and gas are used as inputs, and at the Sasolburg site, gas is used as an input. A small fraction, approximately 1% of production, is sold directly into markets for use in downstream industries. Sasol is currently considering how green hydrogen production will be phased into its production sites in Secunda and Sasolburg. Based on consultations with Sasol, green hydrogen can be easily incorporated in lower volumes through gradual supplementation with green hydrogen through water electrolysis, and used to produce downstream chemicals. Sasol is still assessing the ownership of assets and whether renewable energy generation infrastructure will be owned by Sasol or purchased through an IPP arrangement. Low volumes of green hydrogen feed-in are considered to be reasonably easy to integrate into the current production process. However, for higher volumes of green hydrogen input, the complexity increases as the process has to be made efficient and balanced with the existing grey hydrogen feed. In Sasolburg, hydrogen is already produced as a by-product with electrolysers and, according to the company, green hydrogen production for sale directly to the market could be relatively easily achieved. Investments will involve changing the energy input to renewable energy-based electricity and to retrofit the existing electrolysers, which are currently used to produce chlorine. A further progression towards developing the hydrogen value chain was Sasol's announcement in July 2021 of joining the Hydrogen Council, which is a CEO-led global initiative consisting of energy, transport, industry and investment companies with ambitions to develop the hydrogen economy globally.

In line with its green hydrogen developments, in April 2021, Sasol announced a partnership with Toyota to assess the feasibility of developing a green hydrogen mobility ecosystem in South Africa. The initial investigation is into establishing a mobility corridor such as the N3 route between Johannesburg and Durban for hydrogen powered heavy-duty long-haul fuel cell trucks along with refueling infrastructure (Sasol, 2021a). Sasol has also formed a partnership with the IDC for developing the green hydrogen value chain, which consists of developing upstream and downstream markets. In September 2021, Sasol further announced a partnership with Imperial Logistics, to explore options and solutions for improving freight sustainability and efficiency both domestically and within the region to create a green hydrogen ecosystem.

Afrox also produces hydrogen for sale in the domestic market, at its manufacturing plant in Pelindaba. The Pelindaba plant was upgraded in 2014 (at a cost of R14 million) modernising the technology. Linde, Afrox's parent company, has vast experience in producing grey, blue and green hydrogen internationally. In April 2021, a collaboration between Sasol, Linde, Enertrag, and Navitas was announced to bid for the production of sustainable aviation fuel (SAF) through the German Federal Government's H2Global auction platform. This involves the production of green hydrogen at the Secunda plant to produce SAF for export to Germany (Sasol, 2021b).

Another key industry partner that is allied with Sasol's hydrogen production is Air Products, which sources hydrogen from Sasol's operation and refines hydrogen to the specifications of downstream markets that include platinum refining, glass manufacturing and food processing. Air Products considers both domestic and export markets as important for development. Domestic demand is anticipated to be staged and gradual as supportive policies for fuel cell mobility for example are structured. Export demand is viewed as more proximal with countries such as Germany already indicating their interest in exporting green hydrogen. Cost parity with grey hydrogen is a barrier however, with investments likely happening beyond 2030, given that the cost-competitiveness of green hydrogen still has to occur.

Further, Air Liquide has a national presence, being involved in South Africa since the 1960s. Air Liquide has set goals for reducing its carbon footprint associated with hydrogen production with the aim of producing 50% of hydrogen by carbon-free processes by 2020.

Downstream consumers

Given that no green hydrogen downstream currently exists in South Africa, this section anticipates where demand for green hydrogen and fuel cells is likely to originate based on global trends of decarbonisation of existing value chains and the creation of new markets.

With respect to electrolyser-based green hydrogen, the existing value chains that can benefit from green hydrogen include those consumers within the petrochemical downstream that currently uses beneficiated hydrogen products such as methanol and ammonia. These include downstream consumers in the plastics, rubber, fertilizer and explosives value chains. Further, consumers in the oil refining industry can also benefit from green hydrogen to the extent that liquid fuels markets continue to see demand in the short to medium term. The use of hydrogen within the iron and steel value chains also stands to provide these consumers with lower carbon inputs into steelmaking. Here there is also the potential for new market formation around power generation, heating and transport.

Fuel cell markets do exist in South Africa, however they are currently focused on specific applications such as telecommunications back-up power and have room for substantial growth into other applications. Vodacom, for example has 300 fuel cell units, which provide backup power to its base sites (Engineering News, 2019). These systems are currently supplied by Chem Energy, whose subsidiary Chem Energy SA opened its fuel cell manufacturing facility at Dube Trade Port in 2020. Major future demand is anticipated from fuel cell mobility solutions. Here, developments are already underway with deployment of heavy-duty fuel cell forklifts and trucks by firms such as Impala Plats and Anglo Platinum.

Outside of the existing hydrogen production space, other energy sector participants have indicated interest in integrating their operations with hydrogen production. Eskom has begun looking at the decommissioning of the existing coal fleet and repurposing the power stations in line with the just transition narrative. As part of this process, green hydrogen is currently being investigated as an energy option for deployment at the power stations. Eskom is currently at the R&D stage with respect to development of green hydrogen activities and anticipates finalising its hydrogen strategy by March 2022. Crucial to its investments and direction is policy certainty which is anticipated by the Hydrogen Society Roadmap (HSRM) that is currently under development and in draft form. Eskom views green hydrogen as a promising, however early technology, which is still associated with substantial capex and opex costs, and requiring some period (from 2030 onwards) to be cost feasible. Currently hydrogen is imported or produced at some of the coal-based power stations and is used for cooling purposes. Based on engagements with Eskom, the current supply of hydrogen is insufficient for considerable green hydrogen production and downstream production of hydrogen products such as ammonia.

Eskom is further exploring potential projects in the Richard's Bay region, given the advantages of proximity to ports and reaching export markets such as the EU. The existing 100 MW Sere Wind Farm is also being investigated for expansions to solar PV generation along with potential coupling with electrolysers for green hydrogen production at the site. In August 2020 a tender was put out by Eskom for a 80 MW battery energy storage systems (BESS) at the Sere site, with an energy capacity of 320 MWh. Further, Eskom is still considering its positioning in the green hydrogen value chain and where it wishes to place itself. Consideration is being given to whether Eskom will confine itself to renewable energy-based generation with green hydrogen production to provide flexibility in generation, when wind and solar conditions are not optimal, or whether further downstream expansion into hydrogen products such as ammonia and fertilizers is feasible.

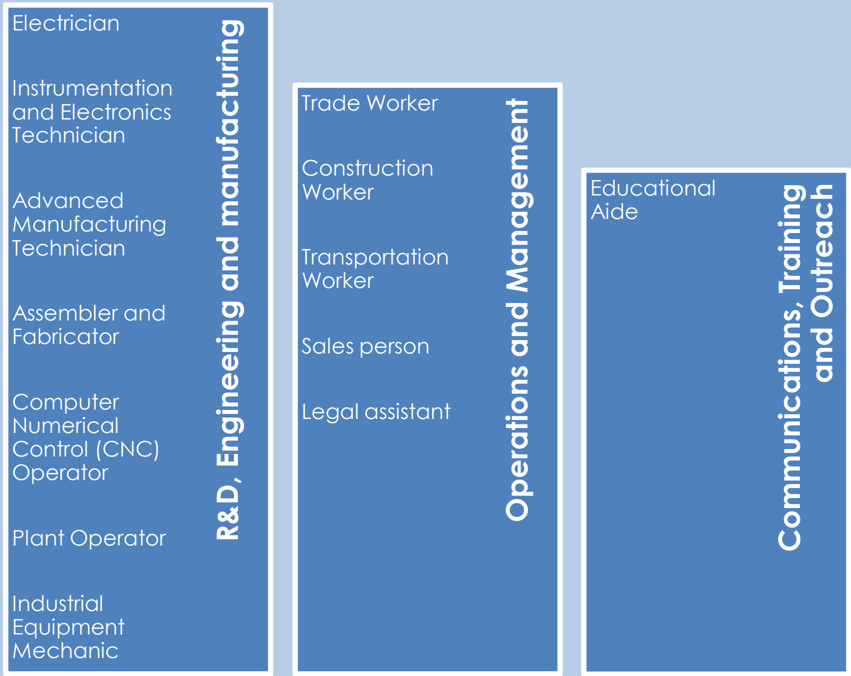
Section 2: Understanding the demand for skills in the emerging hydrogen economy

This section outlines the current and potential jobs and skills demand by mainly private sector firms based on interviews with industry participants at different stages of the value chain. Based on the value chain previously described, the skills demand is assessed at the input, production and downstream stages.

Box 3. Insights from the literature

Given that the interest in green hydrogen development is fairly new, with the latest surge in interest beginning in 2019, the literature linking the development of the green hydrogen value chain, with the demand for labour, skills and training has yet to be articulated in a significant way and is currently scant. The hydrogen and fuel cell economy is anticipated to create a number of new jobs and skills, however predicting the skills that will be demanded is complicated by the fact that many of these jobs do not currently exist, and the skills and education required are not catered to by existing jobs.

Figure 1. Mapping of hydrogen and fuel cells industry related jobs



Source: TIPS, based on (US DoE, n.d.)

(Bezdek, 2019) uses hydrogen economy jobs data from the US Department of Energy (DOE), which estimates the employment impacts of greater inclusion of hydrogen in the US economy from 2020 to 2050. The analysis includes examples of emerging jobs, salaries, and education and training requirements in the hydrogen and FC industries. While new and emerging hi-tech industries generally place a greater reliance on highly skilled employees, such as those with a Masters or Doctorate qualifications, (Bezdek, 2019) found that the hydrogen and FC industries, while still having a reliance on these high skills, also allow for employment creation for employees with associate's degrees, long-term on-the-job training, or trade certifications. The figure above indicates the job roles aimed at the technician and artisan level across the hydrogen value chain.[4]

In the analysis, (Bezdek, 2019) found that the average salary in the hydrogen and fuel cell industries is higher than the average in the rest of the US economy. In addition, the hydrogen and fuel cell industries were found to have a wide variety of occupations at all skill levels, showing potential for jobs that require less than a Bachelors/Masters/Doctorate level of education. Out of the 42 jobs assessed across skills and education levels, 19 were found to require either high school degrees, general education development, on-the-job-training, trade school, apprenticeships, or associate's degrees.

As part of the UK-PACT project, a TVET-Industry Skills Gap Analysis was conducted by Bambili Advisory which shed light on the demand for skills in the green hydrogen economy in South Africa. The analysis identified skills needs in advanced manufacturing, the design and

[4] A table inclusive of all roles and salaries is displayed in the Appendix.

manufacture of fuel cells or hydrogen-driven and Platinum Group Metals (PGMs) batteries (Bambili, 2021). In addition skills demands in transportation applications using fuel cells and some building heat and power applications.

Input manufacturing

There are a number of encouraging developments at the input manufacturing stage, with new infrastructure being set up by firms such as Isondo Precious Metals, HyPlat, Chem Energy SA, and Bambili Energy. The input stage refers to the manufacturing of components that feed into hydrogen production and downstream industries. This refers to membrane electrode assembly (MEA) and the production of catalysts, electrolysers, and fuel cells.

As indicated in the preceding section, while demand for skills is highly oriented towards skilled labour currently, increasing demand for artisans and technicians is anticipated at the input/manufacturing stage. Firms at this stage of the value chain generally categorise the workforce as being involved in development or operations. Development activities involve the design of systems and processes, while operations refer to the activities that involve the actual manufacturing of products. Development activities draw highly skilled workers, generally those with degrees and post-graduate degrees specialising in MEAs, catalysts, electrolysers, and fuel cells. Demand for technicians and artisans materialises in operations where employees are involved in assembling and producing the finished products (See Table 4 below). Given the nascent input manufacturing space in South Africa, the roles of artisan and technicians at this stage will involve new job roles and will require new sets of training requirements and programmes to be developed.

Training currently occurs in-house where firms hire artisans and technicians and provide the necessary skills to contribute to operations. HyPlat, for example, currently trains artisans in-house with respect to catalyst preparation, coating, gasketing[5] and Gas Diffusion Layer[6] (GDL) application and packaging. Isondo Precious Metals is soon embarking on scoping artisan and technicians for deployment into their operations. Training time can vary from a few weeks to a longer period and is dependent on complexity of the tasks involved.

Encouragingly, firms at this stage of the value chain have a strong appetite for training artisans and technicians to feed into the hydrogen economy. Input manufacturing firms indicated a positive sentiment towards working together with the TVET system to co-create the necessary skills and capabilities for artisans through learnership and internship programmes. External funding, however, was highlighted as imperative as many firms are new and would require additional support for such a programme to be feasible. In some cases, where partnerships between academia, government and firms exist, the necessary mandate will have to be

[5] Gasketing refers to the process of installing gaskets in a fuel cell system. This prevents potential fuel leaks and improves efficiency.

[6] Gas Diffusion Layers are vial components of a fuel cell and electrolysers. These layers improve electrical conduction, prevent corrosion and control the mixing of gases.

included for firms to engage in training. Given the specialised nature of MEA, catalyst, electrolyser and fuel cell manufacturing, artisan training is done in-house currently. Based on engagements with firms, the TVET system can play a role in creating the base of skills and theoretical knowledge for technicians and artisans, which can be followed by on-the-job training done within firms to orient technicians and artisans towards firms' individual needs.

Engagements with industry participants combined with a review of the job opportunities in countries with existing green hydrogen projects, have revealed demand for the following skills and capabilities that can be provided through the TVET system.

Table 2. Skills gap analysis at the input manufacturing stage

Function/title	Description	Skills needs
Electrolyser stack assembly technician	Building and manufacturing of the core component in electrolysers	- Manufacture and building of electrolyser stacks - Conducting pressure tests of stacks - Stock control - Assessing quality of components - Cleaning of components - Maintenance of machines
Fuel cell stack assembly technician	Building and manufacturing of the core component in fuel cells	- Assembling and testing fuel cell stacks for hybrid hydrogen Fuel Cell applications (e.g. FC vehicles) - Power module testing for applications (e.g. mobile applications)
Gas Diffusion Layer (GDL) technician	Building and manufacturing of GDL	- Catalyst ink preparation - Coating and gasketing of GDL
Coating technician	Application of coating to catalyst coated membrane (CCMs) used in PEM electrolysis	- Fabrication of CCMs - Maintenance of CCM equipment - Ensuring adequate stock supply - Understanding and implementing safety standards in practice
Fuel Cell Sealer	Assemble and seal fuel cells	- Preparation, sealing and testing fuel cells. - Performs fay surface, pre-pack, injection, fillet and brush coat aircraft sealing operations according to oral and written instructions and standard practices. - Assemble sheet metal to build up fuel cells including drilling, countersinking, fitting, trimming, and riveting - Engages in cleaning procedures prior to sealing using specified materials (e.g. solvent, lint-free cloth, pipe cleaners and/or funnel brushes) - Tests fuel cell and leak checks. - Perform rework required to remove old sealant, re-clean and re-seal to prevent leaks and failure of parts.

Function/title	Description	Skills needs
		- Use various sheet metal hand and power tools, sealing tools, scrapers, rollers, sealing gun, fairing tool and durometer
Systems integration technician	Integrating fuel cell and electrolysers into energy systems	- Characterisation of the fuel cell stack system and specific sub-units for integration into systems. - Sourcing and testing components for 'Balance of Plant' for integration into complete systems.
General assembly technician	Conduct assembly of products, inspection and maintenance	- Perform assembly of products based on specifications and instructions. - Selection of materials to complete standard work. - Identify and implement improvement ideas. - Use inspection equipment to inspect finished work. - Use equipment to accomplish assigned tasks. - Maintenance of equipment - Evaluating and modifying production processes and/or equipment for efficiency. - Quality inspections and resolution of faults - Ensure compliance with health and safety laws, regulations, and best practices.
Field service technician	Support fuel cell products for consumers, including performing preventative maintenance and resolving breakdowns	- Maintenance and service of fuel cells at customer sites. - Performing diagnostics, troubleshooting, and evaluations to maintain fuel cells. - Performing specialised service procedures, e.g. field retrofits and software/hardware upgrades. - Procurement of tools, equipment, and parts for customer service and support. - Problem solving and maintenance of high-pressure hydrogen storage, delivery and fueling systems. - Completing administrative duties and documentation, including: incident reports, service logs, inventory maintenance and site and system documentation.
Shipping & Receiving Specialist	Receiving of goods, quality inspections, and inventory	- Receipt and processing of polymers (powder), membranes (sheets & rolls) and other supply inputs - Inspection of membranes for defects - Inventory organisation for supply inputs - Preparation of polymers and membranes for consumers - Procurement of polymers, membranes and lab materials. - Preparation of shipping documents, packing and shipping polymers and membranes to consumers.
Material Handler (e.g. Forklift Driver)	Manage the flow of input parts into warehouse facilities and supply inputs into production plant	- Forklift operation - Updating inventory and documentation based on movement of parts - Assessment of ideal storage and handling methods for parts. - Meet cleanliness, safety, and accuracy requirements of assigned area

Function/title	Description	Skills needs
		- Train others in the use of warehousing equipment, techniques, processes of workflow, procedures, etc. - Perform analysis to assess and improve the process, accuracy and work flow. - Perform preventative maintenance for forklifts such as checking battery, oil, LP gas, hydraulic fluid
Chemical laboratory assistant		Provide support to laboratory team in: - Sourcing, testing, validation and development of stack materials including membrane, MEA, GDM, electrodes, BPPs, flow geometry and stack hardware - Development of stack product platform for commercial applications - Design calculations of fluid thermodynamic properties including flow rate, temperature and pressure - Stack product development and plate design - Maintain environmental health and safety within the laboratory
Fuel Cell Laboratory Technician	Safe construction, operation and maintenance of laboratory equipment	- Fabricate fuel cells and stacks - Build, operate, and troubleshoot test stations and systems - Set up, calibration, operation and maintenance of laboratory, and pilot scale equipment - Knowledge of safety policies - Development of Standard Operating Procedures and laboratory hazard reviews - Data collection, organisation and recording of experimental details - Experimental system design working with an engineer or scientist - Evaluation of experimental results for adjustment of conditions and identification of trends - Operate lab equipment using Excel for data acquisition and reporting - Ability to work in a multi-disciplinary team to ensure safe, accurate, and timely completion of individual assignments and team goals
Production Operator	Operates equipment to assist with the assembling, manufacturing, processing and packaging of items along the production line.	- Perform light activities required for proper location of individual components. - Knowledge of automated hand tools operation (e.g. to secure components to equipment). - Attach/remove components to/from equipment to coat, clean, braze, or conduct leak checks. - Oven operation for products to ensure efficient operations. - Load/unload various racks, conveyors and pallets in support of production. - Loading components onto presentation devices (flow racks) to support operator - Inspection of components/assemblies for quality control.

Function/title	Description	Skills needs
		- Packing and labelling of completed - Cleaning of work stations and production machines.

Source: TIPS based on stakeholder interviews and triangulation of input manufacturing job adverts in Australia, US, Germany, Canada, and India

Hydrogen production

Existing firms that produce hydrogen via the fossil fuels-based routes have indicated intentions to introduce green hydrogen production into their processes. These include announcements by Sasol and Afrox/Linde. At the hydrogen production stage, hydrogen is currently produced from natural gas or coal and is then used to produce input chemicals into the chemicals value chain, such as methanol and ammonia, which is then used to produce fuels, explosives, fertilizers and an array of other chemicals. Hydrogen is also used for steel production currently.

A similar skills demand evolution is indicated at the hydrogen production stage with initial demand amongst firms for highly skilled labour, with Bachelors, Masters and Doctoral degrees, with specialist skills in designing, planning and optimising green hydrogen systems for potential deployment. Once operations have commenced, demand for technicians and artisans will increase given their roles in operations of systems. The demand for artisan and technician skills in hydrogen production include roles in mechanical, electrical, logistics, production and warehousing (See Table 5 below).

Responses from firms at the hydrogen production level indicate that many roles already exist within the production process and that internal labour will be sought and re-trained and re-skilled for new production roles, before new labour is hired. The roles span process (e.g. operators, controllers, foremen), maintenance (e.g. machinists, welders, electricians), logistics (e.g. forklift drivers, stock control), and supportive roles (e.g. lab assistants). Further, firms have detailed knowledge and systems in place for managing and handling of gaseous and liquified material at scale, and these skills will transfer over to the production of green hydrogen. Firms have also indicated expertise in water and brine treatment systems, along with operating electrolytic systems for the production of other chemical products. Electrolytic systems are currently calibrated for the production of other products (e.g. chlorine), and will have to be adapted to produce hydrogen. Technicians and artisans in the existing hydrogen production processes are trained with a combination of TVET training, and in-house training. In house training in chemical operations is typically carried out for a period of approximately 12 months. In-house training is required to familiarise employees with production processes and plant operations.

Firms at this stage are optimistic about training programmes for the hydrogen economy, with some firms already announcing partnerships that involve training for the development of the hydrogen economy. Technicians and artisans are trained in skills for chemical operations, millwrights, diesel mechanics, fitting, electrical skills, and fabrication. Hydrogen-producing firms already use the TVET systems for training purposes and will continue to do so as green hydrogen activities increase. It is estimated that many of the current roles will be able to be repurposed for hydrogen production and that the existing skills base at the production stage will not require a substantial overhauling. Where new skills are required, firms have identified electrical, plumbing, construction and metal work programmes for upgrading. The focal areas also can be segmented according to energy efficiency, renewable energy, planning and integration. Energy efficiency includes skills in energy saving, energy efficient heating and ventilation systems. Planning and integration skills refer to the skills required for integration of different technologies (e.g. integrating grey and green hydrogen).

Engagements with industry participants combined with a review of the job opportunities in countries with existing green hydrogen projects, have revealed demand for the following skills and capabilities that can be provided through the TVET system.

Table 3. Skills gap analysis at the hydrogen production stage

Function/title	Description	Skills needs
Filling Plant Operator	Technician that is responsible for the management of filling of cylinders	- Preparation of cylinders, quality testing, and cleaning and labelling. - Filling cylinders including start up and shut down processes. - Quality and safety checking of cylinders. - Safety issue reporting to production or safety managers. - Inventory recording and fault reporting - Process improvement functions including identification of any non-compliance, sourcing problems and the proposal of solutions.
On site technician	Responsible for the safe, reliable, and efficient operation of hydrogen production plants	- Maintenance of all safety, quality, and compliance activities. - Initiate and conclude process start up, shutdown, and operation. - Conduct routine maintenance and calibrations on a variety of process equipment - Problem solve and repair defective equipment, electrical components, and production processes. - Planning and executing operations and maintenance tasks for assigned plant - Product and maintenance procurement - Conduct monthly plant billing activities
Maintenance technician	Conduct maintenance of production equipment	- Ability to install, troubleshoot, repair mechanical equipment and facilities - Ability to use hand, power, and machine tools to problem solve and repair mechanical equipment and systems. - Knowledge of disassembly and reassembly of rotating equipment, pumps, gearboxes, and compressors to repair or replace bearings, gears, seals, and structural components. - Ability to read and understand blueprints. - Preventive and predictive maintenance on equipment and mechanical systems. - Knowledge of using computerised systems to plan and conduct maintenance activities. This includes part procurement, supervision of maintenance tasks, and documentation.

Function/title	Description	Skills needs
		- Complete some repairs of mechanical piping systems including threaded and welded pipe systems.
Store and sales coordinator	Building consumer relationships developing business markets	- Conducting administrative duties such as managerial support, monthly inspections, logistics organisation and restocking of inventory. - Organisation of demonstration product displays - Driver dispatching processes and logistic team communication. - Consumer advice on products, prices and availability with product technical knowledge. Processing of sales orders/ - Preparation of quotations and tender documents. - Marketing of sales promotions and other sales activities (e.g. cold calls) - Post sales services (e.g. consumer surveys)
Field Service Technician	Installation and maintenance of bulk gas supply systems, piping installation and sales.	- Pipe and gas fitting skills - Interpreting mechanical and electrical drawings - Welding and brazing skills - Problem solving electronic and computer operated controls and instrumentation - Manage contractors and projects
Site electrician	Electrical maintenance	- Electrical maintenance on batteries, hydrogen fuel cells and power electronics systems - Modifications and electrical maintenance to projects - Diagnostics & fault finding in electrical systems - Conduct activities in accordance with safety policy and procedures - Provide continuous improvements to electrical systems - High voltage DC systems knowledge
Mechanical Fitter	Fit and assemble metal parts to fabricate production machines and other equipment.	- Ability to conduct light fabrication - Ability to work with Computer Numerical Control (CNC) systems that use programmable devices, computers, and robots on the factory floor. - Use blueprints to set up machines - Machine monitoring for faults - Operation of metal, plastic molding, casting, or coremaking machines - Inspection and testing of finished workpieces to specifications
Tanker driver	Operate machinery that transports hydrogen and other gases/liquids	- Possess a license. - Knowledge of tanker and/or tractor trailer driving. - Hazmat and Tanker endorsements - Knowledge of defensive driving tactics - Clean driving record - Physical endurance to lift up to 50 pounds.
Shift supervisor	Mentoring and assisting in on-the-job training	- Oversee personnel required to complete scheduled work - Conduct training and development of employees - Conduct physical inspections and preparation of reports on equipment and operations - Evaluates personnel daily activities for performance

Function/title	Description	Skills needs
		- Ability to operate equipment and prepare laboratory analysis - Understanding of safety risks to employees and environment - Maintenance of required certifications in compliance with regulatory bodies
Logistics planner	Monitors stock levels and ensures efficient delivery of products	- Assess customer demand for adequate inventory levels - Identify solutions to customer service problems and scheduling conflicts - Maintenance of planning and forecasting data - Generate delivery plans - Understand routing software for operation performance. - Understand electronic and telecommunications technologies to ensure deliveries arrive safely and on time. - Use systems to indicate to drivers traffic problems, accidents, congestion, weather conditions, and other hazards.

Source: TIPS based on stakeholder interviews and triangulation of hydrogen production job adverts in Australia, US, Germany, Canada, and India.

Downstream users

The current markets for certain types of hydrogen economy products, such as fuel cells, do exist, however these are currently limited and confined to specific applications such as back-up power systems for telecommunications. There are no current markets for green hydrogen downstream products as green hydrogen is not commercially produced in South Africa currently.

It must be noted that as new markets evolve both domestically and globally it is likely that new roles for technicians and artisans will appear. Job roles emerge in a number of value chains, which include the automotive, heavy-duty transport, maritime, aviation, and power generation value chains.

Given the policy focus globally, demand for roles within the automotive (FCEVs) and heavy-duty vehicle sectors are likely to emerge and increase initially as these value chains are developed.

Table 4. Skills gap analysis in downstream hydrogen economy markets

Function/title	Downstream sector	Skills needs
Fuel Cell Technician	Automotive	- Vehicle instrumentation knowledge - Ability to acquire vehicle and station performance data - Conduct on-road vehicle evaluations and hydrogen station testing

Function/title	Downstream sector	Skills needs
		- Conduct and support chassis dynamometer testing (e.g. vehicle set-up & dyno testing) - Order vehicle parts and manage inventories - Problem solving and repair of vehicle mechanical and electrical systems - Perform maintenance of Fuel Cell vehicles and coordinate with dealerships to schedule services - Issue periodic general and technical reports
Test Cell Operator/Mechanic	Automotive	- Disassemble and reassemble engines and other powertrain system hardware - Setup and update test engine hardware for dyno testing - Setup and operate data acquisition and associated software - Perform engine services and health checks throughout testing - Maintain daily logs on all running engines and test components - Responsible for the quality and integrity of data generated - Maintain inventory of parts needed for testing
Automotive Inspector and Packer	Automotive	- Parts inspection and assessment against customer specifications - Process stoppage if product is non-conforming - Packing parts according to instructions
Heavy Duty Vehicle Test Technician	Heavy duty transport	- Support vehicle test laboratories for fuel cell and self-driving trucks - Installing and setting up tests and rigs for fuel cell trucks and heavy vehicles - Assist in conducting vehicle tests - Collect data from tests - Troubleshooting problems
Bus Assembler	Heavy duty transport	- Knowledge of line installations and assemblies - Perform all installations and/or assemblies within a specified work area. - Perform assembly duties from blueprints, process sheets, and/or written instructions. - Knowledge of hand air tool use - Physical strength to regularly lift and move up to 10 pounds, frequently lift and move up to 25 pounds and occasionally lift and move up to 50 pounds - Ability to bend, stoop, reach, climb up and down, and use a ladder
Fuel Cell and Liquid Hydrogen Safety Engineer	Aviation	- Define safety guidelines in a safety and reliability plans. - Conduct safety assessment processes, including functional safety, risk analysis and zonal safety analysis - Interact with internal teams, suppliers, subcontractors and partners. - Support design processes to ensure compliance to safety processes and airworthiness regulation

Function/title	Downstream sector	Skills needs
Remote Monitoring and Control Center Operations Technician	Stationary (e.g. Power Generation, backup power)	- Engage in remote monitoring of on-site power generation units - Respond to system alarms and conduct system actions - Identify and assess system issue causes, support field service technicians, and troubleshoot issues remotely - Engage with electrical, mechanical and chemical sub-systems of power generation systems - Maintenance of event logs - Escalation of complex issues to supervisors and other groups
Mechanical Assembler	Stationary (e.g. Power Generation, backup power)	- Performs electronic, electro-mechanical, mechanical or measurement product assembly operations on equipment (e.g. product components, assemblies or sub-assemblies) - Performing wiring, component installation, welding and fitting on assembly units. - Setup and adjustments based on blueprint specifications. - Performs hands-on manufacturing tasks ensuring quantity and quality standards and requirements. - Performance of essential functions in line with safety standards - Follows work instructions to meet production requirements - Interpretation of drawings (or blue prints) as required.
Operations and Maintenance power plant technician	Stationary (e.g. Power Generation, backup power)	- Performs all required checks and line-ups prior to starting the heat-up process. - Performs the set-up, calibration, testing and troubleshooting of circuits, components, instruments and mechanical assemblies. - Determine and develop test specifications, methods and procedures from blueprints, drawings and diagrams. - Tests and troubleshooting assemblies including final systems. - Complete rework on assemblies and systems based on testing. - Preparation of technical reports with findings and recommending solutions to technical problems. - Assist in the selection and set-up of test equipment. - Operates mobile equipment including forklifts, cranes and other mechanical assisted lifting devices. - Procurement of parts and materials used in the operations. - Assisting in writing procedures and other technical documents - Performs maintenance activities

Function/title	Downstream sector	Skills needs
Power Plant Field Service Technician	Stationary (e.g. Power Generation, backup power)	- Perform mechanical, electrical and instrumentation work on sites for repair, installation and/or commissioning of fuel cell power plants, including system hardware and software, equipment and systems networking. - Knowledge of safety, health, environmental and quality regulations. - Assisting in power conditioning of fuel cell power plants. - Provide technical support to customers on operational or maintenance aspects of system equipment. - Analyse plant equipment and system operating characteristics to determine operational conditions. - Repair and overhaul of generating equipment and components. - Engage with customers on technical and service challenges. - Diagnose mechanical, hardware, software and systems failures. - Determines cost effective repair/resolutions to minimise customer downtime. - Prepares status reports on plant conditions and work.

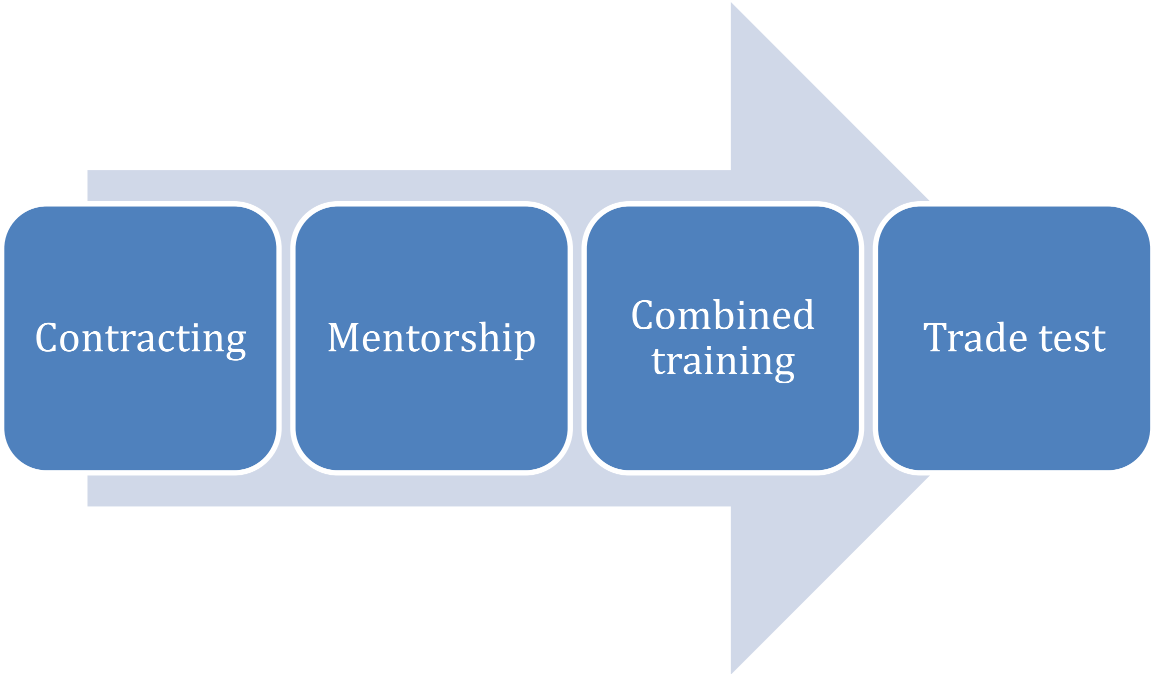
Source: TIPS based on literature review and triangulation of hydrogen production job adverts in Australia, US, Germany, Canada, and India.

Section 3: Understanding the TVET system dynamics in setting up new programmes

TVET colleges want to be more responsive to changing trends and modernise the curriculum. There is a strong desire from the Minister of Higher Education, Science and Innovation to enhance the responsiveness of Colleges. This would also include the hydrogen economy as an emerging sector. The Centre of Specialisation (CoS) programme was initiated in 2019 and has its roots in the German dual system model (DHET, 2016). The dual system model in vocational training combines theory, practical and on-the-job training. A central feature is cooperation between private companies and publicly funded vocational schools in providing technicians and artisans a combination of theoretical and on-the-job training (BMBF, n.d.). These programmes range between 2.5 and 3 years to complete.

The dual system model has a number of supportive and innovate features, as depicted below.

Figure 2. Key features of the dual system vocational model



Source: TIPS, based on (DHET, 2016)

Contracting refers to agreements established between learners, educational institutions and private firms, which afford the learner exposure to theoretical, practical and on-the-job training. The contracting happens at the beginning of the qualification to ensure that the learner has a site for on-the-job training to occur. The dual system also involves mentorship arrangements where registered mentors guide learners throughout the duration of the programme towards completing the programme successfully. The hallmark of the dual system is a sufficient allocation of on-the-job training within the time frame of the qualification. This involves learners working within a private firm to gain experience of the job role that they will occupy in the future and orients learners to the needs of actual roles that they will be hired for upon completion of the qualification. This crucial step aligns the needs of industry with the supply of skills provided through educational institutes. Once the learner has gone through the dual model system, a trade test is written to ensure that the learner has the sufficient knowledge and experience to practice as an artisan or technician. Fundamental to the success of the dual system model is a strong relationship between learners, educational institutions and industrial firms.

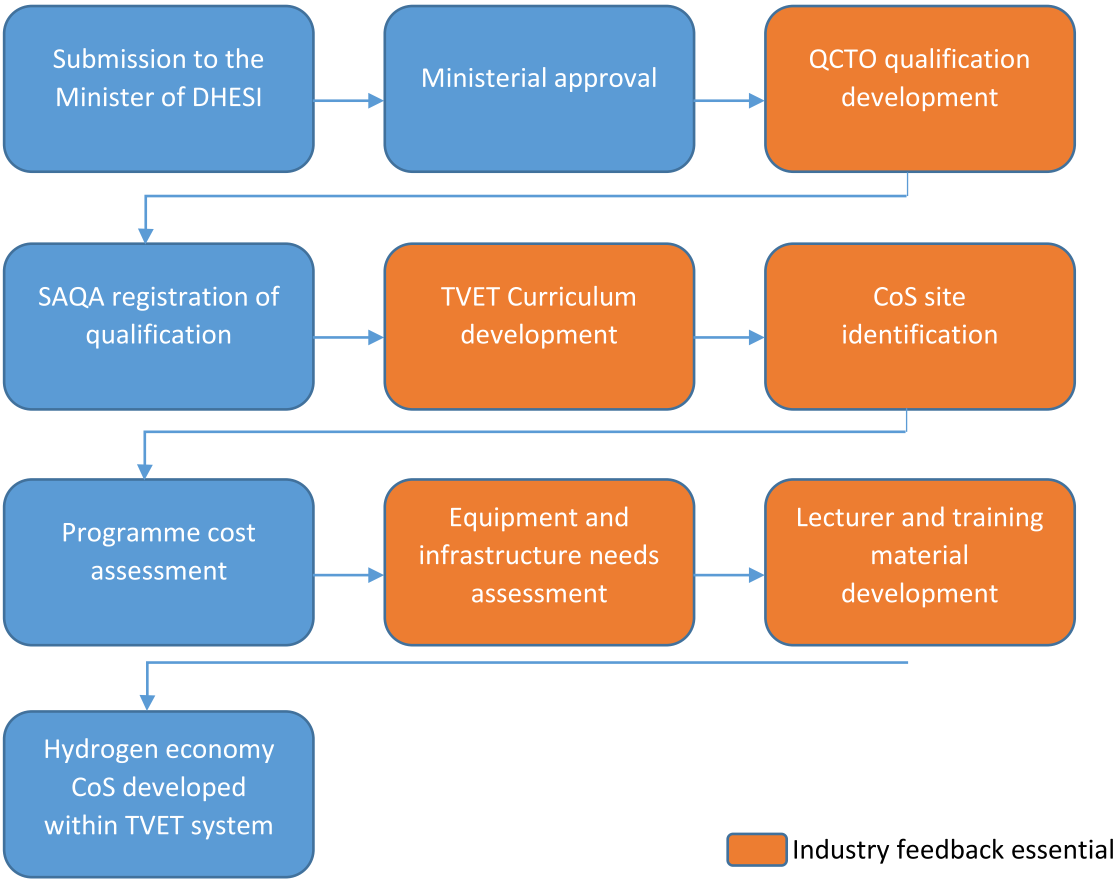
The Centre of Specialisation programme was rolled out in 2019 with the aim of reducing the time taken to gain a qualification, and including a larger proportion of on-the-job training. With the existing NATED and NCV programmes, students have to do two years of on-the-job training after their theory/practical studies should they wish to become a qualified artisan. The CoS programme allows for students to complete their on-the-job training within the three-year course and complete the trade test which allows them to practice within their fields and be employed. The current complement of students within the CoS programme in South Africa account for less than 1% of students, with the remainder of students split between the older NATED and NCV streams.

The CoS route is regarded as a desirable channel for artisan and technician training for the hydrogen economy as industry participants have pointed to the important need for technicians and artisans to have on-the-job experience, particularly given the new nature of the industry and lack of current wide-scale training taking place. Since the CoS route aims for a higher percentage of on-the-job training than NATED and NCV programmes, it is vital for the DHET to have allied industrial partners that are willing to provide roles for technicians and artisans to fulfill this portion of the programme. Without the industry experience, artisans cannot compete their training and write the trade test.

Funding for the programme is currently provided from two sources. DHET covers the theoretical component of programmes, while the SETA system provides the funding for the on-the-job training component.

In order to setup a hydrogen economy CoS, an internal flow of decision-making would need to occur within DHET, which is depicted in the flow diagram below. There are various stages of the CoS development that would require industry input to create the skills base required by industrial participants in the hydrogen value chain.

Figure 1. Stages of hydrogen economy CoS development within DHET



Source: TIPS, based on engagements with DHET

The first step involves a submission from the TVET unit within DHET to the Minister to set up a hydrogen economy CoS and extend the current programme. Based on interactions with the TVET unit, the Minister has identified the need for modernising the TVET curriculum and for the previously distinct departments of Science and Innovation and Higher Education and Training to work in harmony. Given that DSI is currently driving the HSRM, this synergy makes sense when applied to developing the hydrogen economy CoS, and for DSI to play an informative role in the CoS development directly and through the established HySA ecosystem.

Once ministerial approval is granted for the hydrogen economy CoS, then the Quality Council for Trades and Occupations (QCTO) would oversee the design, implementation, assessment and certification of occupational qualifications within the hydrogen economy. The QCTO is regarded as the custodian of occupational qualifications and they would approve a new set of qualifications required to be designed. The QCTO would assess the qualifications required in the green hydrogen value chain in relation to the qualifications that currently exist. The result from the assessment would indicate whether the qualification currently exists or whether it needs to be accommodated within an existing qualification or structured as a separate post-qualification specialisation. This process typically involves some form of industry input to determine the needs of industry and ensure alignment of qualifications with demand for these qualifications. Once the qualifications have been through this process, SAQA registers the qualification. The process from ministerial approval until SAQA registration takes at least a year, particularly if a new programme is being formed.

Once a qualification is registered, the TVET system develops occupational title work packages based on the qualifications required and the structure of the program. This involves decisions on the length of courses and the number of courses within qualifications. The next stages involve the actual setting up of the programme, including identification of suitable sites for the training to be housed within the TVET college system, negotiating funding mixes between the TVET and SETAs, and setting up of infrastructure and equipment. This process should also involve interactions between industry and other government departments around the likely investments in the hydrogen economy, particularly for qualifications related to input manufacturing, involving fuel cell and electrolyser systems. The setting up of infrastructure and equipment tends to be significantly costly for the TVET system if new equipment and infrastructure is required, which will likely be required for the hydrogen economy, particularly for qualifications related to input manufacturing, involving fuel cell and electrolyser systems. Previously, for new equipment and infrastructure, the National Skills Fund has been leveraged to fund these costs. Lecturer development involves assessing the skills possessed by educators, and upskilling where necessary and hiring additional capacity. Course materials are also developed at this stage. The latter process, where the TVET system develops the actual CoS, typically takes a couple of months.

The overall estimate on the time to set up a CoS for the hydrogen economy can range from one to three years in practice particularly where the setup of new qualifications and programmes are required. Based on interactions with the TVET unit, CoS programmes flourish when they are driven by an industry body or industrial champion. Here DSI, HySA or an established industry body consisting of industrial partners in the hydrogen value chain would need to be leveraged to assist in driving the creation of a CoS for the hydrogen economy.

It is important, in this discussion, to also account for the role of SETA's which play an important role in bridging industry needs with the TVET system. EWSETA, which covers the energy and water sectors, for example, conducts in-house research and regularly engages with industry to feedback needs to the TVET system. The SETA structures for sectors conduct skills assessments, and provide mandatory and discretionary funding to firms that engage in training and skills development. Here their role in policy development is paramount and a full policy review of the policy environment as it pertains to the development of a green hydrogen CoS will be covered in a following workstream.

Section 5: Discussion and insights

South Africa is still at an early stage in its (green) hydrogen development, with a heightened interest in the development of a hydrogen value chain from all stakeholders in the economy. Certainly in countries where hydrogen development has occurred, champions within the governments and from industry have driven forward initiatives in collaboration. Fortunately South Africa has a good base to work off of as DSI and the HySA programme have been involved in developing the hydrogen economy for a number of years, laying the foundation for the formation of the green hydrogen economy. With the notable decline in the cost of renewable energy in the past decade, the case for green hydrogen has become stronger. This has led to a number of countries formulating their roadmaps and positioning themselves as producers and consumers of hydrogen.

In the course of developing the hydrogen economy, the requisite skills base will be required to be absorbed into production activities. While new and high technology industries have a high demand on skilled labour, there are a number of roles for artisans and technicians in the hydrogen economy, particularly where they relate to involvement in the production of products and services throughout the hydrogen value chain. Based on a review of the literature, engagements with industry partners, and the higher education system the following insights are gleaned to develop the TVET system to supply artisans and technicians into the hydrogen economy and associated value chains, and increase their supply.

Setting up of a dedicated CoS programme aligned with green hydrogen investments is required. Given the nascent green hydrogen economy in South Africa, a dedicated CoS programme should be set up within the TVET system and the sites of the programme should be aligned geographically based on the likely sources of demand for these skills and qualifications. These sources will be informed by the planned investments into the hydrogen economy which will be informed by the HSRM, industrial policy measures to support the hydrogen economy and activities by the private sector. To date the emerging centres of demand are likely to be around Sasol's operations in Secunda and Sasolburg, the N3 corridor from Limpopo to Durban and around key ports such as Richard's Bay, Durban, Saldanha and Coega. The CoS could, for example, be located along the N3 corridor from Limpopo to Durban where the planned Platinum Valley is expected to be located, or proximal to Sasol's Secunda site where green hydrogen production is likely to initiate at pilot scales. These CoS locations could be potentially used as pilot training spaces to trial initial new CoS programmes and then scaled based on future investments.The newly-announced Renewable Energy Development Zones proposed by CSIR also could be targeted for a CoS, contingent on renewables and green hydrogen investments occurring there.

Skills and capabilities at the input and manufacturing stage would likely require the development of new and specialised programmes. Investigations into the hydrogen value chain as it exists currently in South Africa point to the need for new qualifications at the stage where essential components such as electrolysers and fuel cell systems are manufactured. These roles refer to those on the factory floor and involve skills around fuel cell and electrolyser stack assembly and catalyst coating for example. Firms, such as Isondo Precious Metals, HyPlat and Bambili energy, already train technicians and artisans internally, and should be leveraged in the formation of a CoS programme along the various stages of decision-making and programme formation.

At the hydrogen production stage, there is substantial overlap with existing skills in process operation, instrumentation, mechanical, and electrical roles. Existing roles for technicians and artisans within the various production activities already exist and it is likely that existing qualifications through the TVET system may be modified to include applications for the green hydrogen economy or post-qualification specialisations developed to focus on green hydrogen production. Based on engagements with hydrogen producers, on-the-job training can impart the required skills needed for technicians and artisans in green hydrogen production to upskill them on aligning skills with those of the hydrogen economy.

A green hydrogen champion is required to drive the development of the CoS programme. To increase the likelihood of successful development of the green hydrogen value chain, the CoS should be driven by a central partner. Likely candidates for this role include DSI/HySA who have been the champions of hydrogen economy development in the country thus far. This role could also be championed by a dedicated industry body set up for the hydrogen economy, a new programme within an existing industry body such as the Chemical and Allied Industry Association (CAIA), or by a large industrial player embedded in the hydrogen value chain such as Sasol. Based on investigations in the setup of CoS programmes, a dedicated driver of the process has numerous benefits. The champion can coordinate amongst industrial partners to align industrial needs from the TVET system, motivate for time efficient and fast-tracking of the setting up of the programme, and align available technical and financial resources to areas of need.

The link between the TVET system and industry would have to be cemented and maintained over time. Following its inception, there would be a strong need for the hydrogen economy CoS to be dynamic and responsive to changing technology and market developments that inform industry demand for technicians and artisans. A strong industry-TVET relationship improves employment outcomes for technicians and artisans coming out of the TVET system and creates the sufficiently equipped labour pool required by industry. Here, the formation of industry body for (green) hydrogen can also assist in creating the necessary link for the TVET system to receive feedback from industry and adjust qualifications and programmes where needed. This will be required for the development of the green hydrogen value chain since a number of downstream markets have yet to be formed in South Africa. Markets for hydrogen fuel cell vehicles, building heating, and green hydrogen power generation, for example, do not currently exist and a responsive TVET system can on-board the necessary qualifications as investment plans and market needs arise.

Funding would have to be mobilised to support training/internship/learnership programmes within firms. Encouragingly many firms throughout the value chain have indicated interest in participating in training programmes to increase the flow of artisans and technicians in the hydrogen economy to supply the necessary human capital supply base. Many firms, however, particularly at the input manufacturing stage, are start-ups and do not have the funds to conduct training on their own. The funding required may be a mix of state funds and donor funding – the former currently constrained, the latter possibly more easily secured. Existing funding channels do currently exist within the TVET and SETA system that can be leveraged for TVET education and on-the-job training respectively. For new equipment and infrastructure, existing funding streams such as the National Skills Fund could be leveraged.

Conclusion

There have been numerous waves of interest in hydrogen and fuel cells in the past, however, the current global surge in interest in developing hydrogen value chains is unprecendented. Numerous large countries, on the back of commitments made in the 2015 Paris Agreement, have embarked on ambitious plans to make hydrogen and fuel cells a key part of their energy basket. South Africa stands at a pivotal moment in its energy development trajectory as developing the hydrogen value chain can have numerous benefits for the country. South Africa is a carbon-intensive economy and hydrogen and fuel cell development can aid in decarbonisation of existing value chains such as power generation, petrochemical production, and steel production. Decarbonisation is vital in transitioning towards an economy that is sustainable and has a place in international markets which are increasingly penalising carbon-intensive economies. Further, there are opportunities in creating new value chains that emerge from the hydrogen and fuel cell economy, adding new infrastructure, skills and capabilities for the country, which can serve to increase growth, employment and investment in the economy.

South Africa has a strategic advantage in the hydrogen economy given the country's good renewable energy conditions, access to the platinum catalyst used in electrolysers and fuel cells, and an existing Fischer–Tropsch skills base. Further, a number of stakeholders across industry, the state departments, and from the research fraternity are strongly driving the development of the local hydrogen and fuel cell economy. Given this strong base, the hydrogen and fuel cell economy can thrive in the country. However, in the course of this development, the requisite human capital supply will be required. Undoubtedly, new and high-tech value chains such as the hydrogen and fuel cell value chains place a high reliance on skilled labour, which include scientists, engineers and other specialists. However, as indicated in this report, there is a substantial role for technicians and artisans to play a role across the value chain. Technicians and artisans make up bulk of the workforce in the value chain, and given South Africa's high levels of unemployment, these qualifications can be developed to channel labour towards the hydrogen and fuel cell economy.

In order to develop the requisite supply base, the appropriate skills and training would need to be provided to technicians and artisans. The current TVET system in South Africa could be harnessed to provide these skills and qualifications across the value chain, specifically through the CoS programme. The CoS programme offers the necessary on-the-job training required for a new and emerging value chain such as the hydrogen and fuel cell value chain. This will however require a concerted multi-stakeholder drive and push in order to succeed. As identified in this report, industry and the educational departments would have to work hand-in-hand to develop training programmes to create a workforce that has relevant skills and can be employed in the growing hydrogen and fuel cell economy.

The hydrogen and fuel cell economy is anticipated to grow substantially and it is likely that the skills demand in the hydrogen and fuel cell economy will increase for technicians and artisans. It certainly is the case that the global hydrogen and fuel cell markets are in a state of flux as countries and firms determine their policies, investment plans and value chain participation. A TVET system that is dynamic and responsive is required such that market trends can inform how programmes are structured and scaled across the country. This will require strong relationships between education departments and industry. With major production anticipated to occur beyond 2030, the time is right for South Africa to act swiftly and claim a place in this new and sustainable investment pathway.

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Appendix

Table 5. Job titles, average annual salaries and minimum education requirements for jobs in the hydrogen and fuel cell industries

Title	Avg Salary (US $ 2016)	Minimum Education
Fuel cell engineering intern	6 800	HSD/GED/OJT/apprenticeship
Fuel cell fabrication technician	23 150	HSD/GED/OJT/TS/apprenticeship
Hydrogen energy system installer helper	23 200	HSD/GED
Junior hydrogen energy technician	23 400	HSD/GED/OJT/TS/apprenticeship
Hydrogen fueling station operator	29 700	OJT
Hydrogen energy system installer	31 500	HSD/GED/OJT/TS apprenticeship
Fuel cell retrofit manufacturer plant labor	36 500	HSD/GED
Hydrogen fuel transporter trucker	36 950	OJT
Hydrogen fuel cell system technician	39 500	HSD/GED/OJT/TS/apprenticeship
Fuel cell backup power system technician	40 200	HSD/GED/OJT/TS apprenticeship
Hydrogen lab technician	40 600	Associate's
Fuel cell retrofit installer	41 600	HSD/GED/OJT/TS apprenticeship
Hydrogen vehicle electrician	44 800	HSD/GED/OJT/TS apprenticeship
Fuel cell manufacturing technician	45 650	Associate's
Fuel cell fabrication and testing technician	45 800	Associate's
Hydrogen pipeline construction worker	46 300	HSD/GED/OJT/TS/apprenticeship
Emissions reduction credit portfolio manager	47 400	Bachelor's (Business)
Hydrogen energy systems designer	47 900	Apprenticeship/TS

Title	Avg Salary (US $ 2016)	Minimum Education
Fuel cell power systems operator and instructor	50 900	HSD/GED/OJT/TS apprenticeship
Hydrogen systems sales consultant	53 800	Bachelor's (Business)
Hazardous materials management specialist	55 300	Bachelor's (Science)
Hydrogen fuels policy analyst & business sales	56 200	Bachelor's (Business)
Hydrogen fueling station manager	56 300	Bachelor's (CE)
Emissions reduction project developer specialist	63 450	Bachelor's (various)
Emissions accounting & reporting consultant	64 200	Bachelor's (various)
Hydrogen energy system operations engineer	68 100	HSD/GED
Hydrogen power plant installation, operations, engineering, and management	69 700	Bachelor's (EE, ME, CE)
Senior automotive fuel cell power electronics engineer	69 700	Bachelor's (EE)
Fuel cell vehicle development engineer	69 800	Bachelor's (Engineer)
Hydrogen energy engineer	72 300	Bachelor's (Engineer)
Hydrogen systems program manager	73 220	Bachelor's (Engineer)
Hydrogen fueling station designer & project engineer	74 200	Bachelor's (Engineer)
Fuel cell quality control manager	74 600	Master's (Science/Engineering)
Fuel cell power systems engineer	76 400	Master's (EE)
Fuel cell designer	78 200	Master's (Science)
Emissions reduction project manager	78 600	Bachelor's (various)

Title	Avg Salary (US $ 2016)	Minimum Education
Hydrogen systems safety investigator cause analyst	88 350	Bachelor's (various)
Fuel cell plant manager	90 500	Bachelor's (EE, ME)
Hydrogen systems & retrofit designer	90 600	Bachelor's
Hydrogen plant operations manager	95 200	Bachelor's (EE, ME)
Hydrogen/fuel cell R&D director	129 000	Doctoral
Director of hydrogen energy development	138 000	Bachelor's (Business)

Source: TIPS, based on (Bezdek, 2019)

Notes: HSD = High School Degree; GED = General Education Development; OJT = on-the-job training; TS = Trade School; CE, ME, EE = chemical, mechanical and electrical engineering

Table 6. Interview list

Stage of the value chain	Firm	Respondents (title)
Input manufacturing	HyPlat	Dr. Sharon Blair (CEO)
	Isondo Precious Metals	Dr. Sakib Khan (COO); Vinay Somera (CEO)
	Bambili Energy	Nelisiwe Lynette Vundla (Project Manager)
Hydrogen production	Sasol	David Kawesha (Head Just Transition), Dr. Storm Potts (Head of Global Climate Change and Policy), Chris C. Klopper (Senior Manager Learning and Development Energy Business), Jas Govender (Head of Commercial: Exploration & Production International)
	Eskom (potential entrant)	Vikesh Rajpaul (Senior Manager: Renewable energy), Sumaya Nassiep (General Manager (Acting) of Eskom Research Testing & Development)
	Air Products	Robert Richardson (Managing Director), Arthi Govender (Marketing and Communication Executive)
Education	TVET	Gerda Magnus (Chief Director: Programmes and Curriculum Innovation)

Stage of the value chain	Firm	Respondents (title)
Skills development	EWSETA	Tsholofelo Mokotedi (Acting Executive: Planning, Reporting & Monitoring)

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