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Synthesis Report

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The South African Green Hydrogen TVET Ecosystem Just Transition Strategic Framework

2030 NDP

SAIIA
SOUTH AFRICAN INSTITUTE OF INTERNATIONAL AFFAIRS

Foreword

The launch of the South African Green Hydrogen TVET Ecosystem Just Transition Strategic Framework occurs amid five major challenges:

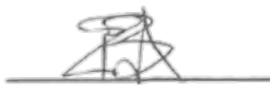
- The geopolitical energy turmoil in the face of climate change;
- the aftermath of the COVID-19 pandemic and its impact on the economy and TVET ecosystem;
- the fast-paced green energy scientific and technological developments;
- the high levels of unemployment in the country and among TVET graduates; and
- the low levels of TVET graduate labour absorption by industry.

The role of the Technical Vocational Education and Training (TVET) ecosystem as a socio-economic transformative tool is perhaps more important than ever to addressing current challenges at this historical juncture. The great acceleration in science, technology and innovation (STI) has left educational systems reeling and in a scramble to catch up to rapidly changing and uncertain learning environments. STI is a powerful driver of change in the implementation of the Economic Reconstruction and Recovery Plan (ERRP) and it is expected to set the pace for building a sustainable, resilient and inclusive economy through several priority interventions. For instance, transitioning to a just and inclusive green hydrogen TVET ecosystem that cultivates a transversal skills-commons and fosters economic wellbeing and ecological resilience will require an enabling environment, collaboration, investment, and innovation to address the five major global shifts and local challenges.

In February 2022, when I launched the Hydrogen Society Roadmap, the first proactive steps were taken to leverage the hydrogen opportunity. Transitioning the country’s TVET ecosystem and aligning it with the hydrogen industry's needs and opportunities to improve labour absorption, is critical to addressing the skills development needs of the overwhelming majority of our people, especially the previously disadvantaged, women, youth and the poor, both urban and rural. A sectoral alignment with industry-specific requirements will facilitate a just transition, where potential job losses in the traditional coal-mining industry, for example, are mitigated through upskilling, retraining and onboarding of workers into green hydrogen-related mining, manufacturing, power fuel production, and transportation industries.

The South African Green Hydrogen TVET Ecosystem Just Transition Strategic Framework is one of the government's key enablers to the successful implementation of the ERRP and provides the foundation for thinking about anticipatory policy interventions to reconstruct and transform the TVET skills development ecosystem. The TVET ecosystem has the potential to train large numbers of green artisans and technicians while becoming responsive to major political, economic, environmental, and socio-technical shifts and to support young people and established workers to make effective transitions into the green labour market. The TVET ecosystem will, therefore, play a pivotal role in launching and supporting the emerging hydrogen economy away from fossil fuel-based economic dependency, the rapid expansion of renewable energy production and employment in the green economy.

I am confident that the effective implementation of this Green Hydrogen TVET Ecosystem Just Transition Strategic Framework, will re-establish the TVET ecosystem at the heart of proactive skills governance that builds stronger partnerships between government, the private sector and civil society to train new graduates, and those in the process of transitioning between sunset and sunrise industries. Successful implementation of this strategic framework must lead to a demand-led TVET Ecosystem that radically improves gender equality and social inclusion through work-integrated learning, integration of state-of-the-art skills anticipation, skills foresight and skills matching systems, an acceleration of a hybrid TVET Centres of Specialisation model for increased flexibility and improved skills development investment, and a balance of payments allocated to the TVET college system to create a transversal skills commons.



Dr BE Nzimande
Minister of Higher Education, Science and Innovation

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Cover image credit: Quality control inspector examining machine part on production line (skynesher via Getty Images)

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Glossary

4IR	Fourth Industrial Revolution
AR	Augmented Reality
BaU	Business as Usual
CNC	computer numerical control
CoS	Centres of Specialisation
DHET	Department of Higher Education and Technology
DMRE	Department of Mineral Resources and Energy
DOL	Department of Employment and Labour
DSI	Department of Science and Innovation
DTIC	Department of Trade, Industry and Competition
ERRP	Economic Reconstruction and Recovery Plan
EU	European Union
EWSETA	Energy and Water Sector Education and Training Authority
FCEV	fuel-cell electric vehicle
GDP	gross domestic product
GHE	green hydrogen economy
GH_2	green hydrogen
GHG	greenhouse gas
GIZ	German Agency for International Cooperation
H3	Third Horizon
HySA	Hydrogen South Africa
HSRM	Hydrogen Society Roadmap
ICE	internal combustion engine
ICT	information and communications technology
IRP	Integrated Resource Plan 2019
LMIP	Labour Market Intelligence Programme
MEA	membrane electrode assembly
MERSETA	Manufacturing, Engineering and Related Services Sector Education and Training Authority
MTEF	Medium-Term Expenditure Framework

NBI	National Business Initiative
NC(V)	National Certificate Vocational
NDC	Nationally Determined Contribution
NDP	National Development Plan
NH_3	ammonia
NQF	National Qualification Framework
NSDP	National Skills Development Plan
NSFAS	National Student Financial Aid Scheme
OFO	Organising Framework for Occupations
OTC	Occupational Team Convenor
P2P	Peer to Peer
PEM	proton exchange membrane
PGM	platinum group metals
PV	photovoltaic
PSET	post-school education and training
REDZ	Renewable Energy Development Zone
SAF	sustainable aviation fuel
SAIIA	South African Institute of International Affairs
SANEDI	South African National Energy Development Institute
SAREM	South African Renewable Energy Masterplan
SATIM	South Africa TIMES
SDG	Sustainable Development Goals
SETA	Sector Education Training Authority
SMME	small, medium and micro enterprises
STEM	science, technology, engineering, and math
TVET	Technical Vocational Education Training
UCT	University of Cape Town
UK	United Kingdom
UK PACT	UK Partnering for Accelerated Climate Transitions
VR	virtual reality

Executive summary

Hydrogen is an energy carrier and industrial feedstock that could be the foundation of a new energy-industrial network based on renewable energy. There has been a global resurgence of interest in the use of hydrogen, notably green hydrogen produced from renewable resources,[1] owing to its potential to help decarbonise sectors for which few alternatives presently exist. These sectors include long-haul transport, iron and steel production, long-term energy storage and liquid fuels such as kerosene and heavy fuel oil. Hydrogen is thus a likely enabler to achieve climate change policy goals, predicated on the notion that greenhouse gas (GHG) emissions resulting from economic activity should be as close to nil as possible as an objective for a movement towards 2050, which is now becoming the new frontier for climate policy ambition around the world. Global appetite for hydrogen presents further economic opportunities for South Africa. The country's renewable energy resources, mineral endowment and manufacturing prowess position it to competitively produce and export hydrogen-derived commodities, such as green ammonia, as well as high-value machinery such as fuel-cell components. These could mirror South Africa's present export market share of automotive catalytic converters.[2]

In addition to green hydrogen's contribution to achieving the 'net-zero carbon' goal by 2050, the extent to which it could contribute to employment growth and low-carbon development in South Africa has also received increasing attention in the past two years.[3] The present study forms part of the South African Institute of International Affairs (SAIIA) – UK Partnering for Accelerated Climate Transitions (UK PACT) South Africa 2021 project on building the green hydrogen economy (GHE) and Technical Vocational Education Training (TVET) Skills Just Transition. It aims to contribute to this body of work by applying advanced and economy-wide modelling of national energy systems, including hydrogen use, and their economic (gross domestic product [GDP] and employment) and GHG emission impacts.

1 The present study has a focus on the development of green hydrogen due to its potential for reaching Net Zero Carbon (Net Zero) by 2050. The study makes use of energy modelling, which starts from the current energy supply and use in South Africa, and thus implies a shift from grey to green hydrogen. This shift is implicit in the sense that grey hydrogen currently is produced at Sasol's Secunda site, and the researchers assume grey hydrogen operations to cease with the retirement of the CTL operations, due to ageing, by 2034–2036. Development of green hydrogen has not been given any geographic restrictions, but this could, of course, also take place at the Secunda CTL site. Green hydrogen enters South Africa's energy system when the energy systems model considers this a cost-optimal way to respond to energy demand over time on a path to achieving Net Zero by 2050.

2 Thomas H Roos, "The Cost of Production and Storage of Renewable Hydrogen in South Africa and Transport to Japan and EU up to 2050 Under Different Scenarios", International Journal of Hydrogen Energy 46, no. 72 (2021).

3 Thomas Roos and Jarrad Wright, Powerfuels and Green Hydrogen, Summary Report (Pretoria: Council for Scientific and Industrial Research, February 2021); Department of Science and Innovation et al., South Africa Hydrogen Valley: Final Report (Pretoria: et al., South Africa Hydrogen Valley: Final Report (Pretoria: DSI, October 2021); IHS Markit, Super H2igh Road Scenario for South Africa: Extended Report (London: IHS Markit, June 2021).

This study therefore also aims to support the orientation of South Africa's TVET college ecosystem towards the GHE by providing insight on the sectors on which to focus and the timelines by which it could be required to provide its graduates with the skills required in the GHE, as well as the potential for up- or re-skilling given those timelines.

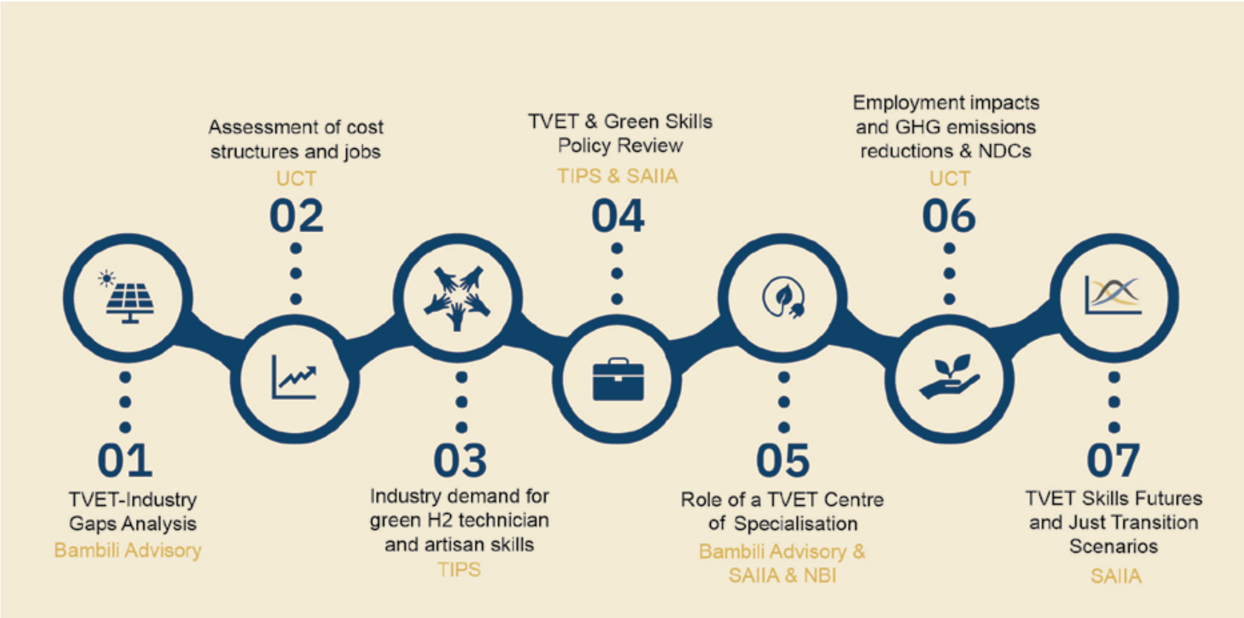

Figure 1 Seven research streams feeding into this report

Source: Compiled by authors (SAIIA)

South Africa should leverage the green hydrogen employment opportunity through its TVET ecosystem as part of its Economic Reconstruction and Recovery Plan

Domestically, the role of TVET as a socially and economically transformative tool is increasingly being recognised. It plays a pivotal role in launching and supporting the emerging South African GHE away from fossil fuel-based economic dependency. Government stakeholders want the TVET ecosystem to train large numbers of artisans and technicians to meet the skills demands of green hydrogen industrial activity while alleviating the country's unemployment crisis. Similarly, TVET colleges want to be more responsive to major political, economic, environmental, and socio-technical shifts. To achieve this, securing a just transition becomes central to ensuring decent futures for existing workers and future industry entrants, particularly those in sectors and industries likely to be impacted by efforts to limit emissions or by the introduction of new, disruptive technology. This includes exploring the possibility of transitioning workers between sunset and growth industries through upskilling or reskilling.

There are, however, critical gaps between government desires, industrial strategy, skills planning and TVET-industry alignment. These threaten to undermine the achievement of a GHE TVET Skills Just Transition. Options for narrowing and bridging gaps are included in the discussion and policy recommendations presented in this report.

In response to the shifting energy landscape and the critical role of skills training, this project provided technical assistance and undertook to build capacity among government stakeholders on pathways towards a just transition, the acceleration of climate change mitigation action, and gender, social and economic inclusion for South Africa in light of the emerging GHE. This report is a synthesis of multiple research outputs produced throughout the project lifespan, with the aim to consider opportunities and leverage points and risks relating to the South African TVET ecosystem that are rooted in a systems innovation approach.[4]

In mapping the action needed to achieve a responsive and anticipatory TVET ecosystem, the report developed a Theory of Change and seven corresponding objectives, outcomes and outputs, with a central vision: 'A just and inclusive green hydrogen TVET ecosystem that cultivates a transversal skills commons, and fosters economic wellbeing and ecological resilience by 2050.'[5]

Support for this vision is presented through the following seven interlinked objectives:

- **South Africa should create an enabling environment for a TVET Skills Just Transition to support the future GHE**

  Supporting a GHE TVET Skills Just Transition and creating an enabling TVET environment that is flexible, hybrid and agile are crucial. Whereas the initial skills need in the GHE is for postgraduate university-level skills, once production of green hydrogen and related industries pick up, so the demand for technical and vocational skills will accelerate. Policies need to be harmonised to ensure skills demand is met in terms of skills development and training. To mitigate the impacts of the energy transition on workers and vulnerable stakeholders and communities, policy measures should also consider technical and vocational training, at both semi- and higher-skilled levels. The enabling environment needs to meet various growing value chain sectors at different time horizons by providing new, high-quality jobs within emerging

4 A systems innovation approach entails integrated and coordinated interventions in economic, political, technological and social systems and along whole value chains to ensure an interconnected set of innovations, where each influences the other, with innovation both in the parts of the system and in the ways in which they interconnect. Geoff Mulgan and Charlie Leadbeater, "Systems Innovation" (Discussion Paper, Nesta, London, January 2013); Dominic Hofstetter, "Innovating in Complexity: From Single-Point Solutions to Directional Systems Innovation", EIT Climate KIC, July 2019.

5 See Theory of Change section of this report.

sustainable industries. These include the generation, beneficiation, transport (road, rail, pipeline) and storage of hydrogen, the manufacturing of hydrogen-related products such as fuel cells and electrolysers, the beneficiation of minerals through the supply of value-added components in the hydrogen value chain, and the export of green hydrogen. Growing demand for platinum in fuel-cell manufacturing would more than make up for losses related to the phasing-out of catalytic converters. Jobs can also be created in the local manufacture of hydrogen-related products and infrastructure construction, and be preserved in the transport and industry sectors.

- **South Africa should develop skills and employment pathways from high-carbon to low-carbon jobs for reduced GHG emissions**

  South Africa faces significant risks associated with climate change and the need to transition to a low-carbon society. Its per capita GHG emissions are well above the global average. The GHE TVET Skills Just Transition will help to reduce GHG emissions by developing skills and employment pathways for replacing fossil fuels in heavy industry, energy-intensive industries. This just transition might include upskilling, reskilling and onboarding workers to low-carbon jobs in the power production, manufacturing and petrochemicals, mining, road and rail transport, shipping, aviation and export sectors. The GHE TVET Skills Just Transition will also enable skills development towards the greening of the power sector by providing renewable energy storage to the grid, and reliable zero-carbon electric and thermal energy for off-grid applications.

- **South Africa should integrate skills anticipation and skills foresight systems to build a stronger partnership between government, the private sector and civil society for improved skills governance**

  To ensure that the development of this report was inclusive, the SAIIA-UK PACT GHE TVET Skills Just transition project consulted widely across various stakeholder groups. This included an in-depth consultation process with more than 20 stakeholder organisations throughout the project period, followed by smaller one-on-one engagements with key stakeholders. The GHE TVET Skills Just Transition will enable skills governance and green skills development by providing an adequate supply of skills through improved partnerships between the private sector, civil society and government. Closer partnerships will ensure skills demand is better anticipated and strategic foresight applied to address perpetual skills training mismatches. Improved skills governance will ensure a green energy-skilled workforce capable of enabling the growth of the GHE and its various technological applications.

- **South Africa should employ a hybrid TVET Centres of Specialisation model for increased flexibility and improved skills development investment**

  The development of artisans has been of critical concern to the private sector and government over the past decade. It is crucial to address some of the mismatches between skills demand and skills supply, and so meet economic growth and job creation objectives. The National Development Plan (NDP) has set a target of developing 30 000 artisans per year by 2030. Government views TVET colleges as a key mechanism for delivering on this target and initiated the Centres of Specialisation (CoS) programme as a means of transforming TVET colleges to work with industry to implement a demand-led approach to skills development, using a dual apprenticeship model. By employing a hybrid CoS model the TVET ecosystem allows for increased flexibility. This will open up qualifying TVET colleges and interested industry partners to collaborate and cooperate on selected green skills development in general and green hydrogen-related specialisations in specific locations.

- **Ensure that gender equality and social inclusion reduces inequality and poverty**

  The implementation of the GHE TVET Skills Just Transition will benefit society, as a move towards a hydrogen economy can assist with the achievement of Sustainable Development Goals (SDGs), with specific emphasis on SDG7 (affordable and clean energy) and SDG8 (decent work and economic growth). Economic growth will be underpinned by job growth, which is needed to reduce unemployment. A green hydrogen just transition will enable decarbonisation in industrial clusters and improve air quality in disadvantaged communities, which are usually co-located near industrial clusters. While South Africa fares well in terms of female enrolment in the TVET ecosystem,[6] unemployment rates among women have stayed higher than those among men[7] for the past decade. This demonstrates a critical gap between skills and qualification benchmarks and industry practice. A deliberate and focused strategy is needed to increase gender equality and social inclusion in both the skills ecosystem and the green hydrogen industrial transition in South Africa, strengthening the linkages between skills and employment for racially marginalised women in particular.

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6 In 2019, the Department of Higher Education and Technology (DHET) recorded a nationwide female TVET enrolment rate of 40% higher than that of males, demonstrating a gradual increase over the past decade.

7 Statistics South Africa's Quarterly Labour Force Survey of the second quarter of 2021 demonstrated that the South African labour market is more favourable to men than it is to women, and that Black South African women are the most vulnerable to unemployment. Men recorded an unemployment rate of 32.4% in 2021, while women recorded 36.8%.

- **South Africa should ensure economic wellbeing by improving the balance of payments allocated to the TVET college system**

  The level of funding available to TVET colleges has been a key factor in limiting growth. While the funding base initially incentivised growth, there has been a persistent funding deficit in real terms. The development of domestic manufacturing for hydrogen products and components, along with the decarbonisation of the emissions-intensive sectors of the economy and hydrogen exports, will encourage inward skills development investment. Together with reduced oil imports and coal-use intensity – given the high current reliance on energy production (electricity and petrochemical) – these changes will support improvements in the balance of TVET college payments towards public sector green skills development.

- **South Africa should use the private and public TVET ecosystem to create a transversal skills commons**

  The training, upskilling and reskilling of workers for the emerging GHE will require both substantive and methodological changes, ie, changes to what is taught and how it is taught. Skills related to the GHE to be added to relevant TVET curricula include

  » technical skills related to hydrogen fuel cells and electrolysers, fuel-cell electric vehicles (FCEVs), green hydrogen and ammonia production, green iron, steel production and technology development and other downstream value chains (eg, heating, Liquid Organic Hydrogen [LOHC], sustainable aviation fuel [SAF]);

  » digital and information and communications technology (ICT) skills, including digital literacy and, where relevant, specialist skills such as working with computer numerical control (CNC) systems;

  » socials and soft skills, including communication, teamwork, problem solving, emotional intelligence, people management, creativity and critical thinking; and

  » relevant science, technology, engineering and math (STEM) modules (eg, working with data) for courses that require STEM skills.

  In the current skills development landscape, not only one specific qualification is required – rather, the TVET skill environment requires the creation of transversal (or generic) skills as an essential part of a professional and training profile. These are the knowledge, skills, dexterities and capabilities that any graduate must have achieved before entering the labour market. Such an adaptable skills development environment should build a skills commons[8] that uses peer-to-peer (P2P) social relations in human networks, as well as a technological infrastructure that makes the generalisation and scaling up of such new skills-sharing relations possible. A transversal skills commons creates communities that share common resources, innovates skills development from generative market mechanisms that work for communities, and enables government support for public platforms.

Priority short-term actions

Recommended policy and strategic actions are categorised according to three implementation timelines within this report: (1) short term (2022–2025); (2) medium term (2026–2036); and (3) long term (2037–2050). Actions are aligned to include provisions for gender equality and social inclusion, and considerations for transitioning between sunset and growth sectors[9] through reskilling or upskilling. The objective, outcome and output considerations outlined in the Theory of Change provide the framework for the proposed actions.

Below is a summarised list of priority strategic actions to be implemented in the short term, targeted at eleven identified stakeholders[10] within the GHE-TVET ecosystem:

- implement TVET teacher training programmes based in industry and workplace training for mentors to ensure fit-for-purpose training;
- strengthens skills–employment linkages to ensure higher absorption of women in the GHE labour market (to match high TVET throughput rates of women) through increased collaboration and targeted skills-building programmes and industry-based apprenticeships;
- update the Integrated Resource Plan 2019 (IRP) to reflect the changing economics of green hydrogen production. The subsequent iterations of the IRP should be developed and aligned with the South African Renewable Energy Masterplan (SAREM) in order to coordinate investments into renewables' capacity and green hydrogen;
- revise the national TVET budget allocation to achieve the desired outcomes as per the central vision;

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8 A skills commons empowers the autonomy of individuals and communities through public—commons partnerships (P2P) and enables TVET transversal skills development that can contribute to the creation and maintenance of shared resources while ensuring communities benefit from it. Michel Bauwens, Vasilis Kostakis, and Alex Pazaitis. *Peer to peer: The Commons Manifesto*. University of Westminster Press, (2019).

9 A sunrise sector is a new industry with potential for substantial and rapid growth, while a sunset sector is one that is in decline or has passed its peak period.

10 See *Policy Recommendations and Strategic Actions Framework* section of this report for elaborated actions for short-, medium- and long-term timeframes.

- establish an overarching body to coordinate relevant stakeholders in the triple helix[11] around the hydrogen (H_2) economy, thereby ensuring a smooth and just transition; and
- adjust the CoS model for increased flexibility, allowing qualifying TVET colleges, universities and interested industry partners to collaborate on selected green hydrogen-related specialisations in specific locations.

11 The triple helix challenge: poverty, inequality and unemployment.

SECTION A

UNDERSTANDING THE GREEN HYDROGEN EMPLOYMENT OPPORTUNITY THROUGH SOUTH AFRICA'S TVET ECOSYSTEM

Credit: Female workers looking at machine part design in factory (Getty Images)

1 Introduction

The world is in the middle of a major energy and technological transition, with far-reaching implications across sectors and industries. This transition has accelerated on the back of an energy security crisis induced by the Russian invasion of Ukraine. This is highly relevant for the coal-dependent South African economy, as it ranks among the most carbon-intensive in the world: it is the 13th highest emitter globally, and the highest in Africa.[12] This will have to change as the world shifts towards green energy. The energy transition is accompanied by a technology revolution, with digital and Fourth Industrial Revolution (4IR) technologies shaking up entire industries.

Crucially, the move away from fossil-fuel based economies will lead to the demise of some industries, even as others emerge and grow. This will cause significant upheaval in the labour market. Managing this transition in a way that seeks the best possible outcome for workers and affected communities is important, but particularly in a country like South Africa, which is facing the triple challenge of poverty, inequality and unemployment. South Africa currently has an unemployment rate of 35.3%.[13] The country cannot afford to lose more jobs; in fact, it is crucial that more jobs are created. The just transition aims to mitigate this impact by providing 'a hopeful and optimistic future for all workers, especially those in industries that may be impacted by efforts to limit GHG or by the introduction of new technology'.[14] Tools to ensure that vulnerable stakeholders are not forgotten in the transition include policies to increase economic diversification in affected regions, provide opportunities for reskilling the workforce for future growth industries (as well as temporary income support during reskilling) and provide increased social welfare support.[15]

This report assesses the role of the TVET ecosystem in helping the South African workforce prepare for an emerging GHE. This is a growth cluster in which South Africa may have a strategic advantage, given:

- abundant renewable energy resources;
- the successful roll-out of renewable energy power generation infrastructure;
- platinum resources used as catalysts in electrolysers and hydrogen fuel cells;

12 Global Carbon Atlas, "Fossil Fuel Emissions", 2020.

13 Statistics SA, "Quarterly Labour Force Survey: Q4:2021Quarterly Labour Force Survey: Q3:2021", March 29, November 30, 2021.

14 IndustriALL Global Union, "A Trade Union Guide to a Just Transition for Workers", May 15, 2019.

15 Muhammed Patel, "South African Industry Demand for Green Hydrogen Technician and Artisan Skills" (Working Paper, SAIIA-UK PACT and Trade and Industrial Policy Strategies, 2021).

- existing industry-TVET pilots;
- Fischer-Tropsch[16] skills base and;
- government's commitment to work progressively towards a net-zero carbon economy by 2050

The report is framed within this just transition framework. It is interested in the role that skills development can play in the vocational skills development (VSD) system, and in particular the TVET ecosystem[17] in helping the country prepare for a skills and training just transition. Government has high ambitions for the TVET sector: it expects the TVET ecosystem to eventually train more people than the university system,[18] and views it as having significant potential for helping young people transition to employment. While this study prioritises the TVET ecosystem, it is important to locate TVET within the broader vocational skills development system. Effective TVET provision requires an intersection between the TVET ecosystem, the higher education system and the skills development system to ensure that young TVET students and those requiring upskilling have access to workplace-based training as well as progression pathways to higher education, thus optimising their employability. As such, in conceptualising TVET provision, cognisance must be taken of the need to create conditions for this intersection to take effect.

The report details the employment impacts for the different GHE options in the TVET ecosystem by means of four quantitative scenarios.

16 The Fischer-Tropsch process is used for coal liquefaction and to convert gas to liquid fuel. Through industry players such as Sasol and PetroSA, the country has access to the skills and capabilities around using the process and adapting it to augment fossil-intensive production with sustainable inputs such as green hydrogen.

17 The vocational skills development (VSD) system refers to the combined system of TVET, some aspects of higher education, and skills development in the workplace, tackling the range of mid-level or intermediate skills. The TVET ecosystem comprises public and private TVET Colleges, offering vocational knowledge and practical instruction across various fields of study. The notion of a VSD system seeks to understand and conceptualise the relationship between different sites of mid-level skills to provide more coherent learning pathways for young people.

18 Bambili Advisory, "The South African Hydrogen Economy: A TVET-Industry Skills Gap Analysis" (Working Paper, SAIIA-UK PACT, 2021).

1.1 Quantitative employment scenarios for the GHE

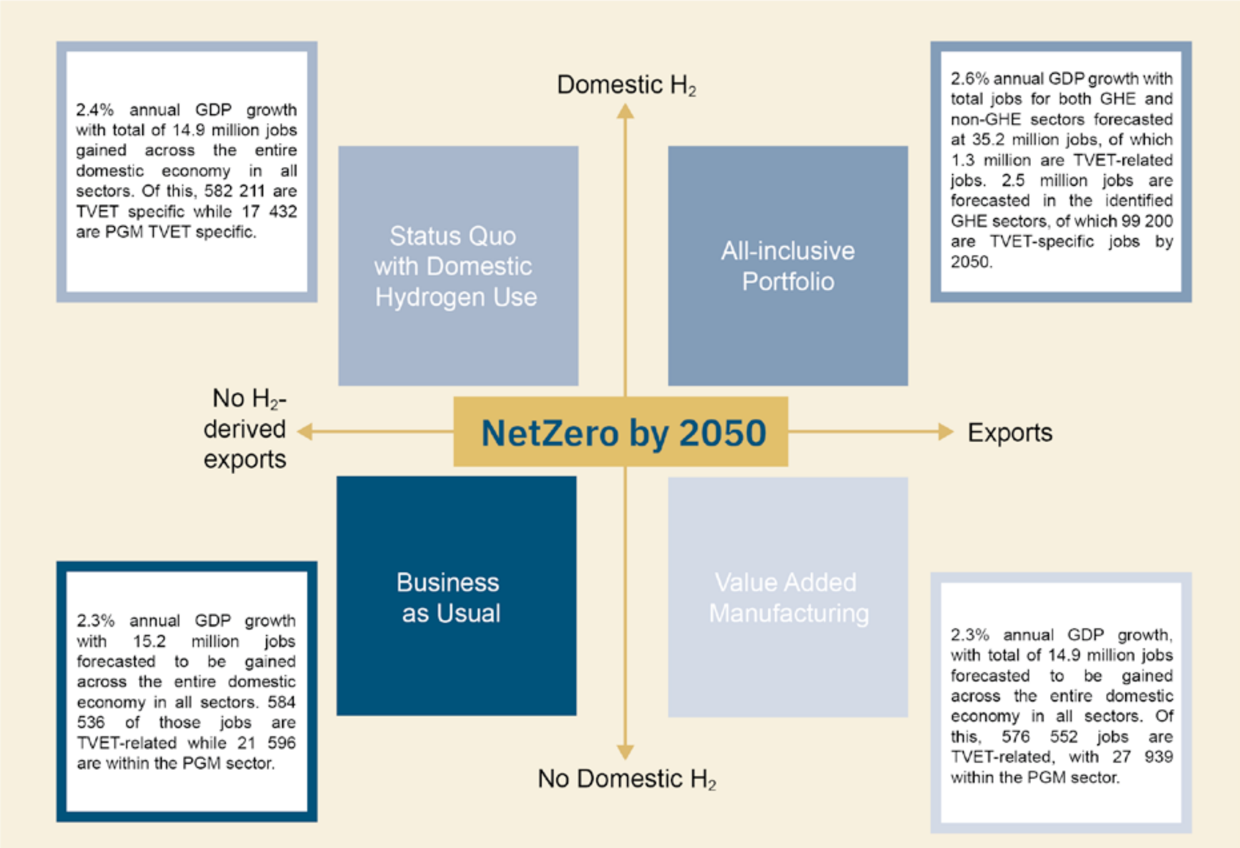

Figure 2 Options modelled for a green hydrogen economy in South Africa

Source: Fadiel Ahjum et al., "Green Hydrogen and TVET Employment Prospects: An Assessment in a Context of Ambitious Decarbonisation for South Africa Towards 2050" (Working Paper, SAIIA-UK PACT and University of Cape Town, 2021)

As per Figure 2 the four quantitative scenarios on employment creation through the South African TVET ecosystem highlight the policy options and impacts of the future GHE:

- **Business as Usual**: This scenario focuses on platinum group metals (PGM) exports only, with no additional beneficiation, and does not include additional elements of a GHE. GHE PGM mining jobs to be gained will surpass coal mining jobs lost from about 2045 onwards in all four quantitative employment scenarios. Year-on-year GDP growth is forecast at 2.3% until 2050, demonstrating total GDP growth of 96% (worth ZAR 2.8 billion) between 2019 and 2050. A total of 15.2 million jobs are forecast to be gained across the entire domestic economy in all sectors by 2050, with 584 536 of those jobs being TVET-related. Of these 584 536 jobs, 21 596 are within the PGM sector.

- **Value Added Manufacturing**: This scenario looks at PGM exports as well as PGM beneficiation into the fuel cell and electrolyser components for export, with no domestic hydrogen utilisations. The impact of the Business as Usual forecast may see as much as 2.3% year-on-year GDP growth and total growth of 98% by 2050. Total GDP growth by 2050 is therefore forecast at ZAR 2.9 billion. A total of 14.9 million jobs are forecast to be gained across all of SA's economy-wide sectors (no domestic hydrogen utilisation), with 576 552 of those jobs being TVET-related and 27 939 PGM-related.
- **Status Quo with Domestic Hydrogen Use**: This scenario focuses on PGM exports with domestic hydrogen utilisation, but with no hydrogen-derived exports. The impact of such a domestically focused option is GDP growth of 102% (2.4% year-on-year) by 2050. Total GDP growth by 2050 is forecast at ZAR 3 billion with total jobs gained across all SA economy-wide sectors (including domestic hydrogen use, but no exports) at 14.9 million. Of these, 14.9 million jobs, 582 211 are TVET specific while 17 432 are PGM specific.
- **All-inclusive Portfolio**: This scenario considers domestic hydrogen utilisation options (including in mobility and power generation), as well as a portfolio of exports (including fuel cells, electrolysers, green hydrogen and ammonia, green iron and steel, and green jet fuel). The impact of a focus on both domestic utilisation and a portfolio of exports is GDP growth of 118% by 2050 (year-on-year growth of 2.6%) and a total growth worth ZAR 3 534 billion. The total number of all jobs for both GHE and non-GHE sectors in the economy at large by 2050 is forecast at 35.2 million jobs, of which 1.3 million are TVET-related jobs. A total of 2.5 million jobs are forecast in the identified GHE-only sectors, of which 99 200 are TVET-specific jobs by 2050. The majority of GHE-only jobs are forecast at 918 000, within the iron and steel sectors, followed closely by the PGM sector with 707 643 jobs.

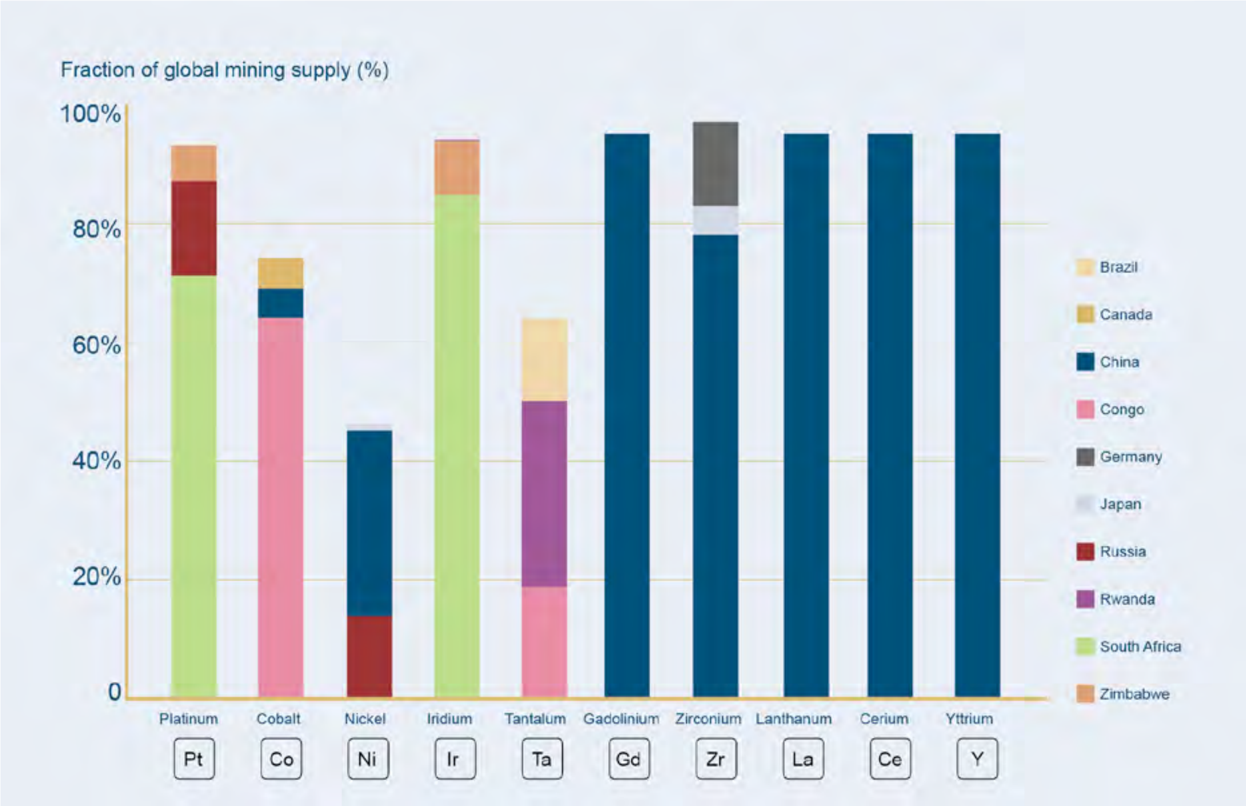

Figure 3 Top producers of critical materials in electrolysers

Source: International Renewable Energy Agency, *Geopolitics of the Energy Transformation: The Hydrogen Factor* (Abu Dhabi: IRENA, 2022), 91

Although South Africa has significant green hydrogen potential, it is not the only country (globally and in the region) with its eye on the sector. In exploring the employment creation potential of the sector, it is crucial to be aware of where South Africa's strategic advantage lies and what the priorities are to ensure that interventions are targeted appropriately. The option of implementing quite substantive regional programmes that develops the hydrogen value-chain and connects the higher education systems to regional TVETs can open the possibility for thinking about regional skills ecosystems from a SADC vantage point as well.

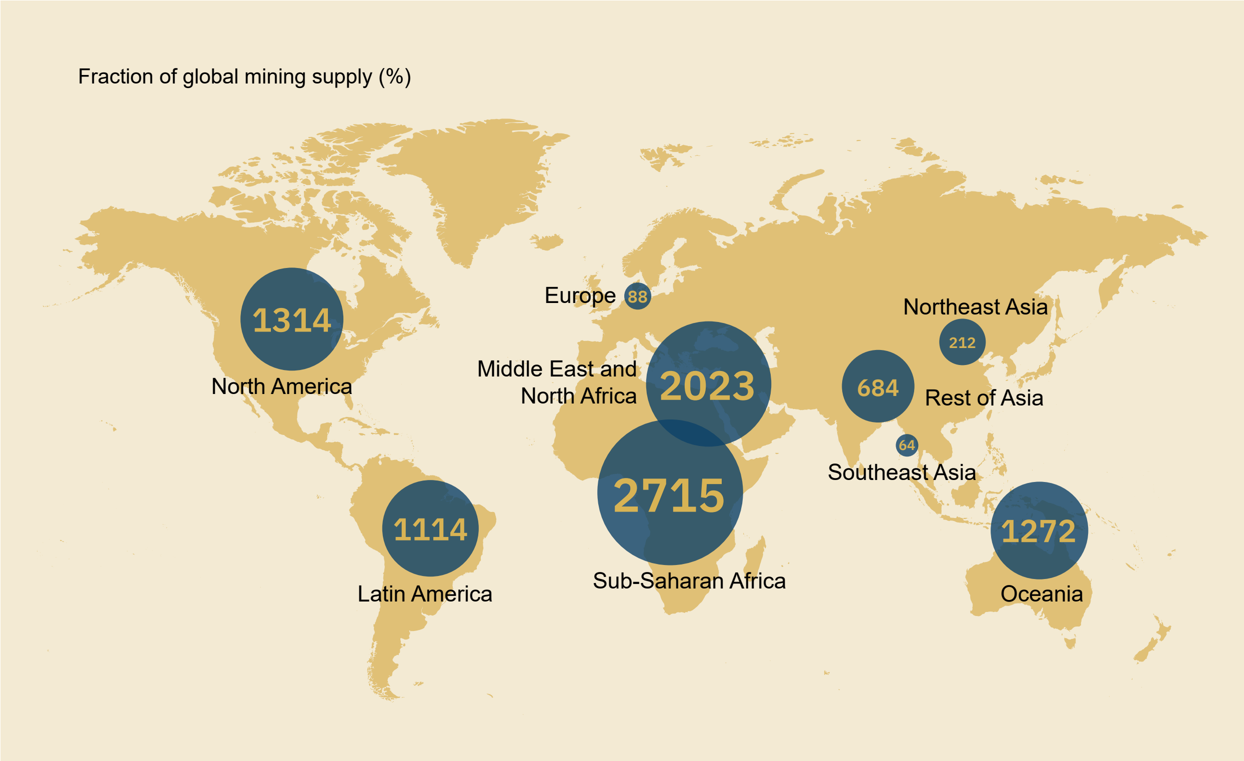

Figure 4 Technical potential to produce green hydrogen under $1.5/kg by 2050, in exajoules

Source: International Renewable Energy Agency, Geopolitics of the Energy Transformation: The Hydrogen Factor (Abu Dhabi: IRENA, 2022), 45

On 17 February 2022, the Department of Science and Innovation (DSI) launched a Hydrogen Society Roadmap (HSRM)[19] for South Africa. The HSRM set out the country's strategy and intentions for creating a hydrogen economy. Government, in partnership with key industry players, is also planning a Hydrogen Valley, stretching from Mogalakwena in Limpopo through Johannesburg to Durban and Richard's Bay. Eskom and Sasol have indicated their interest in green hydrogen and projects are underway with Toyota, Afrox, Air Products, Air Liquide and Imperial Logistics. Input industries for electrolysers and fuel cells are also starting to develop.[20]

Indeed, South Africa sees the GHE[21] as having the potential to contribute to a just transition. It can do this by providing new employment opportunities in the transition – from negatively affected fossil fuel-related sectors or activities such as coal mining to

19 DSI, *Hydrogen Society Roadmap for South Africa 2021* (Pretoria: DSI, 2021).

20 Patel, "South African Industry Demand".

21 Hydrogen has potential as a clean energy source *if* it is produced in a clean way. Green hydrogen is produced by splitting water into hydrogen and oxygen using electrolysis, powered by renewable electricity. This is a very different processto grey hydrogen (used in South Africa today), which involves steam methane reforming or coal gasification. Blue hydrogen is produced in the same way as grey, except that the resulting carbon is captured and stored or used. The production of green hydrogen is currently expensive, although the cost is expected to decrease significantly in the next decade.

downstream sectors such as vehicle-component manufacturing and greening of the steel and transport sectors.

Specific questions that this report considers include

- Can coal mining workers transition to platinum mining?
- Should South Africa beneficiate its platinum resources by manufacturing electrolysers and fuel cells for the GHE?
- What is the potential of fuel-cell electric vehicles (FCEVs) to replace internal combustion engines (ICE) and what would that mean for jobs in the automotive sector?
- What is the potential of hydrogen and hydrogen-derived chemicals such as green ammonia and methanol as industrial feedstock, and what would that mean for jobs?
- What is the value of a domestic vs. an export-oriented GHE, from an economic and an employment perspective?
- What does all of this mean for the country's TVET ecosystem?

In approaching this work, the research consortium engaged closely with key policy stakeholders, the private sector, practitioners and academia in assessing the potential demand for TVET skills for a future GHE. Applying a mixed-method methodology – including desk research, policy and literature reviews, sector-specific policy roundtables and stakeholder interviews – it also drew on approaches from futures studies. Two such approaches were incorporated. Firstly, the report made use of quantitative forecasting and scenarios to model the climate, economic and employment impacts of different green hydrogen futures. This resulted in four scenarios depicting different choices related to both the domestic use of green hydrogen and its export. Secondly, the report draws on the 'Three Horizons' framework for major transitions rooted in strategic foresight. This approach helps stakeholders to make sense of and plan for major transitions – in this case, the shift from a carbon-based economy to a green one – as well as the impacts they will have across industries, the world of work and the education system that prepares the workforce for this new world. Together, these approaches can assist decision makers to prepare for an uncertain world by identifying alternative futures (some more desirable than others) and providing pathways to help role players shape a desirable future.

The report draws together findings from seven research streams or working papers produced by the research consortium, including the evaluation of a TVET-level hydrogen fuel-cell maintenance and installation training course. (See Appendix A for more information about the research approach.)

Three key sections frame the discussion within this report. Section 1 provides the context within which to understand green hydrogen employment opportunities through South Africa's TVET ecosystem, including the country's current employment landscape, the potential green hydrogen value chain and challenges facing domestic vocational skills development. Highlighted in this section is the importance of linking TVET skills requirements to the changing demands of industry.

Section 2 considers the role of the evolving TVET ecosystem – just as industries are in transition, so too is the education and training system. It explores the means to create an enabling governance environment toward a responsive TVET ecosystem and a future-fit GHE labour force. Notably, the section draws on systemic innovation and futures thinking methodology, presenting a vision and Theory of Change for the green hydrogen-TVET skills transition while highlighting the critical need for foresight and anticipation capabilities in skills governance and planning.

Section 3 models the potential employment impacts of green hydrogen in South Africa by presenting and exploring four quantitative scenarios for GHE employment (Business as Usual, Value Added Manufacturing, Status Quo with Domestic Hydrogen Use, and All-inclusive Portfolio). Each forecast discusses both the new skills and jobs that will be required and possibilities for reskilling or upskilling. The section also presents options for transitioning workers between sunset and future GHE industries and the needed governance of the skills transition towards a GHE.

Finally, policy recommendations and strategic actions toward developing the desired GHE-TVET ecosystem are presented, targeted at various public and private stakeholders.

2 South Africa's current employment landscape and the role of the TVET ecosystem

South Africa faces many economic challenges, including declining GDP, rising unemployment, persistently high levels of inequality and millions trapped in poverty. These challenges have been exacerbated by the COVID-19 pandemic and have had a major impact on the low GDP growth registered in South Africa prior to its onset. The knock-on effects of the pandemic have been felt in key industry sectors, including manufacturing, retail, tourism and hospitality, with a disruptive impact on businesses across supply chains. The most immediate outcome is that South Africa's unemployment rate has risen. This places pressure on the state to mitigate the risks to livelihoods while seeking to reignite the process of reindustrialisation and economic recovery that was intended prior to the onset of the pandemic. South Africa's precarious national energy security, owing to unplanned and irregular electricity load shedding, has had a debilitating impact on the economy.

Young South Africans preparing for the job market are particularly vulnerable to the aftershocks of the pandemic, the knock-on effects of continued intermittent load shedding and its impact on their ability to study and be educated with electricity. With the ongoing contraction of GDP and restrictions on economic growth in the medium term, there will be fewer entry-level opportunities for the large number of young people who exit the schooling and post-school education and training (PSET) system each year, resulting in higher levels of exclusion from meaningful economic activity. This context is exacerbated by a number of failures in the supply of, and demand for, skilled labour, and a persistent disconnect between vocational skills development, economic development strategies and the needs of the private sector.

While tackling its economic challenges, South Africa is simultaneously having to address the significant risks associated with climate change and the need to transition to a low-carbon society. South Africa's per capita GHG emissions are well above the global average. A signatory to the Paris Agreement, the country has committed to reducing its emissions in its first submission of its Intended Nationally Determined Contribution in 2015.[22] This international pledge is based on the notion of a 'peak–plateau–decline' (PPD) emissions trajectory that emphasises the decarbonisation of the electricity sector,

22 UN Framework Convention on Climate Change, *South Africa's Intended Nationally Determined Contribution (INDC)* (Bonn: UNFCCC, 2015).

owing to its pre-eminence in the national GHG inventory. Subsequent to the formulation of the PPD, the country reviewed and updated its Nationally Determined Contribution (NDC) commitment, narrowing the range between its upper and lower bounds from 216 Mt to 112 Mt in 2025 and 70 Mt CO_2-eq in 2030.[23] South Africa's declining GHG emission trajectory after 2030 is set to reach Net Zero around 2050.

However, the 2021 NDC Update indicated that this progression would only be possible through the implementation of 'a range of policies and measures, including a very ambitious power sector investment plan as set out in the 2019 Integrated Resource Plan, the Green Transport Strategy, enhanced energy efficiency programmes, and the recently-implemented carbon tax', as well as significant multilateral support.[24] This much-needed transition will also have significant implications for jobs and skills currently dependent on carbon-intensive industries. This highlights the need for a just transition that is responsive and sensitive to those workers and communities dependent on these sectors as the migration to a Net Zero carbon economy takes place.

This is all the more important given that, although South Africa is considered an upper-middle-income country, a substantial share of the population is still officially regarded as subsisting below the official poverty index.[25] As such, South Africa has prioritised economic growth predicated on affordable and accessible energy services, in tandem with a commitment to protecting its natural resources, as espoused in the NDP.

Presently, the country's industrial complex is predominately fossil fuel based, with crude oil and chiefly coal the primary energy sources. Achieving low-carbon development through an overarching vision of 'leaving no one behind' will ensure an inclusive and just labour transition. However, South Africa's aspirations to attract investment, create employment and ensure inclusive growth within a green development framework have to be assessed against the deeply uncertain international context precipitated by the COVID-19 pandemic. Russia's invasion of and war in Ukraine, and Europe's urgent goal to achieve energy independence and security from Russia have sparked a global energy crisis. Locally, South Africa's energy insecurity continues to worsen already-high levels of inequality, unemployment and poverty. The South African just transition needs to be managed in a way that is inclusive and does not perpetuate the structural challenges that limit sustainable growth.

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23 UNFCCC, *South Africa's First Nationally Determined Contribution Under the Paris Agreement*, Updated September 2021 (Bonn: UNFCCC, 2021),15.

24 UNFCCC, South Africa's First *NDC*, 15–16.

25 Roos, "The Cost of Production and Storage".

South Africa's endowment of substantial renewable energy resources, new-energy minerals and an advanced industrial base positions it well to take advantage of the global shift to alternative energy sources. This presents the country with an opportunity to achieve both its GHG emission reductions and its economic growth aspirations by transforming its economy to create new alternative employment in emerging sectors as yester-decade industries decline.

The government's Economic Reconstruction and Recovery Plan (ERRP) highlights a number of priority intervention areas, including green economic development, energy security and industrialisation through localisation, to reposition the South African economy in the post-COVID context. It identifies skills development as one of the key enablers for these interventions in the short term, and for sustaining these interventions into the future.

The need to pursue economic recovery in combination with a just green transition underscores the demand for innovative vocational skills development that can also address some of the persistent weaknesses in the PSET environment. The threat of perpetual high levels of unemployment should be viewed as an opportunity to reimagine skills development and training aimed at sustainable employment creation fit for the future of work. If leveraged well, the TVET college system represents an important vehicle to create scalable employment impacts, ensuring that the economic recovery and the energy transition are just and inclusive.

The question is how potential GHE employment translates into TVET skill-level jobs. Internationally, there is little public expertise on skill intensities in the hydrogen economy.[26] The few available publications at best offer lists of professions that could be linked to different types of education, but without a basis for quantification.[27] What these studies expect is that, initially, the development of a GHE will be marked by relatively educated labour, although not exclusively, and that the hydrogen economy will also require labour at the TVET level – even more so once fully developed.[28] Thus, demand for high skills occurs at the onset of the GHE, but once operations begin, demand for artisans and technicians will rise.

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26 Roger H Bedzek, "The Hydrogen Economy and Jobs of the Future", *Renew. Energy and Environ. Sustain*. 4, no. 1 (2019); 1–6; Jules Schers et al., "Green Hydrogen and TVET Skills' Role in South Africa's Just Transition" (Working Paper, SAIIA-UK PACT and University of Cape Town, 2021).

27 Bambili Advisory, "The South African Hydrogen Economy"; International Labour "International Labour Organization, *Skills and Occupational Needs in Renewable Energy*, Final Report (Geneva: EMP/SKILLS, ILOILO, 2011); Naima Rassool et al., "Assessment of Local Skills for the South African Renewable Energy Value Chain" (Greencape, forthcoming); Bedzek, "The Hydrogen Economy and Jobs"; "Patel, "South African Industry Demand".

28 Bambili Advisory, "The South African Hydrogen Economy"; Schers et al., "Green Hydrogen and TVET Skills".

2.1 The green hydrogen value chain

The value chain segments South Africa's GHE into the following parts:

- the production of green hydrogen, which requires renewable energy, water, electrolysers and a platinum-based catalyst as inputs;
- the manufacture of hydrogen fuel cells and electrolysers, which require PGM as inputs; and
- downstream sectors and industries that use green hydrogen and/or hydrogen fuel cells (eg, transport and power generation).

Progressing along the value chain requires increasing levels of beneficiation or value addition. For example, the manufacture of hydrogen fuel cells and electrolysers requires the beneficiation of the country's PGM resources. So too, the production of green iron and steel using green hydrogen, or the use of hydrogen feedstock to produce methanol for fertilizer manufacturing, or the manufacture of hydrogen turbines or FCEVs that use hydrogen fuel cells could be regarded as value added processes.

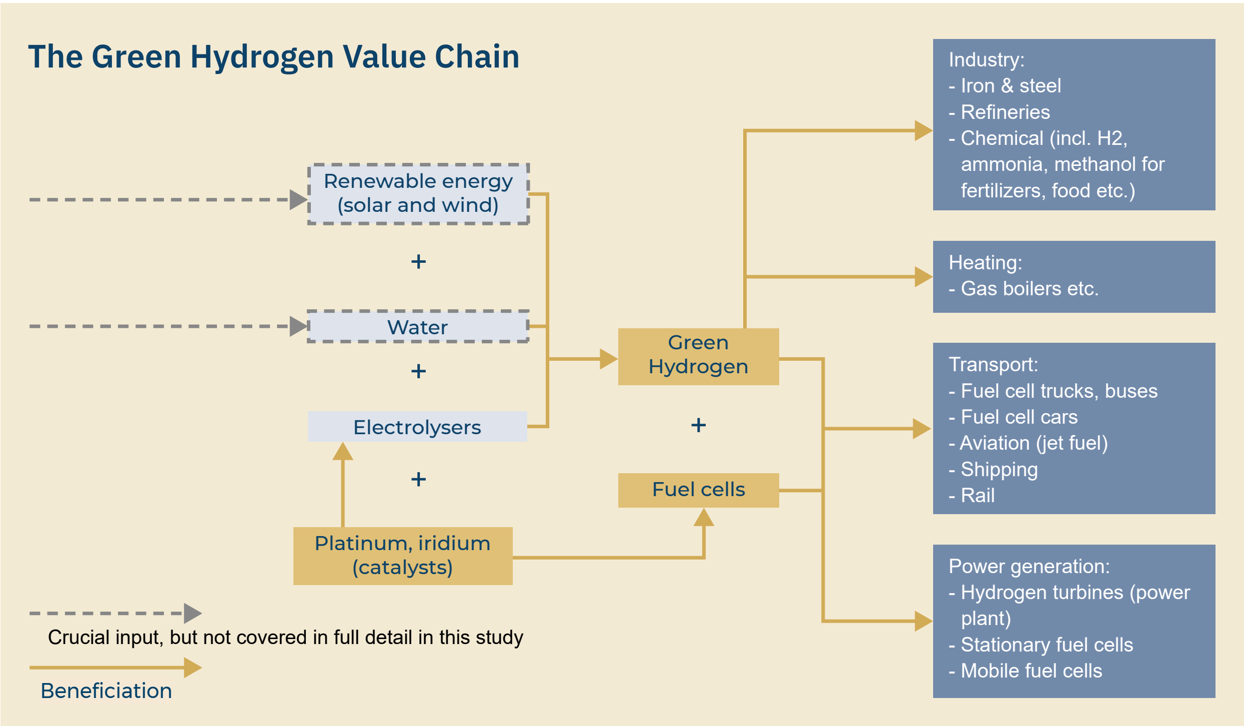

Figure 5 The green hydrogen value chain

Source: Compiled by authors (SAIIA)

2.2 How dominant are TVET sector skills in overall employment trends in South Africa?

In attempting to extrapolate the requirements of TVET skills training for the GHE, it is useful to consider the current TVET skills employment rates in the South African economy. For this analysis, the Post-Apartheid Labour Market Series was used, which is a series of cross-sectional labour force surveys from 1995–2019. The number of workers employed in the South African economy has been increasing at a steady pace since 2009 (Figure 6).

Figure 6 Employment trends in the South African labour force

Source: Bambili Advisory, Anthony Gewer and Suzanne Smit, "Towards a Just Skills Transition in South Africa: Exploring the role of a TVET hybrid Centre of Specialisation for the Green Hydrogen Economy" (Working Paper, SAIIA-UK PACT and NBI, 2021). Calculations based on: Kerr, Post-Apartheid Labour Market Series PALMS [dataset v3.3] (2019)

However, the proportion of TVET workers in the labour force has remained relatively constant over this period.[29] Figure 7 shows the smoothed[30] educational makeup of

29 For the purposes of this study, the term "TVET workers" refers interchangeably to workers with mid- to higher-level skills, predominately in the form of artisans or technicians. They may also include those who are in training towards artisan trades, such as apprentices or learner artisans.

30 Stagnant labour force.

the South African labour force from 2000.[31] The trend shows that there has been a significant increase in the proportion of matric- and secondary-educated individuals, as well as a slight increase in lower- and tertiary-educated individuals. The proportion of TVET-educated workers remains relatively constant, increasing slightly between 2005 and 2010 before levelling off at between 3% and 4% for the past 10 years.

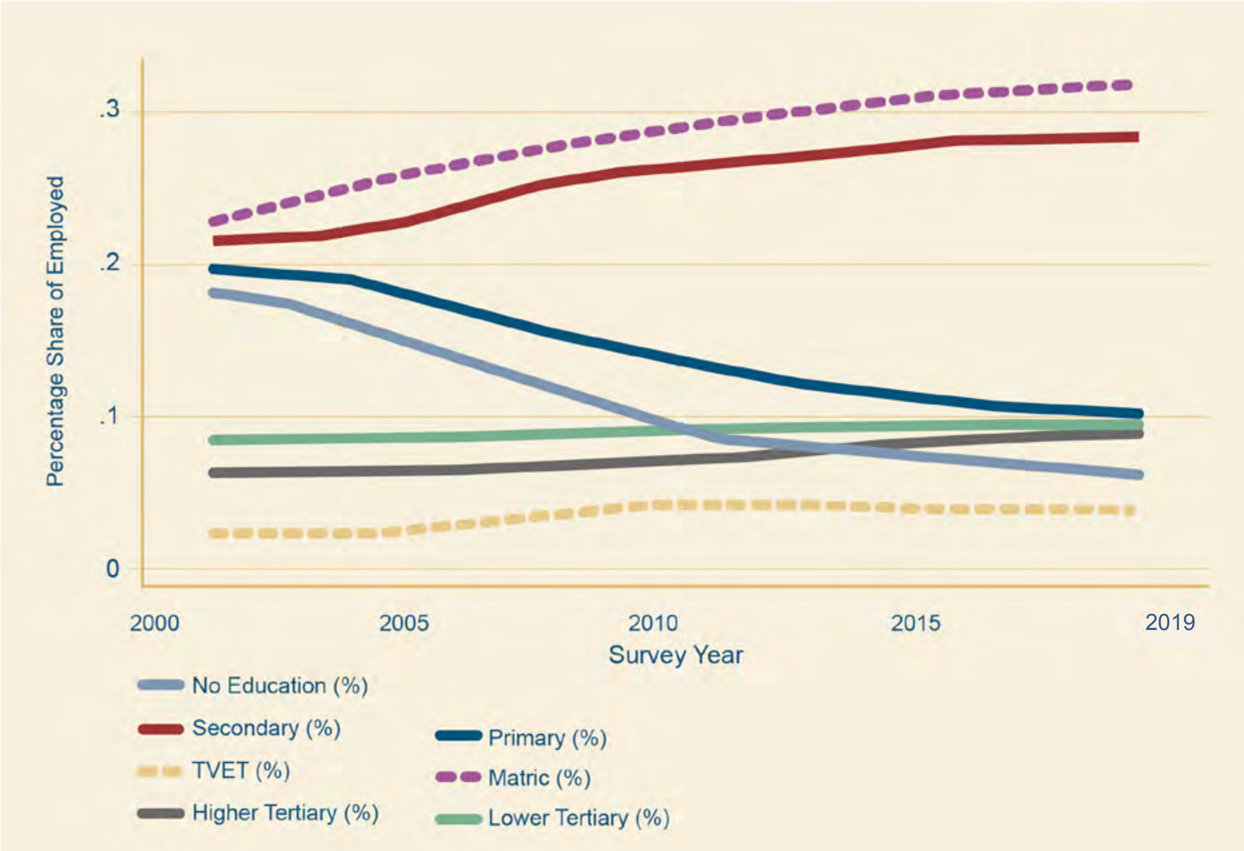

Figure 7 Smoothed proportion of education categories (2000–2019)

Source: Bambili Advisory, Anthony Gewer and Suzanne Smit, "Towards a Just Skills Transition in South Africa: Exploring the role of a TVET hybrid Centre of Specialisation for the Green Hydrogen Economy" (Working Paper, SAIIA-UK PACT and NBI, 2021). Calculations based on: Kerr, PALMS [dataset v3.3] (2019)

Table 1 shows a five-year average (2015–2019) of the proportion of workers in different tertiary educational categories for different sectors relevant to this analysis. There is quite a bit of variation in the proportion of TVET-educated workers between different sectors, with coal mining having the largest proportion of workers with a TVET education level (10.4%). This is followed by the electricity (7.84%) and petrochemical (5.5%) sectors.

31 To smooth the movement in the level of education within each industry, we generate graphs using the ipoly command on the Stata program. This performs a kernel-weighted local polynomial regression of mean education level on years.

Table 1 Five-year average share of tertiary employment by sectors of interest (2015/2019)

Sector	TVET share	Low tertiary share	High tertiary share
Coal mining	10.41%	14.75%	4.43%
Petro-chemical	5.49%	24.02%	18.42%
PGM	4.52%	6.82%	2.72%
Iron and steel	2.90%	8.70%	4.14%
Land transport	3.32%	6.81%	3.20%
Electricity	7.84%	31.90%	16.60%
Electric machinery	3.22%	13.88%	8.44%
Basic chemicals	4.53%	13.87%	10.90%
Motorised transport	4.98%	14.74%	5.82%
Labour force	3.86%	9.41%	8.93%

Source: Bambili Advisory, Anthony Gewer and Suzanne Smit, "Towards a Just Skills Transition in South Africa: Exploring the role of a TVET hybrid Centre of Specialisation for the Green Hydrogen Economy" (Working Paper, SAIIA-UK PACT and NBI, 2021). Anthony) calculations based on: Kerr, PALMS [dataset v3.3] (2019)

To inform policymaking around TVET provision, it is important to differentiate and elaborate which jobs require which type and level of TVET education provision as this gives meaning to the concept of a TVET 'system' in the PSET policy environment. While labour force surveys by Statistics South Africa provide further disaggregation of sub-categories of TVET-educated labour, the sample sizes are too small for meaningful interpretation. However, Bhorat et al.[32] separate employed individuals into three job-type skill levels using a one-digit occupation mapping (see Table 2). Workers are classified as high-skilled, low-skilled or semi-skilled. Most TVET-educated workers in South Africa are employed in occupations classified as semi-skilled (55% of TVET workers in 2019), followed by high-skilled occupations (36% of TVET workers in 2019).

An important qualifier is that labour force surveys measure qualification degrees of workers,[33] but this does not guarantee that a worker holds a specific degree for the job they perform. For example, University of Cape Town (UCT) analysis[34] shows that TVET-educated employees can also work in what Statistics South Africa considers low- and high-skilled job types, and not only in medium-skill job types.[35] Also, on-the-

32 Haroon Bhorat et al.,"Demographic, Employment, and Wage Trends in South Africa" (Working Paper 2015/141, UNU-WIDER, Cape Town, 2015).

33 Kerr et al., PALMS [dataset v3.3].

34 Fadiel Ahjum et al., "Green Hydrogen and TVET Employment Prospects: An Assessment in a Context of Ambitious Decarbonisation for South Africa Towards 2050" (Working Paper, SAIIA-UK PACT and University of Cape Town, 2021).

35 In Statistics SA, "Quarterly Labour Force Survey: Q3:2021", occupational job type categories consist of: Low skill: Elementary workers and domestic workers; Medium skill: Plant & machine operators, craft workers, skilled agricultural workers, service workers and clerks; High skill: Technicians, professionals and legislators. See also Schers et al., "Green Hydrogen and TVET Skills", Appendix.

job training could mean that the real amount of employment at TVET educational-level skills might be higher than the actual amount of TVET-certificate or diploma-holding employees. Lastly, the mandate of TVET colleges is expanding into what until now would have been considered lower tertiary education diplomas.[36] The PSET policy environment also holds potential for greater synergy and alignment between the three levels of TVET, although this is as yet not well developed, but there are examples of how these synergies can be developed (eg, in the renewable PVC environment there are strong links being formed between Higher Skilled TVET training in universities of transformation, TVET colleges and workplace academies / on-the-job training programmes). Thus, a potentially enabling policy environment exists for advancing a connected system of TVET across these levels for the GHE that will need to be actualised in practice within a systemic or 'skills ecosystem' approach, as argued later.

Table 2 Occupations used in the decomposition analysis

Broad task category	Occupations
High-skilled	Legislators, senior officials and managers
	Professionals
	Technical and associate professionals
Semi-skilled	Clerks
	Service workers and shop and market sales workers
	Skilled agricultural and fishery workers
	Craft and related trades workers
	Plant and machine operators and assemblers
Low-skilled	Elementary occupation
	Domestic worker

Source: DHET, "Statistics on Post-School Education and Training in South Africa, 2019" (DHET, Pretoria, 2021)

2.3 Challenges in the scope and scale of vocational skills development

Government has high ambitions for the public TVET college sector and views it as having high potential to support young people to make effective transitions into the labour market. However, an intractable challenge for South Africa has been the development of intermediate or medium-skilled occupations (defined as National Qualification Framework [NQF] levels 4–5) that are appropriate for the green economy.[37] This is critical, as medium-skilled occupations have registered the highest employment growth between 2009 and 2019 when compared to low-skilled and high-skilled occupations.

36 See Schers et al., "Green Hydrogen and TVET Skills", Appendix, interview with Gerda Magnus (TVET expert).

37 Zaakhir Asmal et al., *Skills Supply and Demand in South Africa*, Report (Pretoria: DHET, 2020).

Asmal et al. argue that it is necessary to take cognisance of this shift towards medium-skilled occupations in skills planning, or, more specifically, to see what is driving demand for medium skills rather than high-level skills and how this demand can be more effectively supported by the vocational skills development system. This is further supported by Allen et al.[38] and Bhorat et al.,[39] who argue that the shift to medium-skilled occupations is important for employment and economic growth, particularly in sectors that demonstrate high growth potential. Ramsarup's[40] research shows that this problem in the green economy is partly due to a failure to adequately identify green skills occupations at the medium-skilled levels.

Table 3 Changes in skills shares in the employed population by occupational skill level, Q2 2009 – Q2 2019

	Proportions (%)			Change over Q2 2009 – Q2 2019 in:	
	Q2 2009	Q2 2014	Q2 2019	Percentage points	Numbers ('000s)
	Primary				
High-skilled	7.2	6.7	5.0	-2.3	-18.9
Medium-skilled	39.7	38.5	34.9	-4.8	-10.1
Low-skilled	53.1	54.9	60.1	7.0	150.4
Total	**100.0**	**100.0**	**100.0**	**0.0**	**121.4**
	Secondary				
High-skilled	17.3	19.1	18.1	0.8	19.7
Medium-skilled	64.2	61.5	63.1	-1.1	-62.5
Low-skilled	18.5	19.3	18.8	0.3	3.8
Total	**100.0**	**100.0**	**100.0**	**0.0**	**-39.0**
	Tertiary				
High-skilled	28.5	28.7	26.7	-1.8	319.6
Medium-skilled	42.2	42.8	44.8	2.6	1093.4
Low-skilled	29.3	28.4	28.5	-0.8	455.7
Total	**100.0**	**100.0**	**100.0**	**0.0**	**1869.9**

Source: Bambili Advisory, Anthony Gewer and Suzanne Smit, "Towards a Just Skills Transition in South Africa: Exploring the role of a TVET hybrid Centre of Specialisation for the Green Hydrogen Economy" (Working Paper, SAIIA-UK PACT and NBI, 2021). Anthony Gewer calculations based on: Kerr, et al. PALMS [dataset v3.3] (2019)

38 Caitlin Allen et al., "Employment Creation Potential, Labor Skills Requirements, and Skill Gaps for Young People: A South African Case Study (Working Paper 202102, Development Policy Research Unit, Africa Growth Initiative, Brookings, Cape Town, February 2021).

39 DHET, "Statistics on Post-School Education and Training in South Africa, 2019" (DHET, Pretoria, 2021).

40 Presha Ramsarup, "Greening occupations and green skills analysis." In E Rosenberg et al., *Green Skills Research in South Africa. Models, Cases and Methods*. London: Routledge 2020,175–191; Presha Ramsarup, 'A critical realist dialectical understanding of learning pathways associated with two scarce skill environmental occupations within a transitioning systems frame' (PhD diss., Rhodes University, 2017); Presha Ramsarup, "Systems Elements Influencing the Emergence of Learning Pathways from a Green Skills Perspective". SAQA Bulletin: Learning Pathways, the National Qualifications Framework (NQF), and Lifelong Learning in South Africa. 17(1): 181–211. 2017.

Importantly, while there has been a decline in the number of young people in the South African labour force with only primary or lower-education qualifications, the labour force still remains predominately low skilled. This poses a risk for realising South Africa's long-term growth opportunities.

In assessing the TVET skills requirements for the GHE, it is also important to consider the ability of the public TVET college system to provide the types of low, intermediate and high level skills required by the sector. These skills must be demand-led; adaptable and responsive to an emerging sector and the needs of industry; scalable; sustainably funded; and inclusive. This is particularly important given the mandate of the public TVET College System to expand access for young people to technical and vocational skills that prepare them for entry into the labour market. An assessment of the current skills provision by the public TVET college system highlights some of the challenges that need attention to ensure that the full potential of the GHE is achieved. The following areas are considered: TVET college enrolment, graduation and throughput, and labour market absorption, with a special focus on artisan development and funding.

2.3.1 Public TVET college enrolment

The Public TVET College sub-system has not reached the level of growth anticipated in the White Paper on PSET or the NDP 2030, which expects the TVET ecosystem to eventually train more people than the university system.[41] As of 2019, there was a total of 673 490 enrolments in TVET colleges, compared to the target of 1 250 000 by 2030 set out in the NDP.[42] While the gross enrolment ratio for TVET colleges more than doubled between 2010 and 2015 – from 3.8% to 8% (358 393 to 737 880 enrolments) – with a particular spike in enrolments in 2012, these numbers declined to 705 397 in 2016. From 2016 to 2019 there was a further decline of 4.5%, to 673 490 enrolments.

The main contributor to the decline in enrolments for the three-year NC(V) qualification is the reality that school leavers, and particularly those who left before completing Grade 12, struggle to cope with its technical requirements. This has also filtered through in the age profile of TVET college students. Whereas around 25% of enrolments in college were between the ages of 15 and 19 in 2013, this age group represented only 11.5% of enrolments in 2019. This suggests that far fewer young people are enrolling in colleges as an alternative to the senior secondary schooling system. (In contrast,

41 Bambili Advisory, "The South African Hydrogen Economy".

42 DHET, "Statistics on Post-School Education".

semester/trimester-based Report 191 programmes continue to attract large numbers of enrolments).[43]

Table 4 Enrolment in TVET colleges, 2010–2019

Qualification category	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
NC(V)	130 039	124 658	140 575	154 960	166 433	165 459	177 261	142 373	131 212	138 912
Report 191 (N1-N6)	169 774	222 754	359 624	442 287	286 933	519 464	492 026	510 153	482 175	494 070
Occupational qualifications	23 160	20 799	62 359	19 000	19 825	20 533	13 642	10 969	20 106	22 886
Other	35 420	32 062	95 132	23 371	29 192	32 424	22 468	24 533	23 355	14 025
PLP	–	–	–	–	–	–	–	–	285	3 597
Total	**358 393**	**400 273**	**657 690**	**639 618**	**502 383**	**737 880**	**705 397**	**688 028**	**657 133**	**673 490**

Note: NC(V) = National Certificate Vocational, PLP = Pre-Vocational Learning Programme

Sources: Bambili Advisory, Anthony Gewer and Suzanne Smit, "Towards a Just Skills Transition in South Africa: Exploring the role of a TVET hybrid Centre of Specialisation for the Green Hydrogen Economy" (Working Paper, SAIIA-UK PACT and NBI, 2021). Anthony Gewer calculations based on Statistics on Post-School Education and Training, 2018; TVETMIS 2019, data extracted in December 2020

2.3.2 TVET graduation and throughput

The initial massive growth of the TVET college sub-system between 2010 and 2015 brought with it declining completion rates. The drop in enrolments in more recent years has seen improving completion rates, particularly for N3 and N6 students, with a marginal improvement in NC(V) completion rates. As indicated in Table 5, there has been increased output of graduates from N6, while N3 and NC(V) have largely stagnated.[44]

The large majority of graduates from TVET colleges have business-related qualifications/part-qualifications, while only around 24% of N6 students and 19% of NC(V) graduates graduated from engineering programmes in 2019. Unlike the N3 or N6 certificate, the NC(V) is a three-year qualification resulting in a National Certificate at NQF Level 4 (the equivalent of a matric certificate). The graduation numbers are low relative to other programmes and to the number of people who enrol in the NC(V).

43 Report 191 programmes comprise N1-N3 (only Engineering), which targets school leavers below Grade 12, and N4-N6 (Engineering and Business Studies) for post-Grade 12, the latter resulting in a National Diploma at NQF level 6 if an 18–24 month period of workplace learning is completed.

44 N6 is a National Diploma at NQF level once a period of workplace learning is completed. N3 and NCV 4 are both NQF Level 4, although NCV is a full qualification while N3 is a part-qualification that can be converted to a National Senior Certificate (Technical Matric) with the addition of Sake Afrikaans and Business English.

Table 5 TVET graduates by certificates 2010–2019

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
N3	7 808	2 909	2 902	18 383	23 411	31 023	39 102	46 641	34 793	37 863
N6	13 885	2 428	3 724	15 268	24 396	46 569	60 642	112 508	73 377	113 393
NC(V)	3 715	7 638	6 018	8 114	7 624	10 465	11 716	11 377	11 837	10 920
	25 408	12 975	12 644	41 765	55 431	87 900	111 460	170 526	120 007	162 176

Source: Bambili Advisory, Anthony Gewer and Suzanne Smit, "Towards a Just Skills Transition in South Africa: Exploring the role of a TVET hybrid Centre of Specialisation for the Green Hydrogen Economy" (Working Paper, SAIIA-UK PACT and NBI, 2021). Anthony Gewer calculations based on Statistics on Post-School Education and Training 2010–2019

While there has been a general improvement in completion rates, an analysis by the Department of Higher Education and Training (DHET) indicates throughput rates of students from the NC(V) programme at Level 4 of 9.2%.[45]

Table 6 NC(V) throughput rate

Number of students enrolled for NC(V) Level 2 in 2016	Number of students who completed NC(V) Level 4 in 2018	Throughput rate (%)
88 771	8 135	9.2

Sources: Bambili Advisory, Anthony Gewer and Suzanne Smit, "Towards a Just Skills Transition in South Africa: Exploring the role of a TVET hybrid Centre of Specialisation for the Green Hydrogen Economy" (Working Paper, SAIIA-UK PACT and NBI, 2021). Anthony Gewer calculations based on TVETMIS 2016 and National Examinations Database, November 2018

The throughput rates are influenced by high drop-out rates at NC(V) L2, which calls into question the student support and selection processes that guide enrolments. Anecdotal indications[46] are that a portion of young people are not well informed about which programme they are best suited for and are instead incentivised by the availability of National Student Financial Aid Scheme (NSFAS) funding rather than the career pathways offered by the programme. In addition, young people who have not done well in maths and science at school struggle with the NC(V) curriculum (particularly engineering and IT). This occurs despite the shift in age profile to older learners, which would suggest that learners have had the opportunity to reflect on their career goals.

Due to inefficiency in the sub-system, particularly given the poor throughput, the average cost of producing an NC(V) graduate is high. The funding mechanisms

45 M Khuluvheand R Mathibe"Fact Sheet: Throughput Rate of TVET College Students (National Certificate Vocational) for the Period 2016 TO 2018" (DHET, Johannesburg, 2021).

46 Anthony Gewer, "Interviews with TVET colleges" (National Business Initiative, Johannesburg, 2022).

currently disincentivise improvement in performance, as colleges are funded upfront on the basis of an approved enrolment plan with no clawback owing to poor performance.

2.3.3 Labour market absorption

There has been a range of tracer studies of TVET college students over the past two decades. More recent tracer studies have generally found that just over half of graduates were employed within a 36-year period, with a low level of earnings.[47] The most recent tracer study in 2019, commissioned through the EU-funded Capacity Building Programme for Employment Promotion, found an absorption rate of roughly 40%, when the percentages of completers in work-based learning programmes, self-employment and employment from the figure above are added together.[48] (A high percentage of graduates in this cohort were in work-based learning [learnerships, apprenticeships, etc.) Engineering graduates were more likely to be employed and earn more than business studies graduates, although a larger number of business studies than engineering studies graduates were working in a role that was relevant to their field of study.

2.3.4 Artisan development

The development of artisans has been of critical concern to government over the past decade, to address some of the mismatches between skills demand and skills supply and so meet economic growth and job creation objectives. The NDP has set a target of developing 30 000 artisans per year by 2030.

In reality, the number of college students enrolled in occupational programmes has fluctuated over the past decade, hitting a low of 3% in 2018 compared to 9% in 2012. Given the expectation in the National Plan for PSET that occupational training will become the primary offering of TVET colleges, the low level of occupational training at present is concerning. This is indicative of the persistent disconnect between TVET colleges and workplace-related training being funded through the Sector Education Training Authority (SETA) system.

Government views TVET colleges as a key mechanism for delivering on this target. It initiated the CoS programme in 2019[49] as a means of transforming TVET colleges to

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47 Anthony Gewer, "Choices and Chances: FET Colleges and the Transition from School to Work" (DHET, Johannesburg, 2010); Swiss-South African Cooperation Initiative, *Statistics on Post-School Education and Training in South Africa*, Report (DHET, Johannesburg, 2016); J Papier, S Needham and T McBride, "Pathways of TVET College Learners through TVET Colleges" (Presentation, HSRC/DHET LMIP 5, National Skills Conference, March 23–24, 2017).

48 DHET, "A Baseline Study on the Destination of TVET College Graduates to Strengthen Employment Promotion in South Africa" (DHET, Johannesburg, 2020).

49 *Research Bulletin on PSET: Centres of Specialisation (CoS) Programme Midterm Evaluation*. (DHET, Johannesburg, 2021).

work with industry to implement a demand-led approach to skills development through a dual apprenticeship model.

The impetus for artisan development is part of government's focus on developing an industrial strategy that can respond to rising unemployment and weak economic growth in the aftermath of the global economic crisis of 2009. The Labour Market Intelligence Programme of the Human Sciences Research Council found skilled trades in high demand throughout the period 2015–2019, particularly in the context of changing technology, although the scale of such demand is difficult to quantify. In addition to demand from the private sector, the development of artisans is also necessitated by government's strategic projects to improve national infrastructure and service delivery.

The development of artisans has been hampered by high inefficiencies in the system, including low throughput, weak system administration, poor engagement of public TVET colleges, weak grant administration by SETAs and multiple, confusing routes to artisan qualifications. For example, funding for occupational training in colleges is ad hoc and varies from year to year. In addition, colleges tend to run DHET-funded programmes and occupational programmes as separate operations, thereby creating two different organisational structures within a single institution. As a result, many colleges de-emphasise their occupational training, in terms of both strategy and planning.

Table 7 Artisan development cohort analysis

Quarter entered	Completion after 3 years	Not completed after 3 years	Completion after 4 years	Not completed after 4 years	Completed after 5 years	Not completed after 5 years	Total completed by end 2015/16	Not completed by end 2015/16
2011/12Q1	33,3%	66,7%	40,7%	59,3%	42,2%	57,8%	42%	75%
2011/12Q2	45,4%	54,6%	52,3%	47,7%	–	–	52%	73%
2011/12Q3	46,9%	53,1%	49,0%	51,0%	–	–	49%	93%
2011/12Q4	27,5%	72,5%	30,6%	69,4%	–	–	31%	57%
2012/13Q1	21,3%	78,7%	25,7%	74,3%	–	–	25%	46%
2012/13Q2	30,0%	70,0%	–	–	–	–	31%	59%
2012/13Q3	34,3%	65,7%	–	–	–	–	34%	66%
2012/13Q4	29,5%	70,5%	–	–	–	–	28%	52%
2013/14Q1	25,3%	74,7%	–	–	–	–	25%	47%
	31,7%	68,3%	38,9%	61,1%	42,2%	57,8%	35,1%	64,9%

Source: Bambili Advisory, Anthony Gewer and Suzanne Smit, "Towards a Just Skills Transition in South Africa: Exploring the role of a TVET hybrid Centre of Specialisation for the Green Hydrogen Economy" (Working Paper, SAIIA-UK PACT and NBI, 2021). Anthony Gewer calculations based on DHET QMR from SETAs 2011/12 to 2015/16

A DHET analysis of throughput found that only 37% of those enrolled in artisan programmes in 2011 completed their training in three years, while 38.9% completed it in four years and 42.2% in five years.[50] It is estimated that the amount allocated to artisan training over the five years was about R13 billion. This implies that 57.8% of apprentices did not complete their training at the end of five years. The cost of delayed and non-completion was calculated at R3.6 billion.

Table 8 Number of artisans certificated by SETAs and INDLELAs, by economic sector, 2014/15–2019/20

SETA		2014/15	2015/16	2016/17	2017/18	2018/19	2019/20
AGRISETA	Agriculture	190	186	219	193	277	234
CATHSSETA	Culture, Arts, Tourism, Hospitality and Sports	–	1	1	–	–	–
CETA	Construction	479	582	1 058	1 500	1 427	1 279
CHIETA	Chemicals	572	861	1 020	917	1 314	2 013
ETDPSETA	Education & Training	–	–	–	–	–	–
EWSETA	Energy & Water	964	1 170	993	666	1 202	1 969
FOODBEV	Food Processing	2	–	14	63	69	106
FP&MSETA	Fibre Processing & Manufacturing	98	106	106	111	189	449
HWSETA	Health & Welfare	16	79	73	116	59	175
INDLELA	Non-SETA Candidates	4 983	3 791	3 692	4 381	3 277	2 405
LGSETA	Local Government	486	98	233	415	442	566
MERSETA	Manufacturing & Engineering	6 890	6 600	7 061	6 108	6 320	4 182
MICT SETA	Media, Information and Communication	–	–	–	–	–	–
MQA	Mining and Minerals	1 876	2 056	1 974	1 963	1 978	1 734
PSETA	National & Provincial Government	–	29	14	36	15	11
SASSETA	Safety & Security	12	21	133	168	260	245
SERVICES	Services Sector	1 685	928	1 271	1 246	1 272	1 639
TETA	Transport	1 028	1 402	1 541	1 212	1 250	1 312
W&RSETA	Wholesale & Retail	–	–	3	5	4	–
Total		**19 281**	**17 910**	**19 406**	**19 100**	**19 355**	**18 319**

Source: Statistics on Post-School Education and Training, 2018, National Artisan Development Support Centre (NADSC) – National Artisan Recommendation for certification data management system, 2020

50 National Skills Authority, *Evaluation of the National Skills Development Strategy: NSDS III 2011–2016* (DHET, Johannesburg, 2018).

The total number of artisans issued with national trade certificates by SETAs and Indlela during the 2019/20 financial year was 18 319, compared to the target of 30 000.[51] The number of artisans registered every year has remained relatively static. Out of the total certificates issued over the six-year period, one-third were issued by the Manufacturing, Engineering and Related Services SETA (MERSETA), followed by Indlela (20%).[52]

Tracer studies have found high levels of labour market absorption for qualified artisans. A tracer study conducted by the Swiss-South African Cooperation Initiative in 2016 found that 79% of newly qualified artisans found employment, with most finding employment easily, and 58% of these finding permanent employment.[53]

2.3.5 Funding

The level of funding available to TVET colleges has been a key factor in limiting growth. While the funding base initially incentivised growth, there has been a persistent funding deficit in real terms. TVET enrolments have largely been capped since 2015 and colleges are expected to fund the gaps from other sources. In 2016, the DHET reported to the Presidential Commission on Higher Education that, based on the fully costed funding norms, only 429 638 of the 664 748 enrolments in the TVET college sub-system at the time were funded. The 2019/20-approved TVET enrolment plan had a funding deficit of R1,027 billion. The COVID-19 pandemic has brought about an anticipated funding cut of 9% over the Medium-Term Expenditure Framework (MTEF) period (2021/22–2023/24), translating into a TVET headcount reduction of approximately 139 000 enrolments over the MTEF.

In general, college allocations for enrolment do not fully cover all planned enrolment into the ministerially approved programmes. NSFAS bursary recipients have tripled in number – from 114 968 in 2011 to 346 270 in 2019 – representing 54% of enrolments in ministerially approved programmes NC(V) and Report 191.

2.3.6 Inclusion

Gender inequality and social exclusion contribute significantly to socio-economic outcomes of unemployment, inequality and poverty, often termed the ‘triple helix’ challenge in South Africa. Parallel to this, TVET provision holds potential as a transformative tool for development planning globally and in South Africa – without skills

51 DHET, “A Baseline Study on the Destination of TVET College Graduates to Strengthen Employment Promotion in South Africa” (DHET, Johannesburg, 2020).

52 The National Artisan Development facility for artisan assessment, registration and recognition of prior learning (ARPL)

53 SSACI, *Statistics on Post-School Education*.

to sell on the labour market or make a viable living in subsistence or self-employment activities, individuals are more likely to be in poverty. In addition, the GHE provides a new epoch for social inclusion, where the skilling, upskilling and reskilling of workers, including women and marginalised groups, are a means to narrow inequality and social marginalisation.

While South Africa fares well in terms of female enrolment in the TVET ecosystem,[54] unemployment rates among women consistently remained higher than that among men[55] over the past decade. This demonstrates a critical gap between skills and qualification benchmarks and industry practice. This necessitates a deliberate and focused strategy to increase gender equality and social inclusion in both the skills ecosystem and the green hydrogen industrial transition in South Africa, strengthening the linkages between skills and employment for racially marginalised women in particular.

The findings regarding the challenges around the skills and graduates delivered by the TVET college system are instructive of the pitfalls to be avoided in developing an appropriate skills pipeline for the GHE. They also signal the need to re-imagine the TVET colleges' training system to make it more effective and responsive to the wider needs of the economy and industry, and more financially sustainable.

54 In 2019, the DHET recorded a nationwide female TVET enrolment rate that was 40% higher than that of males, demonstrating a gradual increase over the past decade.

55 Statistics South Africa's Quarterly Labour Force Survey of the second quarter of 2021 demonstrated that the South African labour market is more favourable to men than to women, and that Black South African women were the most vulnerable to unemployment. Men recorded an unemployment rate of 32.4% in 2021, while women recorded 36.8%.

3 The South African TVET ecosystem in transition: Integrating foresight and anticipation in skills governance and planning

While there is potential in both the TVET ecosystem and the green hydrogen value chain, harnessing this potential is not a simple matter. Firstly, the education system is changing. There is an urgent need to re-imagine post-school education and training in the context of global climate change, technological disruption, and economic and other crises (eg, COVID-19).[56] Secondly, green hydrogen and related industries are nascent, and South Africa is at the earliest stages of market development. The country's HSRM was published only in February 2022, and national departments and other stakeholders are still investigating their roles.[57] While the HSRM sets a strategic direction and intention, a lot is likely to change as the GHE develops both domestically and internationally, spurred by the current dynamic international energy context. Finally, in some cases, private sector stakeholders may move faster than government's plans.

All of this makes for a complex and fast-changing context, rife with uncertainties. To date, the South African TVET ecosystem has not done particularly well at navigating this context. It functions without a systematic approach to foresight or a systemic innovation-based approach for coping with accelerating, complex forms of change. The vocational skills system furthermore has negligible institutional systems to deal with long-range time horizons. It has also struggled to deliver demand-led skills fit for industry needs. For their part, policymakers are overwhelmed by prevailing issues at the expense of longer-term planning, and are not acting in step with industry. In addition, siloed planning often leads to a lack of policy coordination and disjointed governance systems.[58]

As is, the risk is that South Africa will end up being out-planned, out-paced and vocationally under-skilled for current and evolving industry demands, compared even to other developing countries that are proving better at developing and executing long-range policy.[59]

56 Muhammed Patel and Deon Cloete, "TVET Skills in the South African Green Hydrogen Economy: A Policy Review" (Working Paper, SAIIA-UK PACT and TIPS, 2022).

57 Patel and Cloete, "TVET Skills in the South African".

58 Patel and Cloete, "TVET Skills in the South African".

59 Patel and Cloete, "TVET Skills in the South African".

Technical and vocational education and training evolved to serve the requirements of the industrial revolution. Now it is important to consider how it may support today's major shifts to accommodate the impacts of climate change and the changes brought about by the 4IR, while supporting a just labour transition in South Africa.

The implications of these shifts for industries (and, by extension, for the education system) are far-reaching. The overarching question to be addressed is how to ensure that the TVET ecosystem can be responsive to these changes. However, this study is not concerned with this question in a general sense only. It seeks to assess how the TVET ecosystem can help to prepare the South African workforce for an emerging GHE.

South Africa has to plan for this new world. It has to be done in an adaptive, responsive way. This is where tools from participatory foresight and systems practice come in. Decision makers need to grow their capabilities to navigate uncertain technological futures over extended timeframes. They need to do this in a participatory way, so as to ensure the input and buy-in of key stakeholders. This will allow stakeholders to anticipate emerging challenges and co-create future-orientated innovative governance responses that are fit for purpose in a complex and changing world. In practical terms, anticipatory governance will increase government and the TVET ecosystem's capacity to respond to a dynamic external environment and evolving industry demand at earlier rather than later stages of development.[60]

There is growing recognition globally of the need to use strategic foresight in TVET skills governance and anticipation that goes beyond traditional approaches to skills planning, which lean heavily on quantitative forecasting.[61] Traditionally, forecasting skills supply and demand have been done using the 'manpower planning approach', in which data from past and current workforces (and populations) is collapsed at the occupation and sectoral level, and predictions on how this will evolve in the future are then made. The DHET and the TVET college system have a strong record of using similar forecasting methods.[62] While there is definite value in this kind of forecasting, the dynamic nature of the environment – whether the pace of technological development, changes in the labour market and the world of work, or geopolitical shifts – is increasing levels of complexity and uncertainty. In this context, it becomes ever more necessary to supplement quantitative forecasting with additional tools that can provide insights on emerging technologies, shifting job profiles and changing skills requirements.[63] This is

60 Patel and Cloete, "TVET Skills in the South African".

61 ILO, *Using Technology Foresights for Identifying Future Skills Needs:: The Moscow School of Management SKOLKOVO's Education Development Centre (SEDeC)* (Geneva: ILO, July 15, 2014).

62 Patel and Cloete, "TVET Skills in the South African".

63 Patel and Cloete, "TVET Skills in the South African".

also the reason why this report adopts a mixed-methods approach that includes both modelling/forecasting and critical strategic foresight. Table 9 covers different tools for carrying out skills assessment and anticipation.

Table 9 Tools for carrying out skills assessment and anticipation

Type of activity	Data collected
Descriptive statistics or stock-taking	Estimates of overall demand and supply of skills and technology use, often based on collating data from various sources (eg, sector skill studies)
Quantitative forecasting	Forecasting or projecting future demand for skills, typically using econometric modelling
Skills and jobs surveys (questionnaire surveys)	Assessments of demand for, and supply of, skills and technology use, usually with an assessment of the extent to which demand and supply are in balance
Graduate tracer studies	Using matched administrative data sets or surveys to track people through education and the labour market to see how the former influences the latter
Qualitative research	Use of non-quantitative techniques to gauge in-depth information about current and future skill demand/supply and technology trends, eg, via company case studies, use of focus groups
Foresight	Critical thinking about the future of skills supply/demand and technology trends, using participatory methodologies
Big data	Use of web sourcing, combined with text mining and machine-learning approaches, to collect and classify data about skills, vacancies, technologies, etc.

Source: European Centre for the Development of Vocational Training, "Understanding Technological Change and Skill Needs: Technology and Skills Foresight" (Cedefop Practical Guide 3, EU Publications Office, Luxembourg, 2021), 11

It is important that a skills foresight approach is participatory. Participatory foresight methods enable a discussion of technological change and anticipated skills in cooperation with stakeholders. The participatory nature of the skills foresight approach is one aspect that distinguishes it from conventional skills assessment methods (such as skill forecasts, skills surveys, big data analyses). The aim of the latter is also to predict future skills demand – a limited approach in conditions of high uncertainty and rapid technological change.

Participatory skills foresight broadens the boundaries of skills perception by:

- identifying new or emerging technologies (through a technique such as horizon scanning);
- assessing the implications of present actions, decisions, etc. (consequence assessment);
- detecting and avoiding problems before they occur (early warning and guidance);

- considering the present implications of possible future events (pro-active strategy formulation); and
- envisioning aspects of desired futures (clarity around long-term strategic goals and direction).

The Three Horizons provides a useful framework for the transition faced by the South African TVET ecosystem.

3.1 The Three Horizons: A framework for major transitions

The Three Horizons is a framework for making sense of major transitions.[64] It is widely used in strategic foresight. The Three Horizons framework was used to distil high impact key uncertainties used in the development of TVET skills governance scenarios and was central in guiding the theory of change and the policy recommendations and strategic actions detailed in subsequent report sections. As detailed in Figure 8, the framework maps systems in transition along two axes: time on the x-axis and strategic fit on the y-axis. On this canvas, it plots three horizons.

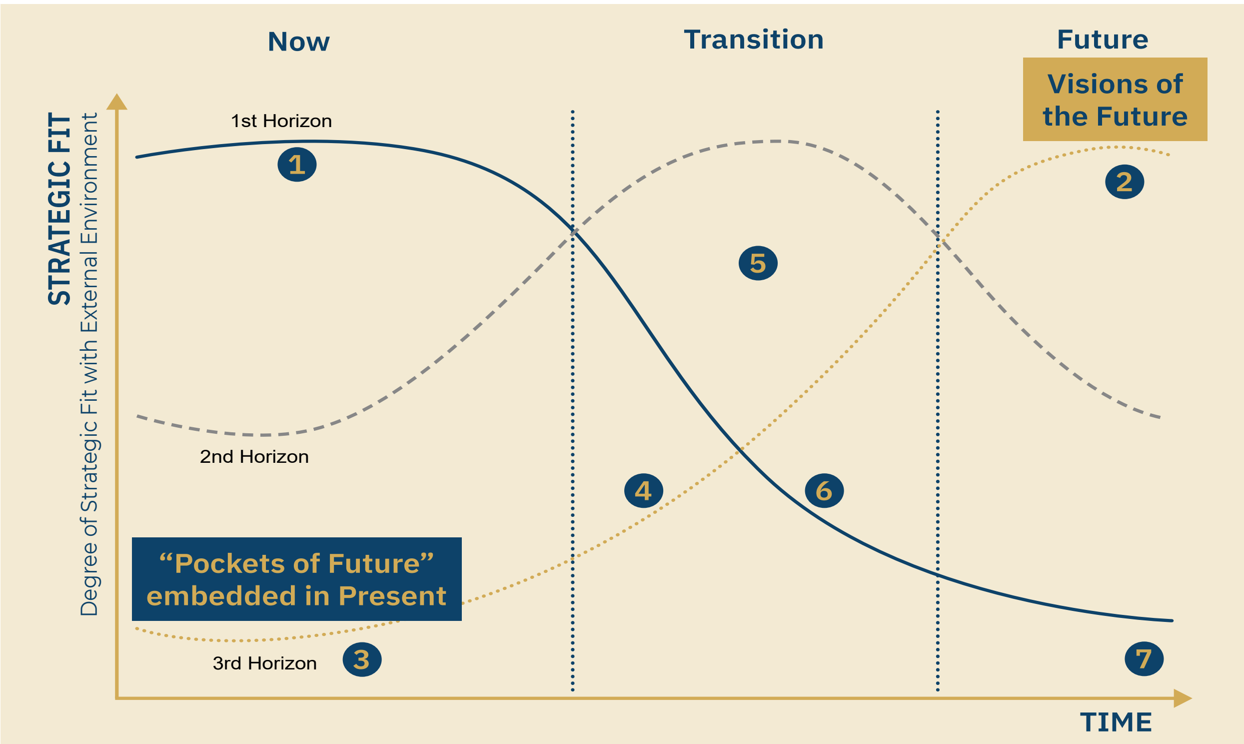

Figure 8 The Three Horizons Framework

Source: Andrew Curry and Anthony Hodgson, "Seeing in Multiple Horizons" (*Journal of Futures Studies* 13,1, 2008)

64 Bill Sharpe, *Three Horizons: The Patterning of Hope* (Charmouth: Triarchy Press, 2013); Andrew Curry and Anthony Hodgson, "Seeing in Multiple Horizons" (*Journal of Futures Studies* 13,1, 2008).

The First Horizon describes the current, dominant system. It refers to the way things work today. Institutions are set up for this system – there is a high degree of strategic fit with the external environment. Over time, however, this system will lose relevance and no longer be fit for purpose.

The Third Horizon (H3) describes a future system. In the present time, this system is in the very early stages of development. It still seems strange or unfamiliar. Over time, however, this will become the dominant way of doing things. Even in its early stages, the H3 system already holds the seeds of what will be (also referred to as ‘‘pockets of the future in the present’).

The Second Horizon describes a system in turbulent transition. This is the space where a dominant system in decline and an emerging system are fighting for prevalence. It is a zone of tension and disruption, but also of innovation.

The Three Horizons Framework provides a canvas to think about complex systems in transition. The numbers 1–7 on Figure 9 correspond with the guiding questions below.

Key questions:

1 What are the characteristics of the current system?

2 What visions exist for a desirable future system?

3 Is it possible to identify any pockets or seeds of the future in the present?

4 How does one help the (desirable) new system to grow?

5 What tensions exist in the transition and how can those be managed? Any opportunities for innovation?

6 How does one help the old system to retire well?

7 What should be kept from the old system?

3.1.1 Applying the Three Horizons Framework to a TVET ecosystem in transition

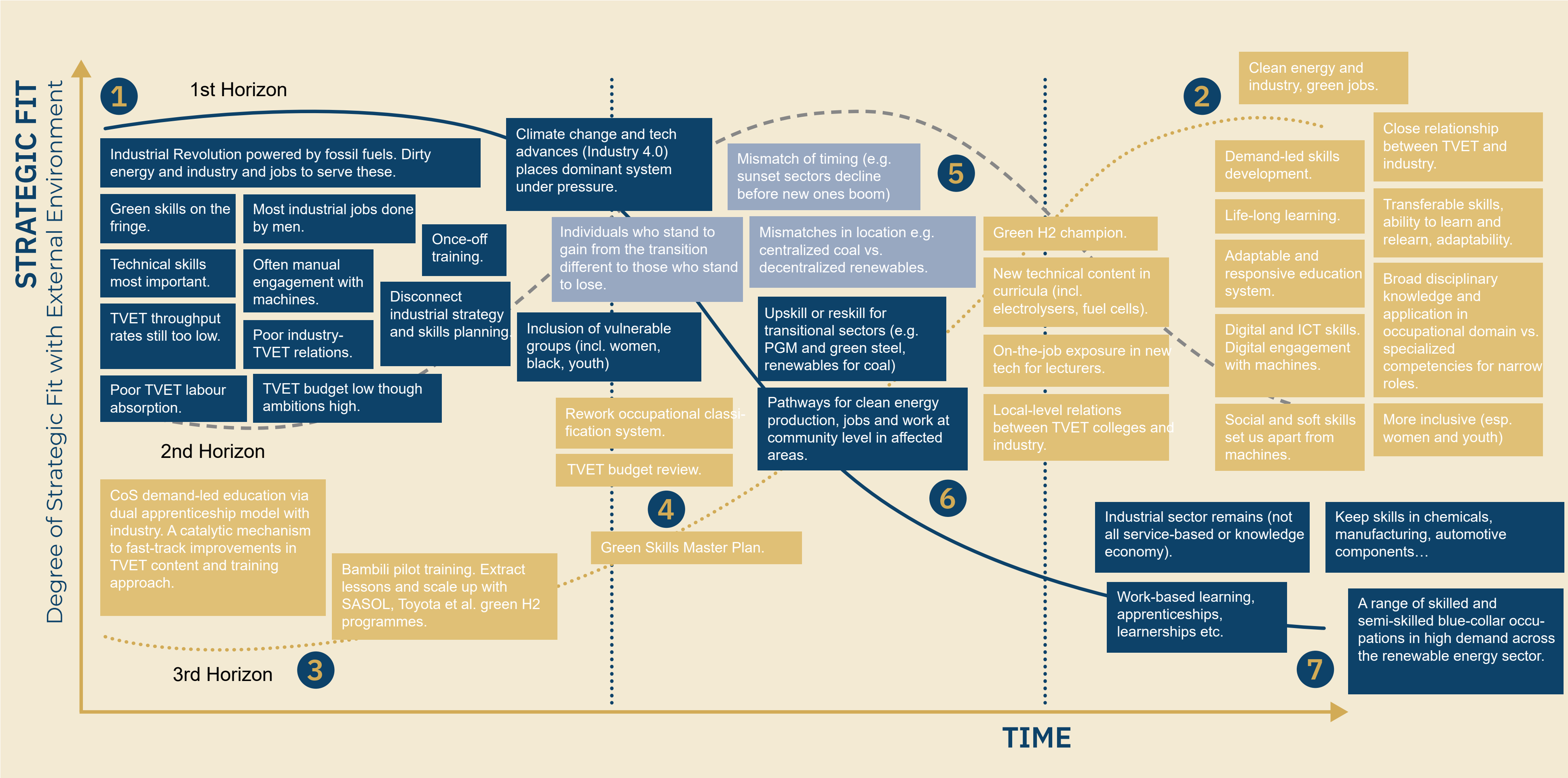

Figure 9 A changing world of TVET in Three Horizons

Source: Compiled by authors (SAIIA)

Currently, the TVET ecosystem still serves the previous industrial revolution, training students for jobs in an economy powered by fossil fuels and characterised by carbon-intensive energy and industry. As discussed, green skills are on the fringe. However, climate change and technological advances are placing this system under pressure. Changes are required both in course content and in the way teaching and learning happens.

The current system is characterised by poor industry–TVET relations, as well as a mismatch between vocational training and industry needs, resulting in low TVET labour absorption.[65] What is required instead is demand-led skills development supported by a close working relationship between the TVET ecosystem and industry nationally, and, more importantly, locally between individual colleges and firms.[66]

There is also a need to move away from training for narrowly defined specialist roles and static qualifications, towards a capabilities approach that focuses on job families and broad disciplinary knowledge applied in occupational domains.[67] This should be coupled with work-integrated learning, with the bulk of highly specialised training linked to specific technologies taking place in the workplace. The German dual apprenticeship model offers insightful examples.[68] For this to happen, the reviewed TVET budget allocation mentioned earlier should include funds specifically for work-integrated learning.[69] Lecturers too should receive continuing on-the-job exposure to new technologies.[70]

In the case of workers, whereas individuals used to study or train once-off for a job that stayed the same for many years, the rapidly changing world of work is increasingly requiring an adaptable workforce with transferable skills and the ability to learn and re-learn. Lifelong learning is becoming the norm and needs to be supported by a move towards a capabilities-based approach with work-integrated learning.

In addition, to ensure a whole-of-society approach, it is important to consider that in the technical and vocational skills space specifically, many of the jobs used to be and continue to be done by men. In South Africa, the average age of tradesmen is also high. There is therefore a need for more young people and women to enter these

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65 Bambili Advisory, “The South African Hydrogen Economy”; Bambili Advisory, Anthony Gewer and Suzanne Smit, "Towards a Just Skills Transition in South Africa: Exploring the Role of a TVET Hybrid Centre of Specialisation for the Green Hydrogen Economy" (Working Paper, SAIIA-UK PACT and National Business Initiative, 2021).

66 Bambili Advisory, Gewer and Smit, "Towards a Just Skills Transition”;” Bambili Advisory, “The South African Hydrogen Economy”; Patel, “South African Industry Demand”.

67 Bambili Advisory, Gewer and Smit, "Towards a Just Skills Transition”.

68 Bambili Advisory, Gewer and Smit, "Towards a Just Skills Transition”; Patel, “South African Industry Demand”.

69 Bambili Advisory, Gewer and Smit, "Towards a Just Skills Transition”.

70 Bambili Advisory, “The South African Hydrogen Economy”.

professions. Whereas many of the jobs in technical and vocational arenas used to entail a substantial amount of manual engagement with machines, this engagement is increasingly becoming digital. Digital and ICT skills are therefore becoming crucial, as are STEM skills in the 4IR world, and social and soft skills including skills for transformative learning (un-learning and learning throughout the life course given the rapid rates of change).

The TVET ecosystem is considering ways to ensure that the kind of demand-led, responsive occupational offering described above is integrated into its curriculum. Boxes 1 and 2 cover two promising initiatives on this front that also serve as 'seeds' or 'pockets of the future', namely the CoS model and a pilot course in hydrogen fuel cells presented by Bambili Advisory.

3.1.2 Towards a demand-led TVET ecosystem – The Centre of Specialisations Model [71]

BOX 1 TOWARDS A DEMAND-LED TVET ECOSYSTEM: THE CENTRES OF SPECIALISATION MODEL

Government initiated the CoS programme to transform TVET colleges to work with industry on a demand-led approach to skills development. A CoS is a faculty or department in a well-functioning TVET college dedicated to the delivery of the knowledge component of a specified trade, in response to demand, coupled with the adoption of a dual-system apprenticeship model. For the first phase of the programme, the DHET selected 19 colleges and 26 sites (two per trade covered).

A review of the model revealed that the following factors contributed to its success:

- The programme conducted a rigorous selection of colleges. Criteria included: financial management capacity, willingness to take up the CoS role, learner enrolment and success rates, proximity to workplace learning opportunities, availability of facilities, partnerships (with employers, SETAs, professional bodies) and the presence of trade test centre. Buy-in from the college executive also proved crucial. Colleges were required to recruit qualified artisans as instructors and to ensure that training workshops met industry standards.
- Employer participation was driven by Occupational Team Convenors (OTCs) – persons nominated by industry associations. Allowance was also made for 'lead employers' and 'host employers' (smaller companies that are unable to take on a big administrative burden associated with supporting the college in terms of developing the curriculum and learning materials, the training of mentors and the monitoring of programme rollout).
- Finally, the programme ensured the rigorous selection of participants. Criteria included a relevant educational background, fitness for the workplace role, and location. Location is particularly important for this model, and it is also important that centres are set up in or near areas of skills demand. This avoids additional travel, relocation or accommodation expenses.

71 Gewer and Smit, *Hybrid Centre of Specialisation*.

However, the programme also faced challenges:

- The large investment of resources and effort required to implement the model in its current form makes the programme difficult to scale, both financially and practically. For example, the first intake in the programme was 732 across 26 campuses. This is in comparison to the number of students enrolled in engineering qualifications, which is in the range of 200 000–300 000 across the system.
- A disconnect between fiscus funding (for the college tuition component) and skills levy/tax rebates (for workplace learning) caused fragmentation in programme funding. It is recommended that provision be made for multiple but integrated and well-governed funding streams, potentially including funding earmarked for the just transition. The model should also be integrated into college funding norms. This would serve to encourage commitments from the SETAs.
- Work-integrated learning is a central component of the model, yet it proved challenging to find sufficient workplaces to host and train apprentices. This may be an even bigger problem with emerging industries, for example in the case of the GHE. Timing and skills demand assessments will prove crucial. In addition, the programme may require additional support, for example from the industry champion in charge.

The DHET is working towards institutionalising the CoS model as part of the shift in focus towards occupational qualifications, which may address some of the challenges. In addition, it may be necessary to adapt the model to make it more flexible and easier to scale, while drawing on the lessons mentioned here.

In conclusion, an adapted CoS model can contribute to greater alignment of college and workplace provision, creating pathways into apprenticeships, and building social partnerships to drive these programmes.

BOX 2 TOWARDS A DEMAND-LED TVET ECOSYSTEM: A PILOT TRAINING IN HYDROGEN FUEL CELLS[a]

In December 2020, 25 TVET graduates and nine professionals completed a six-week pilot training course on stationary hydrogen fuel-cell systems conducted by Bambili Advisory. A SWOT analysis of the course revealed a number of lessons:

Strengths

- A rigorous screening process ensured that applicants were both qualified and competent. It emerged, however, that despite meeting formal qualification requirements, many of the candidates lacked certain soft skills and digital skills, which could impede their employability. The course was extended by two weeks to include sections on these, as well as a mentorship component. This proved successful in helping to prepare students for real-world employment.
- Course relevance and rigor were ensured by training-of-trainers from international partners active in the hydrogen space, involving industry partners in curriculum design, and a knowledge partnership with the University of Pretoria.
- An industry partnership with Ario Meta Power provided opportunities for work-integrated learning, as well as a limited number of post-course internships. Involving industry in curriculum design also served to build trust between colleges and industry.

- Strategic partnerships were made with government agencies, including with the DSI, which assisted in championing the development of the course, and EWSETA, which played a major role in funding and attracting candidates.
- The programme actively pursued female candidates to ensure a fair gender balance and also paid special attention to youth representation (ages 24–34).

Weaknesses

- The location of the pilot in Pretoria, at the University of Pretoria, meant that most of the students had to travel great distances, with many requiring financial assistance to attend the course. The preference would be to consider TVET colleges that are based near industry partners. This will cut down on costs and also assist with managing the demand and supply of learners.
- Feedback from students indicated that, although they appreciated an opportunity to work on demonstration models, the course could be enhanced with further practical training. This highlights the importance of work-integrated learning. Workplace experience was further complicated by the fact that the course was presented during the pandemic.
- Only three of the students were selected for internships. This is partly due to the limited number of spaces available for industry uptake. Employment will likely remain low until the sector develops and there is greater demand for these skills.

Opportunities

- The pilot is a successful model that could be replicated. Students who have completed this course are ready to be absorbed into internships or employment opportunities. As the demand for these skills grow, and as more industry partners come on board, there is potential to enhance the accessibility of the course, initially along the Hydrogen Valley.

Threats

- The level of resources required for scaling requires careful consideration of the model and potential financing options.
- If the demand for these skills outpaces delivery of quality programmes and candidates, there is a risk of scaling too quickly without the necessary quality assurance taking place.
- The GHE currently enjoys a range of support mechanisms, but these benefits are yet to be realised, and this during a period of global financial strain and upheaval, which may lead to changing national priorities.
- South Africa is not the only country considering a GHE. Depending on how well the country is able to position itself in this race, certain value chain activities, processes or products may become less lucrative or competitive to produce on home soil compared to other nations, causing contraction of the market and a reduction in the demand for learners.

a Gewer and Smit, *Hybrid Centre of Specialisation*

3.2 TVET skills governance scenarios

The transition towards a desirable or preferable future for South Africa's TVET ecosystem in the context of an emerging GHE as expressed in the Three Horizons is beset by a number of uncertainties.

Scenario planning is a useful tool from the foresight toolbox to work *with* uncertainties instead of being overwhelmed by them. This section uses high-impact, key uncertainties related to the future GHE and TVET skills to build out four possible scenarios for the future of TVET skills governance. Using the Three Horizons framework, the populated high impact uncertainties displayed in Figure 9 were distilled into six uncertainties relating to:

- innovative funding models for TVET colleges;
- digital infrastructure and assets to increase accessibility and leverage the 4IR;
- political will (policy certainty and effective action) to change educational outcomes in light of a green hydrogen economy;
- demand-led educational outcomes to ensure economic wellbeing (the personal and collective ability to mobilise economic, social and material resources to achieve individual and collective wellbeing);
- open system supported by a Total Quality Management Framework to enable optimal knowledge production; and
- ecosystem to support collaboration and alignment across the green hydrogen value chain.

A quantitative ranking exercise using the indicators of impact and level of uncertainty was then carried out revealing the two cumulatively highest-ranking uncertainties of:

- **Political will:** policy certainty and effective political action to change educational outcomes in light of a green hydrogen economy
- **Demand-led educational outcomes:** to ensure economic well-being (the personal and collective ability to mobilise economic, social and material resources to achieve social and collective well-being)

The scenario analysis, therefore, grapples with two variables: policy certainty and effective political action (y-axis) and the suitability and effectiveness of TVET skills (x-axis) redesign. The interplay between the four quadrants enables foresight through different lenses, thereby challenging business-as-usual approaches and shaping future anticipations. Scenario analysis broadens the future analysis through analytical methods (scanning and trend analysis), interpretive methods (participatory learning) and prospective methods (developing alternative futures).

The scenarios (with the timeframe being 2050) highlight a point in our present where we reflect on macro-historical trends and explore possible, plausible and preferred futures within the cone of plausibility. The scenarios are not predictions of the future but open pathways for alternative futures created by actions in the present. In addition, scenario analysis enables resilience to disruptive forces of change through collective foresight.

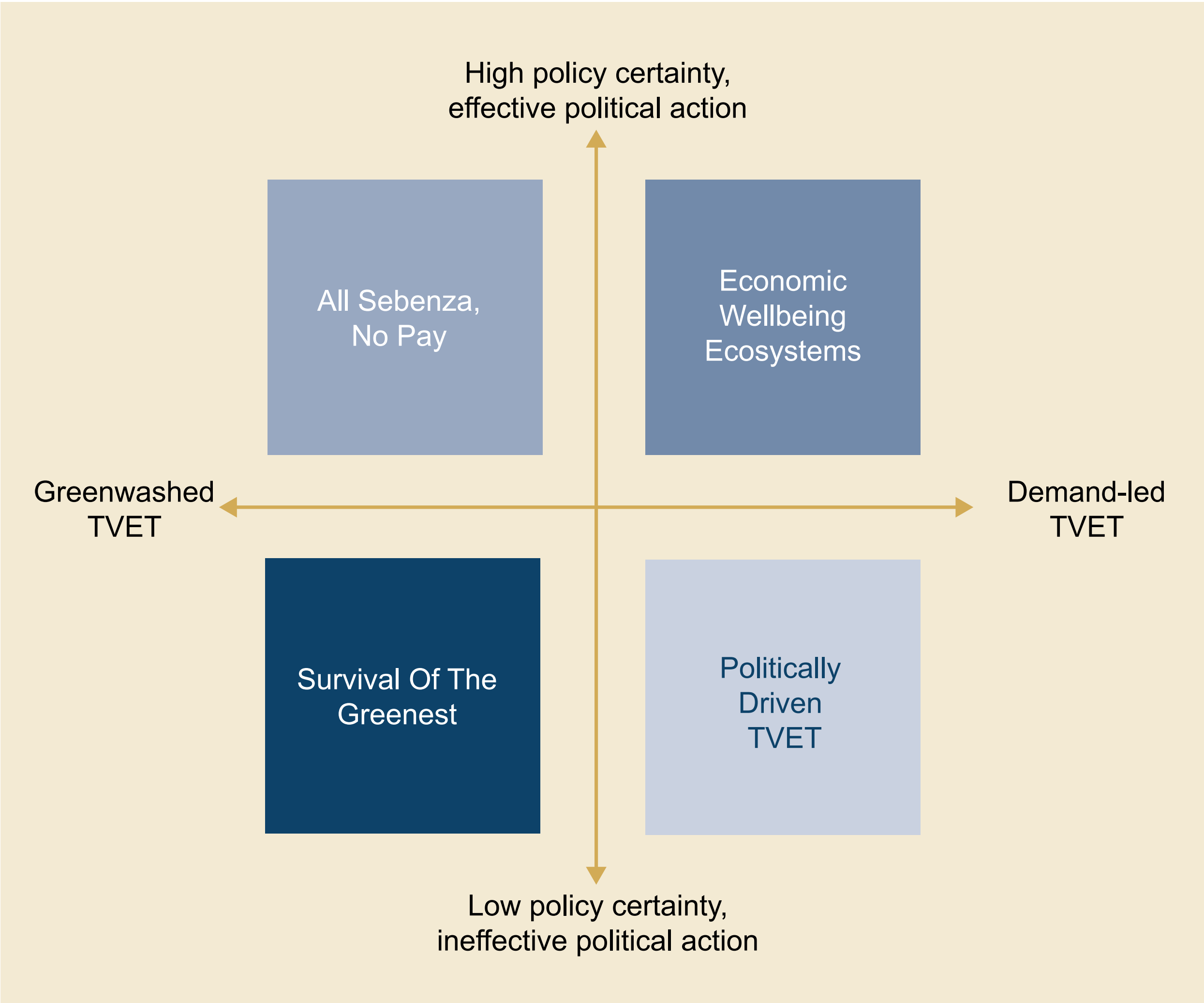

Figure 10 Scenario matrix for TVET skills governance in South Africa (2050)

Source: Compiled by authors (SAIIA)

The quadrants reflect how the forces of change interplay into possible, plausible and probable futures. Each quadrant highlights the possible futures, and the synthesis of the forces related to a specific quadrant reflects in the quadrant heading.[72]

A summary of each quadrant heading is below.

3.2.1 Desired TVET skills governance futures

- **Economic wellbeing ecosystems future**

TVET students are empowered to achieve demand-led educational and training outcomes to catapult the GHE. Students receive whole-person training to care for their households (the young and the old). In addition, students become good citizens who enhance democracy and collective wisdom and become socio-ecological beings who see themselves as integrally part of the natural environment and dependent on all the ecosystems services.

The TVET ecosystem permeates social, psychological, economic and physical infrastructure and investments provided by the state institutions as facilitators of a well-being ecosystem. The education system transcends and increases marginalised persons' collective socio-economic wellbeing by increasing economic activity and ultimately leveraging the demographic dividend to achieve a just transition.

The economic wellbeing ecosystem opens numerous possibilities by leveraging digital, social, economic and environmental innovations and scaling to facilitate the whole-person education system and the additional benefits of economic wellbeing. The economic wellbeing ecosystem encapsulates high political will (ie, policy certainty and effective action and implementation by government) where communities and individuals believe they can create desired futures.

- **Shadow boards**

Shadow boards[73] are implemented to facilitate collaboration among various stakeholders, including TVET management, educators, students and industry. This creates interactive and iterative processes for education by ensuring more inclusive outcomes through business model reinvention, creativity, flexibility and a strong sense

72 For a detailed account of the mini-scenarios in Figure 10 within all the quadrants see Deon Cloete, Ndeapo Wolf and Letitia Jentel, "Futures of TVET Skills: A Green Hydrogen Strategic Framework" (SAIIA-UK PACT, Working Paper, 2022).

73 "Shadow boards" mimic traditional boards of organisations and institutions, but include younger generations, support diverse thinking patterns and approaches, ensure more inclusive outcomes and serve as a catalyst to promote radical innovation, thereby steering away from used futures. An emergent quality of shadow boards is that they provide reverse mentoring by creating capacity for collective wisdom.

of community. Through shadow boards, youth are part of the education process redesign and TVET college organisational transformation, sustaining inclusive outcomes through transformative action. The shadow boards enable a thriving GHE.

- **Problem-orientated education**

Demand-led and problem-orientated TVET education flipped the curricula by embracing complexity of problems over simple solutions, flexibility in learning, and failing-forward principles that enhance social wellbeing. The 'teach by problems' framework enables learners to see interrelationships between problems by moving beyond traditional static snapshots of things as they are in different parts, and rather seeing the patterns that connect larger wholes and the relationships among the parts and the wholes. This systemic approach to teaching and learning creates open innovation and experimentation ecosystems that allow for failure and learning from mistakes, rather than only from successes. The redirection of funding that prioritises demand-led and problem-orientated education enables industry and government organisations such as SETAs to address the most pressing complex problems in society head-on, and to imagine alternatives by creating conditions for multiple safe-to-fail experiments. This scenario is characterised by policy certainty and supportive, effective action from national government. Problem-orientated education creates a new era of highly skilled green artisans who are sought-after all over Africa and abroad. SADC member states become global leaders in supplying green energy to international markets owing to integrated communities and diverse fit-for-purpose skill sets.

- **Web 3.0 education**

Source data supporting educational outcomes is decentralised by making use of Web 3.0[74] systems that enable optimal decision-making when growing skills pipelines for the GHE transition. The skills pipeline 'catches' youth as they transition to higher educational outcomes, ensuring that they are equipped with the knowledge and skills to be employed, create self-employment opportunities or generate employment for others. Data transparency is a key enabler for TVET colleges, strengthening the accountability relationship between the private and public sectors. This ensures the optimal balance of supply of knowledge workers with the industry demand, thereby diffusing the narrative of perpetual unemployment.

74 Web 3.0, also called the semantic web or the spatial web, is a user-friendly, more secure, more private and better-connected internet that uses blockchain technology to create true decentralisation in a fair metaverse, with digital data ownership through non-fungible tokens (NFTs). All of this is only possible on Web 3.0.

- **Inverted pyramid**

The overwhelming demand by youth for public and private universities in South Africa is completely flipped on its head – like an inverted pyramid. TVET colleges are the educational pathway of choice owing to excellence in training for high-paying, decent jobs and the plurality of direct employment opportunities after graduation. TVET certificates related to the green economy and green hydrogen become sought after by students, leading to the majority of PSET students undergoing TVET learnerships, internships and skills programmes when entering workplace-based learning ecosystems. The registration of students at TVET college systems allows them automatic entry into open-ended, high-paying, flexible careers. The previous extraordinary situation where the greatest number of graduates came from universities and constituted the majority of students in the education pyramid is completely turned around. TVET graduates become the largest portion in the hierarchy of graduates in the education pyramid. TVET colleges are well funded and known for excellence and close cooperation with the private sector. In the flipped education pyramid, TVET colleges have overcome perceptions of inferior certificates and low-income potential career pathways. TVET colleges are the primary choice for sourcing top talent by talent hunters/brokers.

3.2.2 Undesired TVET skills governance futures

- **Politically driven TVET**

This scenario is characterised by a demand-led TVET ecosystem that connects private sector demands and students from marginalised communities.

However, decision makers do not have the capacity to use evidence-based research to the benefit of the TVET ecosystem. This reinforces policy uncertainty and misalignment, ineffective policy, and misguided efforts on the part of the government to turn the TVET ecosystem into a major source of employment creation. This, in turn, leads to a breakdown in the private sector's trust in the stated new direction of demand-led TVET and forces it to invest in demand-led TVET with limited government regulation, resulting in an unjust transition.

- **Survival of the greenest**

The TVET ecosystem produces low and ineffective education outcomes owing to weak and ineffective political action shifting towards a sustained green economy. The TVET ecosystem delivers 'greenwashed' education and training paradigms. Here, 'greenwashed' education and training refers to the redesign of skills training aimed at supporting green economies that is ultimately ineffective in meeting the demands of emissions reduction, climate adaption, biodiversity loss and fostering resilience for sustainability transformations. The sustainability requirements of transitioning to a GHE and the subsequent skills requirements are unattainable. The emerging qualities of greenwashing educational outcomes become evident in the long term, having detrimental impacts on unemployment and labour absorption rates. Given the ineffective political action and poor skills outcomes, a self-interested, self-maximising attitude prevails in the green economy and green skills training, as opposed to a collaboration and cooperation mindset. Career entrants and those already skilled in high-carbon sectors are susceptible to unemployment, poor labour mobility and, ultimately, socio-economic exclusion.

- **'All Sebenza, No Pay'**

Education and training outcomes are 'greenwashed' and poorly designed to anticipate and meet the needs of South Africa's future GHE, despite the existence of effective political action and policy coherency. Instead, efforts (ie, 'sebenza', meaning work in isiZulu) by public and private TVET and green hydrogen value chain stakeholders have 'gone to waste', delivering an unjust labour transition (ie, 'no pay') accompanied by the associated social externalities.

3.3 Alignment of the GHE TVET Skills Just Transition strategic framework to the Hydrogen Society Roadmap

To ensure that the development of the GHE TVET Skills Just Transition strategic framework was comprehensive, and aligned and responsive to the HSRM,[75] the project consortium reached out to stakeholders in both the public and private sectors and wider civil society. They were asked to participate in the stakeholder consultation process, aimed at aligning stakeholders on a common vision for a green hydrogen TVET Skills Just Transition. This requires an environment where skills development decisions are supported by industry, and TVET skills governance leads to increased employment impacts for the country. The development of the GHE TVET skills strategic framework was, therefore, a collaborative, multi-stakeholder endeavour to coalesce all efforts towards unlocking the full potential of the country's TVET college system. Its ultimate aim is to improve vocational education and training so that the future hydrogen economy secures the highest socio-economic benefits for society.

The theory-of-change process enabled the DSI, DHET and Department of Trade, Industry and Competition (DTIC) to bring together government, the private sector and civil society to set the vision that defines success for the South African future GHE and the TVET Skills Just Transition. Table 10 shows how the Theory of Change was applied to ensure alignment with the components of the HSRM.

75 DSI, *Hydrogen Society Roadmap*.

Table 10 SAIIA-UK PACT GHE Skills Just Transition Theory of Change

Vision	A just and inclusive green hydrogen TVET ecosystem that cultivates a transversal skills commons, and fosters economic wellbeing and ecological resilience by 2050						
Objectives	Just transition	Reduced GHG emissions	Transversal skills commons	Skills development investment	Reduced inequality and poverty	Improved balance of TVET college payments	Improved skills governance
Outcomes	Transformative quality and relevant training and education	Fostering socio-ecological systems resilience	Inclusive economic wellbeing	Excellent physical and technological infrastructure	Effective partnerships for enhanced social mobility	Adequate and sustained TVET financing	Institutionalised anticipatory governance
Levers of change	Local and international demand for green skills (including green hydrogen [GH2] skills) and pre-emptive domestic energy policy	Compliance and regulation	Enabling TVET infrastructure and policy supports GH2 skills development	Skills competitiveness, innovation culture and skilled workforce	Attractive career development & skills investment environment	Corporate targets for green skills development through CoS	International commitments for peer learning and vocational education and training exchange programmes
Outputs	Labour market development/ skills development business cases	Favourable and integrated policy, fiscal measures, and regulatory environment	Financial framework that provides access to demand-led skills development	Gender equality in skills development drawing on socially excluded communities	National and international partnerships	Demonstration of CoS pilot projects, including industrial clusters	Research, development and innovation toward a transversal skills commons

Source: Compiled by authors (SAIIA)

3.3.1 Theory of change for the green hydrogen TVET Skills Just Transition

3.3.2 Vision

A just and inclusive green hydrogen TVET ecosystem that cultivates a transversal skills commons, and fosters economic wellbeing and ecological resilience by 2050.

3.3.3 Objectives

The GHE TVET Skills Just Transition will contribute to the goal of a just and inclusive green hydrogen TVET ecosystem that cultivates a transversal skills commons, and fosters economic wellbeing and ecological resilience by 2050 through supporting the following interlinked objectives:

- **Just transition**

The GHE TVET Skills Just Transition 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 electrolysers, beneficiation of minerals through the supply of value-added components in the hydrogen value chain, and 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. Importantly, special attention will be paid to upskilling and reskilling workers for a transition from sunset industries (including coal mining and coal-fired power, refineries, ICE vehicle and parts manufacturing, and "dirty' or "grey' chemicals, steel and cement production) to growing industries, notably those related to the GHE, including renewable energy.

- **Reduced GHG emissions**

The GHE TVET Skills Just Transition will contribute to a reduction in GHG emissions by developing skills and employment pathways for replacing fossil fuels in energy-intensive industries, road and rail transport, shipping and aviation. The GHE TVET Skills Just Transition will also enable skills development towards greening of the power sector by providing renewable energy storage to the grid, and reliable zero-carbon electric and thermal energy for off-grid applications.

- **Improved skills governance**

The GHE TVET Skills Just Transition will enable skills governance and green energy skills security by providing an adequate supply and demand of skills through improved skills governance. This will ensure the establishment of a green energy-skilled workforce that can enable a zero-carbon contribution to the national electrification plan and that is able to provide backup energy to the electricity grid for critical applications.

- **Skills development investment**

The development of artisans has been of critical concern to the private sector and government over the past decade, in order to address some mismatches between skills demand and skills supply and so meet economic growth and job creation objectives. The NDP has set a target of developing 30 000 artisans per year by 2030. Government views TVET colleges as a key mechanism for delivering on this target, and initiated the CoS programme as a means of transforming TVET colleges to work with industry to implement a demand-led approach to skills development through a dual apprenticeship model. Adaptation, expansion and strengthening of the CoS model will ensure that TVET colleges are appropriately positioned to ensure the effective roll-out of the GHE skills transition.

- **Reduced inequality and poverty**

The implementation of the GHE TVET Skills Just Transition will benefit society, as a move towards a hydrogen economy can assist with attaining the SDGs with specific emphasis on SDG7 (affordable and clean energy) and SDG8 (decent work and economic growth). Economic growth will be underpinned by green 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. Renewable energy will have a larger, more beneficial multiplier effect on job creation than traditional carbon-intensive energy generation. For example, the rise in demand for platinum in fuel-cell manufacturing would more than make up for the losses related to phasing out catalytic converters.

- **Improved balance of TVET college payments**

The level of funding available to TVET colleges has been a key factor in limiting growth. While the funding base initially incentivised growth, there has been a persistent funding deficit in real terms. The development of domestic manufacturing for hydrogen products and components, along with the greening of the economy and hydrogen exports, will encourage investment in inward skills development. Together with reduced oil imports, these changes will support improvements in the balance of TVET college payments towards public sector green skills development.

- **Transversal skills commons**

The GHE TVET Skills Just Transition will create transversal (or generic) skills as an essential part of the professional and training profile related to the knowledge, skills, dexterities and capabilities that any graduate must have achieved before entering the labour market. Transversal skills[76] include cognitive and metacognitive skills, instrumental knowledge and attitudes such as lifelong learning including transformative learning skills (unlearning and re-learning along the life course). Yet transversal skills development will not be enough if not connected to a new mode of knowledge production that creates a commons-oriented economy. A skills commons[77] utilises professional and technical learning and cultivates P2P social relations in human networks, as well as a technological infrastructure and partnerships that make the generalisation and scaling-up of such new skills possible. A transversal skills commons creates communities that share common resources, innovates skills development from generative market mechanisms that work for communities, and enables the support of government for public platforms.

3.3.4 Outcomes

Seven high-level outcomes have been identified for the GHE TVET Skills Just Transition, based on the Theory of Change shown in Table 10. The outcomes are as follows:

1 Transformative quality and relevant training and education

Designing education and skills development ecosystems[78] to optimise their functions and potential in developing socially engaged graduates who can contribute to building strong resilient societies.

2 Socio-ecological systems resilience fostered

Enabling the TVET ecosystem's capacity to anticipate, respond, adapt or transform in response to shocks, uncertainty and change, especially novel systemic changes, in order to facilitate the desired skills development, which focuses on understanding the complex interconnections between human activities, human well-being and nature.

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76 Transversal skills, as defined by the National Agency for Quality Assessment (ANECA) from the Tuning Project, are categorised into (1) instrumental skills: cognitive skills, methodological skills, technological skills and linguistic skills; (2) personal skills: individual abilities and social skills; and (3) systemic skills: skills regarding the understanding of complex systems. Natalia Larraz and Sandra Vàzquez Toledo, "Transversal Skills Development Through Cooperative Learning: Training Teachers for the Future", *On the Horizon* 25, no. 2 (2017): 85–95.

77 A skills commons empowers the autonomy of individuals and communities through public–commons partnerships (P2P) and enables TVET transversal skills development that can contribute to the creation and maintenance of shared resources while ensuring communities benefit from it. Michel Bauwens, Vasilis Kostakis, and Alex Pazaitis, *Peer to peer: The Commons Manifesto,* University of Westminster Press, (2019).

78 There is a need to develop a transversal skills commons which creates communities that share common resources, innovates skills development from generative market mechanisms that work for communities, and enables the support of government.

3 Inclusive economic wellbeing

Enabling policies and legal frameworks that reimagine the relationship between PSET and TVET sectors; and strengthen partnerships and collaborations that catalyse the development and implementation of strategy, research and monitoring and evaluation systems that extend beyond access to jobs, and include the personal and collective ability to mobilise social and material resources to achieve personal and collective economic wellbeing.[79]

4 Excellent physical and technological infrastructure

Developing and supporting physical and technological infrastructure, such as data availability, so that all communities have equal and quality access to PSET and TVET institutions and systems.

5 Effective partnerships for enhanced social mobility

Creating policies and legal frameworks so that effective, mutually beneficial operational partnerships and collaborations, such as those between employers and training providers, can flourish.

6 Adequate and sustained TVET financing

Ensuring appropriate financing model(s) that contribute to, and catalyse, cohesive, equitable PSET and TVET ecosystem that delivers on the objectives of more inclusive and sustainable societies for the region.

7 Institutionalised anticipatory governance

Interrogating the practical capabilities and systemic innovations required to build the vocational skills systems of institutions; instituting rules and norms that provide a way to use foresight, networks and feedback systems to reduce risk and increase capacity to respond to industry demand at earlier rather than later stages of development. Institutionalised anticipatory governance[80] means that the TVET ecosystem builds the capability to harness the collective intelligence and wisdom of collaborating

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79 Economic wellbeing and security create four focal points that reinvent economics beyond the formal economy, namely (1) paid work (forms of employment and exchange); (2) household provisioning (caring for persons that are not in the formal economy, such as taking care of children, preparing food for households and the elderly); (3) provisioning of the commons (access to clean water, air, food, viable ecosystems and trustworthy information sources); and (4) the state (the infrastructural resources creating the conditions for the other three provisions to flourish). Education is, therefore, a societal pillar where the return on investment is noticeable not only in GDP growth rates but also in various forms of holistic wellbeing. Keri Facer, "It's Not (Just) About Jobs: Education for Economic Wellbeing" (Working Paper 29, UNESCO, Paris, 2021).

80 Leon Fuerth, "Foresight and Anticipatory Governance", *Foresight* 11, no. 4 (2009): 14–32; Jose Ramos, Ida Uusikyla and Nguyen Tuan Luong, *Anticipatory Governance: A Primer* (Vietnam: UN Development Programme, 2020).

organisations and citizens, to deal with strategic risks and leverage emerging opportunities for meeting development goals to improve 'social navigation' – the ability of a society to navigate the complex terrain of social change.

3.3.5 Levers of change

Levers of change comprise 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 skills (including GH_2 skills) and pre-emptive domestic energy policy;
- compliance and regulation;
- an enabling TVET infrastructure and policy support for GH_2 skills development;
- skills competitiveness, innovation culture and a skilled workforce;
- attractive career development and skills investment environment;
- corporate targets for green skills development through CoS; and
- international commitments for peer learning and TVET exchange programmes.

3.3.6 Outputs

Some of the outputs envisaged from the Theory of Change process include

- labour market development/skills development business cases;
- favourable and integrated policy, fiscal measures and regulatory environment;
- financial framework that provides access to demand-led skills development;
- gender equality in skills development, drawing on socially excluded communities;
- national and international partnerships;
- demonstration of CoS pilot projects, including industrial clusters; and
- research, development and innovation towards a transversal skills commons and skills ecosystem for green hydrogen.

3.3.7 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 the lead and supporting roles in the achievement of the outputs and the outcomes. The overarching Theory of Change (Table 10) gives the high-level outcomes, outputs and stakeholders expected to take a lead in their achievement. In the final section, detailed policy recommendations and actions are given for each of the high-level outcomes.

3.3.8 Creating an enabling environment for TVET skills to support a green hydrogen economy

Government and related stakeholders have a key role to play in creating an enabling environment for the development of South Africa's GHE, and in ensuring that the transition to such an economy is a just one. This is as true for the area of vocational skills development and training – the focus of this report – as it is for industrial policy or energy planning.

In fact, policy measures related to vocational skills development and training are crucial to ensuring a just skills and labour transition. To date, much of the support for skills development related to renewable energy more broadly has been for high-level tertiary skills, at the Masters and PhD level.[81] However, to mitigate the impacts of the energy transition on workers and vulnerable stakeholders and communities, policy measures should also consider technical and vocational training at both mid- and higher-skilled levels. The government considers the TVET sector to hold great potential to contribute to job creation and the reduction of inequality. Its stated objective is that, by 2030, over 2.5 million people will be learning at TVET colleges while 1.6 million will be learning at universities, thus shifting the balance to TVETs as the main PSET pathway to work.[82] However, this ambition is not reflected in the budget allocation. A first recommendation, therefore, is to review the budget allocation for TVET colleges to ensure that government's ambitions are matched in funding. This could entail revising the allocation from the fiscus, and reconsidering skills levies or tax rebates. It is also worth considering whether the 'just transition' financing South Africa is receiving from France, Germany, the UK, US and EU can be harnessed to support any of the recommendations in this report (for example, supporting the transition of workers between sunset and growth sectors).

81 See, for example, DSI, *Hydrogen Society Roadmap*.

82 Bambili Advisory, "The South African Hydrogen Economy".

As is, there is a disconnect between fiscus funding (used for the college component of work-integrated learning programmes) and money from the skills levy or tax rebates (used for the workplace-based learning component), not to mention additional sources of funding, eg, from development partners. This creates fragmentation and makes it hard to implement a coherent and demand-led green specialisations programme, building on the current CoS model. The TVET financing system should therefore allow for multiple but coordinated funding streams. It is also crucial to create a clear and transparent system to govern TVET financing. Efficiencies in the TVET ecosystem also need attention to create value from existing investment (eg, through improved throughput, higher quality and more relevant education and training etc.) which indicates a 're-purposing' of existing resources could be possible.

In the case of the GHE specifically, whereas the initial need is for postgraduate university-level skills, once production of green hydrogen and related industries picks up, so will the demand for technical and vocational skills. This shift requires close relationships between high skills VET institutions and medium skills VET institutions to be established in good time to avoid silo approaches to intermediate and high skills VET institutions. As elaborated in the first part of this study, the green hydrogen value chain also has a role in absorbing displaced labour from sunset industries and contributing to the economic diversification of coal-reliant municipalities and communities.[83]

3.3.9 Policy and related support for an enabling policy environment for the green hydrogen economy

As noted earlier in this report, the development of a GHE is a key part of the strategic shift towards the increased use of renewable energies and a reduction in reliance on coal-based power generation. This shift to renewables will not only be highly beneficial in creating more sustainable, low-carbon energy sources for South Africa but is also necessitated by pressures from global trade partners. These partners are setting ambitious transition goals and will seek to impose carbon taxes in the future. The renewable energy manufacturing value chain, as well as the value chains more specifically associated with green hydrogen production, offer both upstream and downstream employment opportunities in new industries.[84]

The realisation of these opportunities depends on a better aligned, more conducive post-school education and training system that aligns with, and supports, the development of an appropriate skills base, with capacity to respond pro-actively to

83 Patel and Cloete, "TVET Skills in the South African".

84 Bambili Advisory, "The South African Hydrogen Economy"; Patel, "South African Industry Demand".

emerging demand sectors such as the GHE. At present, however, there is little evidence of a framework for skills development within the policies and strategic documents that have been developed over the past decade and are meant to guide the transition to a green economy.[85] In addition, while policy documents refer to job creation in the green economy, the nature of these jobs and the skills needed to realise these jobs are not defined, and are therefore underdefined in the national system of skills development. Furthermore, the incorporation of green skills into sectoral skills planning by many SETAs has not necessarily resulted in earmarked funding for green skills interventions and remains largely at the level of 'research' in Sector Skills Plans. As a result, there is little evidence of the translation 'green' policies into substantive skills development programmes or large-scale employment.[86]

As of 2013, the Organising Framework for Occupations (OFO), which guides sector skills planning through the various SETAs and develops qualifications through the Quality Council for Trades and Occupations, has included the identification of 'new green occupations' (categorised as 'scarce skills') and new 'green skills' (categorised as 'critical skills') in existing occupations. As a result, 90 new occupations and a range of new skills were identified by 2015, but there are persistent challenges in finding coherence in the representation and definition of occupations and occupational tasks. This manifests through 'confusion between green skills, the skills required of environment-based occupations and the skills which overlap South Africa's traditional economy and a future, green economy'.[87] The characterisation of green skills as 'scarce or critical skills' indicates their status outside the core framework for occupational analysis. This further restricts the capacity of SETAs to capture clear data on employment demand that can guide planning.

A recent study by GreenCape[88] found a range of clearly defined blue-collar occupations in high demand (both skilled and semi-skilled) across the renewable energy value chain, as defined through desktop research and industry surveys but with no reference to the OFO. These occupations range from standard, recognised trades and occupations to new and more specialised skills in the wind and solar industries. The various industry informants who were surveyed and interviewed for this study emphasised the challenges in finding a sufficient supply of skills, and the lack of alignment of the skills produced by higher education institutions and TVET colleges with industry needs. They

85 ILO, *Skills for Green Jobs in South Africa* (Geneva: ILO, 2018).
86 ILO, *Skills for Green Jobs*.
87 ILO, *Skills for Green Jobs*. see also Eureta Rosenberg, Presha Ramsarup and Heila Lotz-Sisitka, "Green Skills Research in South Africa" (London, 2020).
88 GreenCape, *Assessment of Local Skills for the South African Renewable Energy Value Chain*, Report (Cape Town: GreenCape, 2021).

recommended greater involvement by industry in the development of curricula and emphasised the need for increased workplace training.

There is little evidence of green curricula in TVET colleges, and the DHET highlighted limited uptake of green skills electives within the core college curricula, which has largely rendered these subjects redundant. As a result, many colleges no longer offer these subjects. When combined with the shortcomings in SETA prioritisation of funding for green skills, there is little scope for meaningful vocational skills development interventions, particular for small, medium and micro enterprises (SMMEs) that have the potential to generate demand for entry-level skills. Instructive for the development of the GHE, evaluations of small pilot programmes implemented by the German Agency for International Cooperation (GIZ) and National Business Initiative (NBI) demonstrated the significant skills gaps in the plumbing industry in both foundation plumbing skills as well as more specialised solar water heating installation skills, for both TVET students and workers in SMMEs. The pilots emphasised the high demand for solar water heating installation skills among SMMEs, but also demonstrated limitations in the capacity of TVET colleges to provide the required skills to meet this demand – despite the availability of infrastructure and equipment. Sustainable funding for such programmes through SETAs has also been a key constraint in sustaining these skills interventions. This presents a microcosm of the broader challenges in the vocational skills development environment.

Addressing the disconnect between industrial strategy and skills planning includes integrating green skills (including skills for the GHE) in strategies, policies and plans. As noted above, green skills are seen as fringe rather than mainstream, reflected in references such as 'scarce' or 'critical', with no specific provision made in the country's OFO.[89] The inclusion of green skills in the OFO and elsewhere should be informed by a co-created Green Skills Master Plan.[90] Such a plan should, in turn, be informed by a mapping of the skills (including TVET skills) required for a green economy (including renewable energy and a GHE) in the context of rapid technological change. This, in turn, can inform the development of appropriate programmes and qualifications that will support emerging skills demands in the short and medium term. Given the time required to develop new qualifications and embed them in the funding and institutional framework, sound anticipation of medium-term skills requirements is an important enabler of demand-led TVET provision.

89 Bambili Advisory, Gewer and Smit, "Towards a Just Skills Transition".

90 Bambili Advisory, "The South African Hydrogen Economy". See also Eureta Rosenberg, Presha Ramsarup and Heila Lotz-Sisitka, "Green Skills Research in South Africa" (London, 2020) who argue similarly for a national programme of 'Skills for Sustainable Development'

Table 11 covers related strategies, policies and plans into which to integrate green skills. A Green Skills Master Plan should, as far as possible, align with these existing policies. Considering the highly dynamic nature of the green economy, and the GHE in particular, this is not a once-off process. It is important that plans are informed by this and, when needed, changed. This requires ongoing monitoring of the changing landscape.

Table 11 Strategies and policies relevant to green skills planning

Policy	Mechanism of policy	Regulated by	Responsible authority
Skills governance framework policies	Skills anticipation and matching systems	• National Skills Authority • Human Resource Development Council	• DHET • SETAs • NDLAC
Sector skills plans	Skills needs assessments to the SETAs that enable aggregation of data	• SETAs • Private sector	• SETAs
Labour market information/ Skills intelligence/ Skills matching	Forecasting for demand-side data projections is planned to be undertaken as part of the Labour Market Intelligence Programme (LMIP) – the LMIP phase 1 did undertake projections of both skills supply and demand, as well as mismatches between the two Supply-side projections for TVET colleges universities are currently undertaken by the DHET as part of the enrolment planning processes	• Skills Development Act • White paper for PSET • LMIP • SETAs • Artisan and Technician Development Technical Task Team	• DHET • SETAs
National Skills Development Plan	A roadmap for the development and reinvigoration of post-school education and training and an implementation framework for the policy goals until 2030	• National Skills Development Plan (NSDP) • National Plan for Post-School Education and Training • White paper for PSET	• DHET • SETAs
Skills funding	To grow and diversify the sector, based on revised funding norms and standards, eg, colleges largely provide for students from poor families, and need to differentiate between rural and urban colleges, and between colleges at various stages of development. The integration of the National Skills Development Strategy III and the new National Skills Development Plan into the National Plan is part of the creation of a common funding strategy	• Medium-Term Strategic Framework • National Skills Fund • Skills Development Levy • NSFAS	• National Treasury • DHET • SETAs
Economic recovery	Skills strategy to respond to the ERRP	• NDP 2030 • NSDP • ERRP	• National Treasury • DHET

Skills foresight and skills anticipation	No formulated plan or strategy	• NDP 2030 • NSDP • ERRP	• DHET • SETAs
Monitoring and evaluating medium- to long-term impact of training programmes	Tracer studies or graduate tracking surveys are an invaluable tool for monitoring and evaluating the medium- to long-term impact of training programmes The DHET, through Indlela, also undertakes tracer studies of students who completed a trade certificate (not currently embedded in the system)	• NDP • National Artisan Development Programme	• DHET • SETAs • National Artisan Development Centre
Health and safety	In addition to complying with the usual health and safety standards as inspected by the Department of Employment and Labour, there is a need to develop hydrogen-specific (DOL) health and safety regulations and guidelines, including for training programmes. This does not exist currently, though the HSRM makes provision for skills development and training related to hydrogen safety in the near-term (2021–2024).[a] Potential to draw on existing experience with industrial use of hydrogen (eg, at Sasol). Also opportunities to learn from international partners. For example, see The Hydrogen Technology Collaboration Programme's (Hydrogen TCP's) Task 37 on Hydrogen Safety[b] or what other countries or states are doing[c].	• Occupational Health and Safety (OHS) Act 85 of 1993 • Basic Conditions of Employment Act 75 of 1997	• DHET • SETAs • Department of Labour

a DSI, "Hydrogen Society Roadmap for South Africa 2021".

b Hydrogen Technology Collaboration Programme, Task 37: Hydrogen Safety (2015-2021). Available at: https://www.ieahydrogen.org/tasks/closed-task/.

c See, for example, the State of Queensland in Australia's (an early mover) hydrogen regulations at: https://www.business.qld.gov.au/industries/mining-energy-water/resources/safety-health/petroleum-gas/safety-news-education/hydrogen.

Source: Compiled by authors (SAIIA)

3.4 Green specialisations: Centres of Specialisation for the green hydrogen economy

Table 12 provides suggestions on the location of green CoS that are aligned with the HSRM and the Hydrogen Valley concept through partnering with qualifying TVET colleges and interested industry partners on selected green hydrogen-related specialisations in specific locations. These suggestions could result in a flexible CoS-type arrangement that may be adjusted as other GHE production centres develop throughout the country.

Table 12 TVET specialisations and locations for a green hydrogen economy

Along Hydrogen Valley, and in specific locations as detailed:	
New technical skills in green hydrogen and the green hydrogen value chain (including occupational health and safety-related to a volatile gas like hydrogen), as well as:	
Manufacturing for a green economy (specialising in **electrolysers, fuel cells** and **FCEV)**	The emerging electrolyser and fuel-cell industry is concentrated in Johannesburg and Durban – convenient for transitioning workers from the automotive sector in Gauteng and KwaZulu-Natal A number of the catalytic Hydrogen Valley projects target FCEV mobility, including bus conversions, heavy-duty trucks (along the N3 freight corridor from Johannesburg to Durban), forklifts (eg, at Durban and Richard's Bay ports), mining trucks (eg, platinum in Limpopo) and refuelling infrastructure[a]
Green chemicals production (specialising in **green hydrogen** and **green ammonia)**	The biggest incumbents that have expressed an interest in green hydrogen production are located in Sasolburg and Secunda (Sasol), Pelindaba (Afrox) and Alberton (Air Liquide). Catalytic projects planned along the Hydrogen Valley include the production of ethylene and ammonia in Sasolburg.[b] There are additional plans for green ammonia exports at Boegoe Bay and at Coega and Nelson Mandela Bay ports (with Linde and Hive Hydrogen)[c]
Green industry (specialising in **green iron** and **steel production)**	Near steel producers (eg, ArcelorMittal at one of its sites near Johannesburg[d] or in Vanderbijlpark or Newcastle). Iron mines in the Northern Cape
Renewable energy (specialising in **photovoltaic (PV) solar** or **wind energy)**	Plans to locate REDZs in coal and gold mining areas that are in decline (eg, Emalahleni in Mpumalanga),[e] in order to assist with a just transition. Additional plans, eg, as part of the Boegoebaai green hydrogen development[f]
Across all TVET courses: • Digital and ICT skills (including digital literacy and, where relevant, specialist skills such as working with Computer Numerical Control [CNC] Systems) • Social and soft skills (including communication, teamwork, problem-solving, emotional intelligence, transformative learning, and critical thinking) • Introduction to climate change and the green economy, to introduce students to reasons for, and opportunities for green specialisations)	
For courses that require STEM skills: **Relevant STEM modules** (eg, working with data)	

a DSI, *Hydrogen Society Roadmap*.

b DSI, *Hydrogen Society Roadmap*.

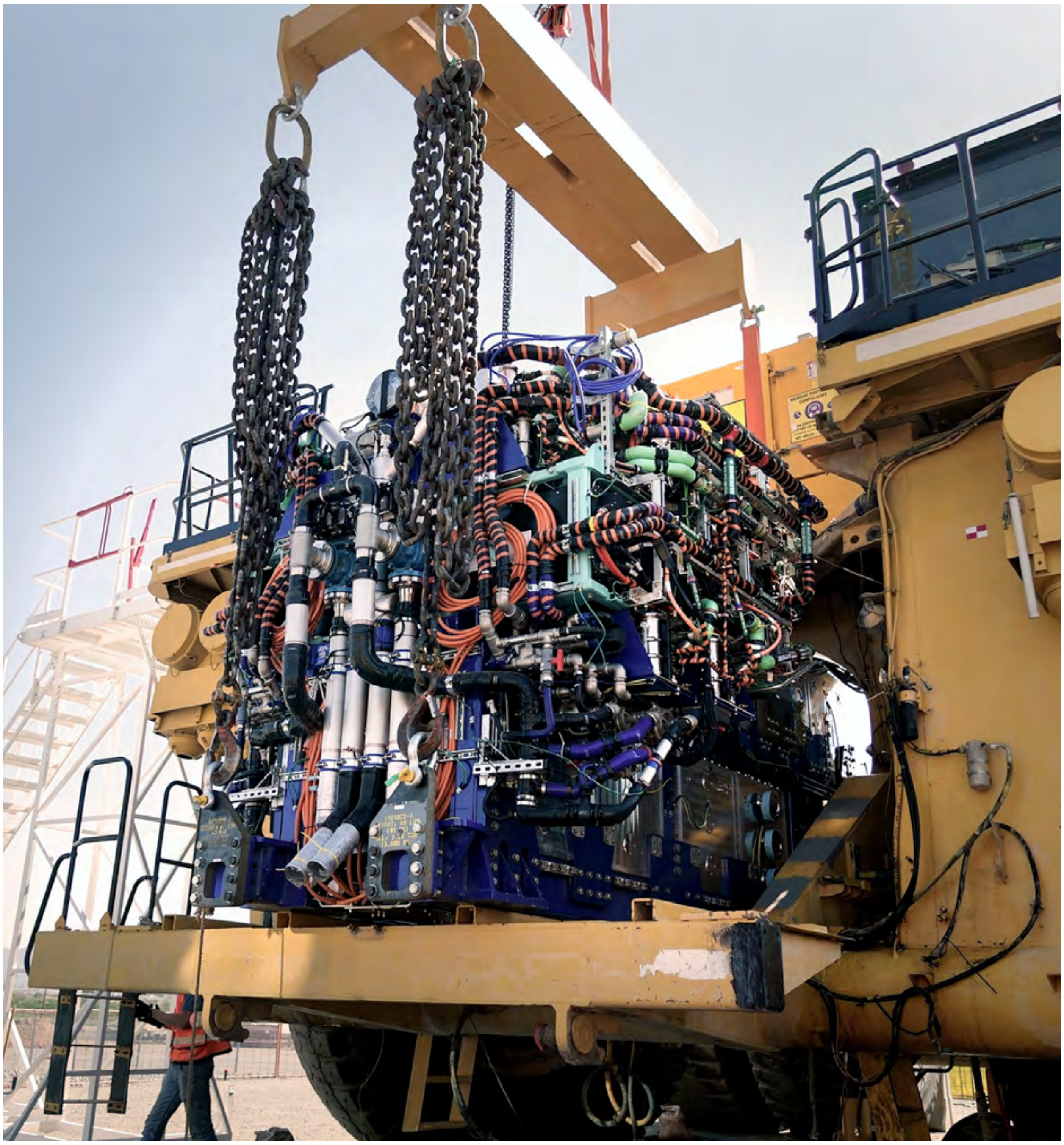
c Martin Creamer, "Formal Launch of South Africa's First Green Ammonia Project on Tuesday", Mining Weekly, January 12, 2022.

d DSI, *Hydrogen Society Roadmap*.

e Terence Creamer, "Renewables Sector's Just Transition Roadmap to Target Coal and Gold Regions", *Engineering News*, October 9, 2019.

f DSI, *Hydrogen Society Roadmap*.

Source: Compiled by authors (SAIIA)



SECTION B

MODELLING POTENTIAL EMPLOYMENT IMPACTS OF GREEN HYDROGEN IN SOUTH AFRICA

Image credit: Anglo American Plc, South Africa: The power module being lifted into the hydrogen heavy-haul electric truck being assembled at the Mogalakwena PGMs mine in Limpopo

4 Forecast employment impacts

The Energy Systems Research Group at the UCT modelled the climate, economic and employment impacts of different green hydrogen futures for South Africa.[91] The model it used – SATIMGE – is a linked energy systems-computable general equilibrium model. It consists of two individual models, namely the South Africa TIMES (SATIM) energy systems model and the South Africa General Equilibrium model, which account respectively for a full energy sector description of alternative technologies and a detailed full-sector economy-wide general equilibrium model. Using them in a linked way helps represent an energy-economic transition to provide a comprehensive and holistic picture of the employment impacts of the GHE. See Figure 11 for a schematic of the model.[92]

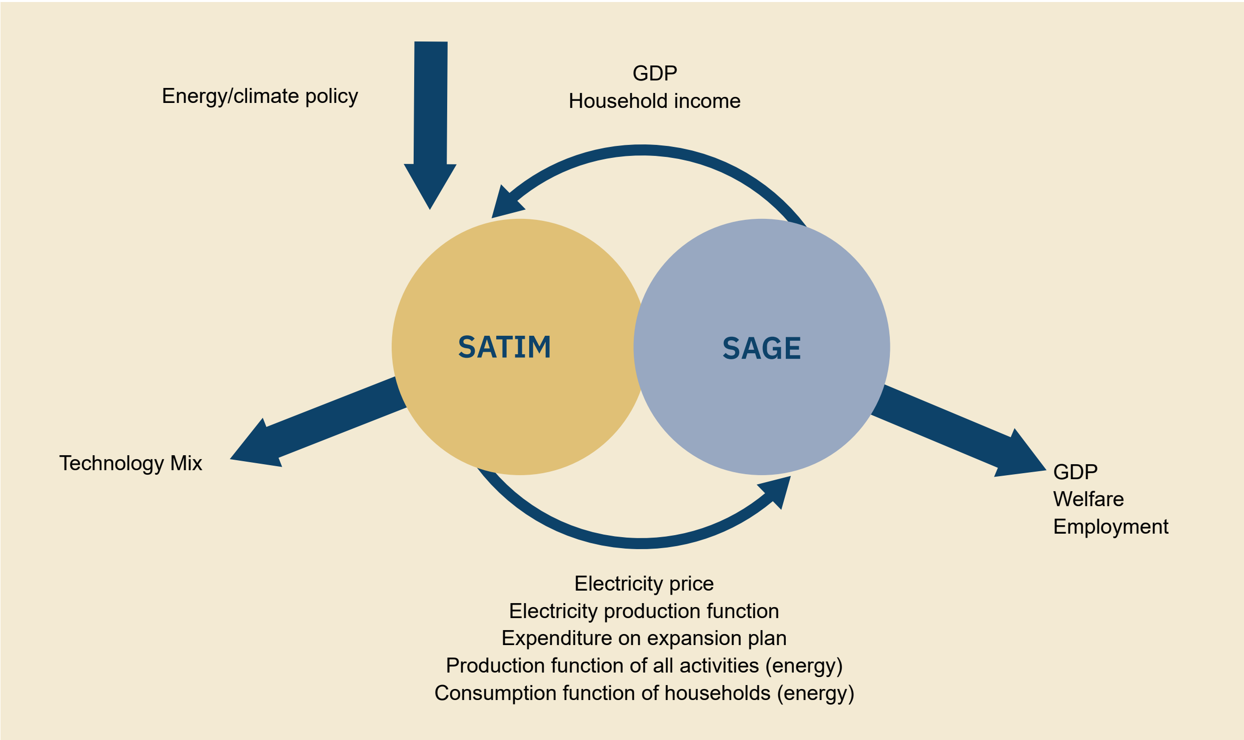


Figure 11 Iterative exchange of data between energy and economic models in SATIMGE

Source: Fadiel Ahjum et al., "Green Hydrogen and TVET Employment Prospects: An Assessment in a Context of Ambitious Decarbonisation for South Africa Towards 2050" (Working Paper, SAIIA-UK PACT and University of Cape Town, 2021), 9

Using this model, the research group developed quantitative scenarios that consider the economic and employment impacts of different hydrogen economy options for South

91 Schers et al., "Green Hydrogen and TVET Skills"; "Ahjum et al., "Green Hydrogen and TVET Employment".
92 Ahjum et al., "Green Hydrogen and TVET Employment".

Africa. As per Figure 12 the four options they developed differ in their emphasis on the combination of the domestic utilisation of green hydrogen versus adopting an export orientation in green hydrogen production. All the scenarios assume climate commitments in line with the Intergovernmental Panel on Climate Change goal espoused in the Paris Agreement, to which South Africa is a signatory. As noted earlier, ahead of COP26, South Africa submitted an ambitious revised NDC and promulgated its Climate Change Bill, both of which signal a commitment to decarbonise the economy. All the options considered therefore assume progress towards a goal of a Net-Zero carbon economy by 2050.

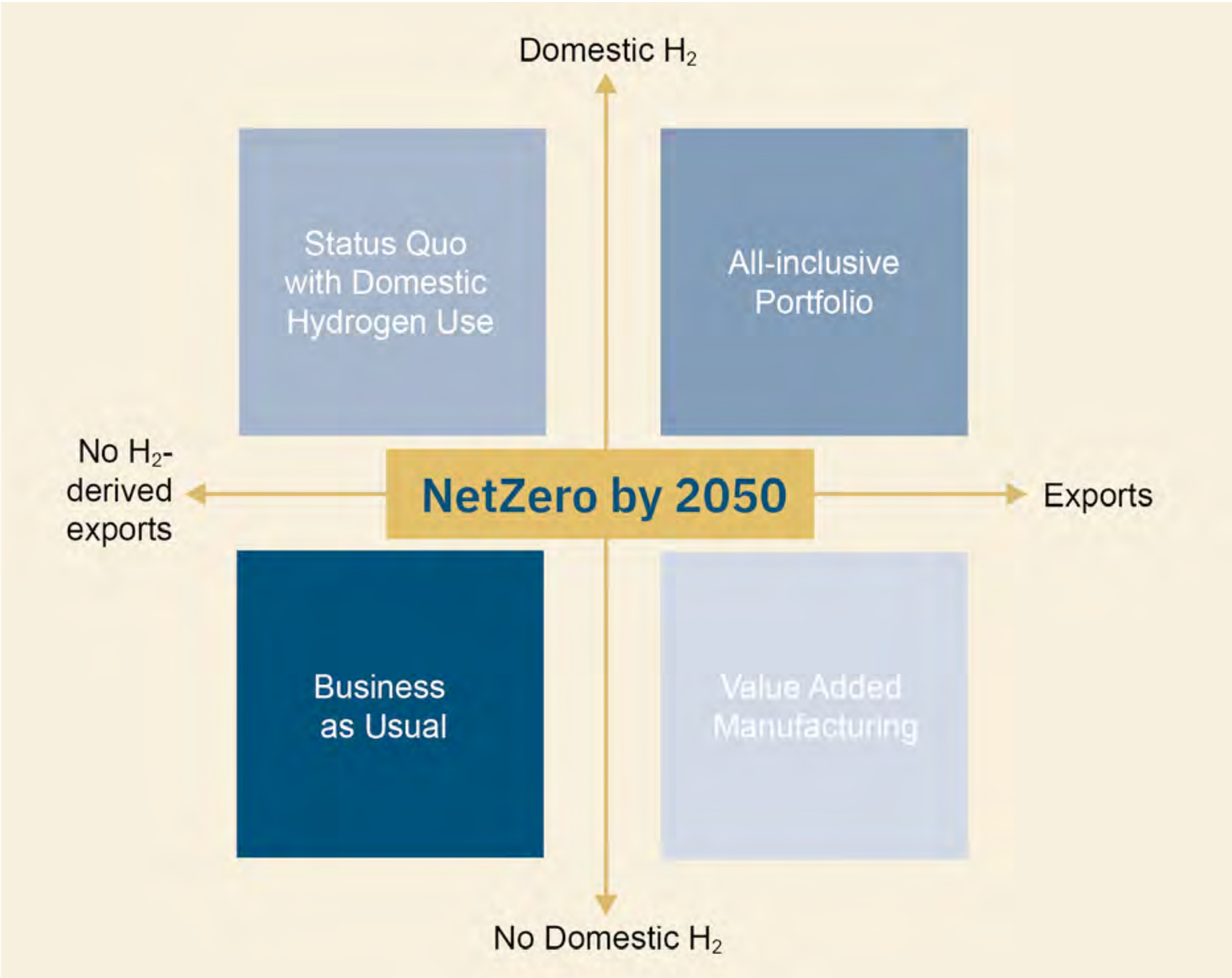


Figure 12 Options modelled for a green hydrogen economy in South Africa

Source: Fadiel Ahjum et al., "Green Hydrogen and TVET Employment Prospects: An Assessment in a Context of Ambitious Decarbonisation for South Africa Towards 2050" (Working Paper, SAIIA-UK PACT and University of Cape Town, 2021)

Without quantitative international estimates of skill intensities, the best indication of TVET skill intensity of employment in a GHE comes from the current TVET intensity of South African economic sectors similar to those of a GHE, namely electrical, petro-chemical, solar and other renewable energy, manufacturing and mining. A useful prism through which to analyse the full job-creation potential of the GHE is a green hydrogen value chain analysis that is aligned with the sectors and priorities in South Africa's Hydrogen Society Roadmap (HSRM).[93]

The modellers developed four quantitative scenarios for the development of green hydrogen and its application in the South African economy. In the discussion below, these have been named Business as Usual, Value Added Manufacturing, Status Quo with Domestic Hydrogen Use and All-inclusive Portfolio.[94]

4.1 Quantitative Scenario 1: Business as Usual

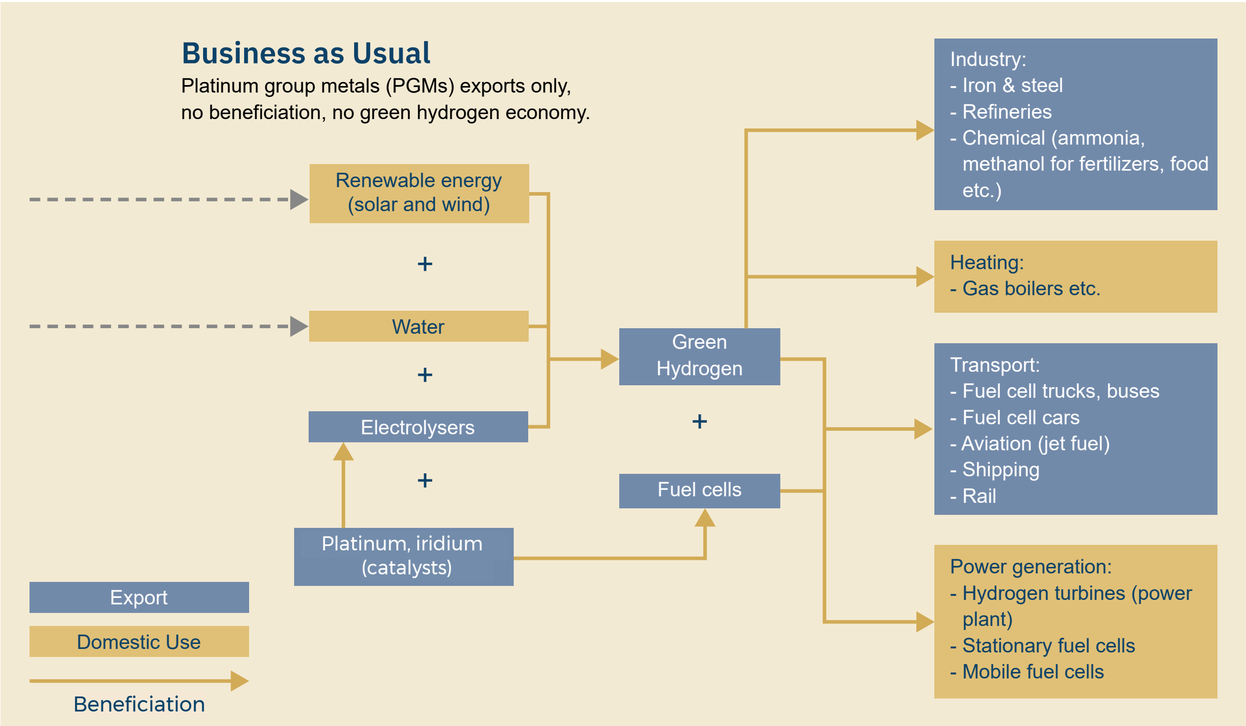


Figure 13 Business as Usual Scenario

Source: Schers et al., "Green Hydrogen and TVET Skills"

This scenario focuses on PGM exports only, with no additional beneficiation. It also does not include additional elements of a GHE. The scenario shows South Africa's PGM mining sector is forecast to do well, solely based on international demand, even without the creation of a local hydrogen economy (both domestically or export-oriented). This is provided that South Africa maintains its current global dominance in the PGM mining sector and that the platinum-catalysed proton exchange membrane (PEM) remains the

93 DSI, *Hydrogen Society Roadmap*.

94 As the Business as Usual forecast is the most restrained in terms of assumptions about domestic and export opportunities for hydrogen, it will serve as the reference point to assess economic impacts of the other forecasts.

preferred technology in fuel cells. Under this scenario, year-on-year GDP growth is forecasted at 2.3% until 2050, demonstrating total GDP growth of 96% (worth ZAR 2.8 billion) between 2020 and 2050.

A total of 15.2 million jobs are forecast to be gained across the entire domestic economy in all sectors, with 584 536 of those jobs being TVET-related. Of these 584 536 jobs, 21 596 are within the PGM sector.

Figure 14 TVET jobs in platinum and coal to 2050, per scenario

Note: The upper section of Figure 14 presents the net total change in TVET jobs for coal and PGM mining combined relative to 2019, for 2035 and 2050 for each scenario. The lower section presents the same change relative to 2019 but now split per sector and per TVET job skill sub-category.

Source: Jules Schers et al., "Green Hydrogen and TVET Skills' Role in South Africa's Just Transition" (Working Paper, SAIIA-UK PACT and University of Cape Town, 2021)

As shown in Figure 14, despite an initial reduction in net TVET employment by 2035 of 47 000, the total TVET employment is forecast at 149 000 jobs by 2050. In contrast, PGM TVET mining jobs to be gained will surpass coal mining jobs lost by 2050 in this scenario. A total of 100 600 jobs (as per table 14) across the coal mining and refinery sectors only are forecast to be lost by 2050 with 6 600 of those being coal-related TVET jobs, under the Business as Usual Scenario.

4.2 Quantitative Scenario 2: Value Added Manufacturing

The Value Added Manufacturing scenario models the impact of a GHE focused on PGM exports, as well as PGM beneficiation into fuel-cell and electrolyser components for export, with no domestic hydrogen utilisation.

The impact of a focus on value added manufacturing in the PGM sector, specifically that of fuel-cell and electrolyser manufacturing exports may contribute to year-on-year GDP growth of 2.3% and total growth of 98% by 2050. Total GDP growth by 2050 is therefore forecast as ZAR 2.9 billion under the Value Added Manufacturing scenario, but growth in capital-intensive industries comes at the cost of less growth in other sectors, such as the services industries.

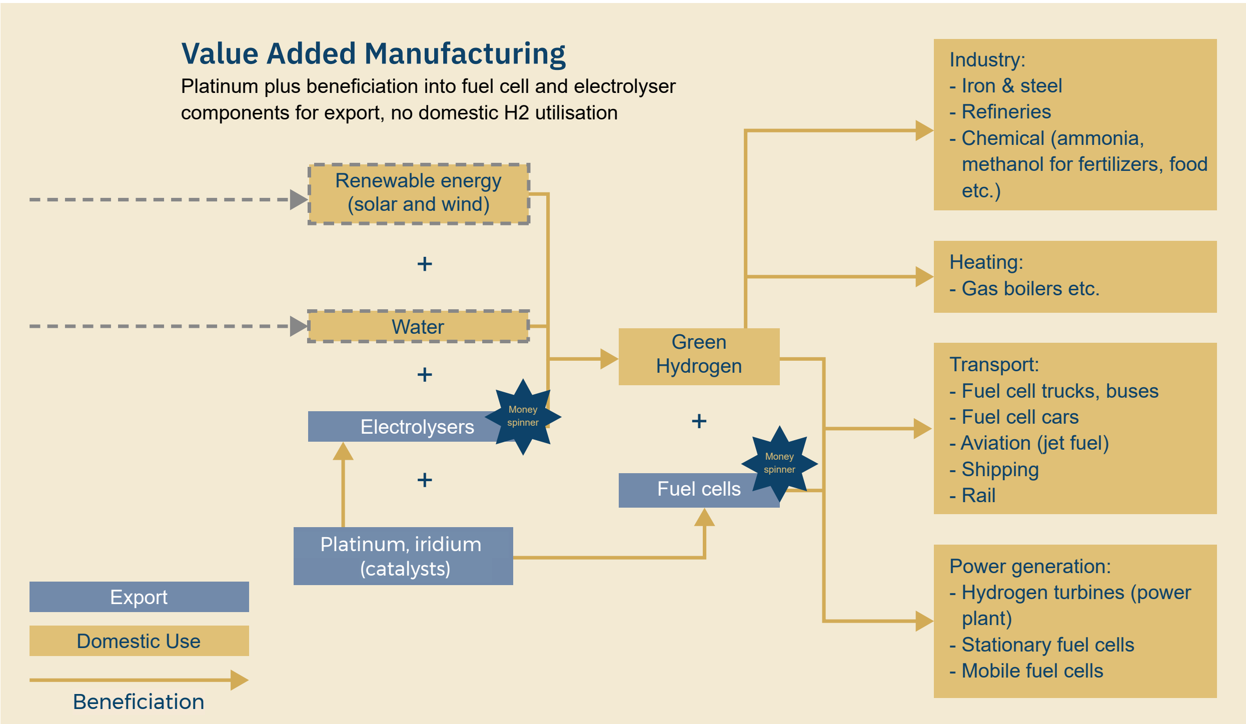


Figure 15 Value Added Manufacturing Scenario

Source: Schers et al., "Green Hydrogen and TVET Skills"

A total gain of 14.9 million jobs are forecast across all of SA's economy-wide sectors (no domestic hydrogen utilisation), with 576 552 of those jobs being TVET-related and 27 939 PGM-related. A reduction of 100 489 jobs in the refinery and coal mining sector by 2050, 6 626 of which are coal-related TVET jobs is forecast, which is similar to the Business as Usual scenario.

4.3 Quantitative Scenario 3: Status Quo with Domestic Hydrogen Use

The Status Quo with Domestic Hydrogen Use scenario models the impact of a GHE focused on PGM exports and domestic hydrogen utilisation, with no hydrogen-derived exports.

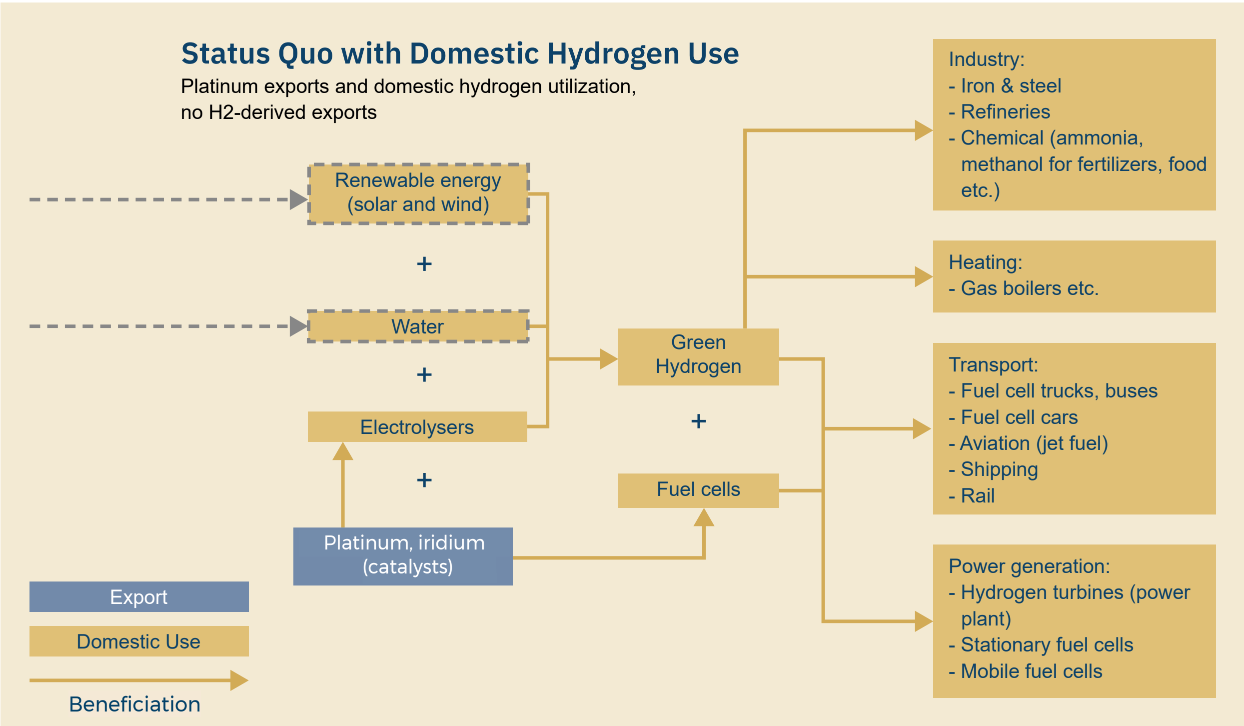


Figure 16 Status Quo with Domestic Hydrogen Use Scenario

Source: Ahjum et al., "Green Hydrogen and TVET Employment"

The impact of such a domestically focused hydrogen utilisation option – as opposed to a future with no domestic hydrogen utilisation or a hydrogen economy – is GDP growth of 102% (2.4% year-on-year) by 2050. Total GDP growth by 2050 is forecast at ZAR 3 billion with total jobs gained across all SA economy-wide sectors (including domestic hydrogen use, but no exports) at 14.9 million. Of these 14.9 million jobs, 582 211 are TVET specific while 17 432 are PGM specific. Again, a reduction of 104 045 jobs by 2050 is forecast for refineries and coal mining with 6 809 being coal mining TVET jobs.

This scenario would negatively impact the tertiary sector – a sector comprising a multitude of industries, primarily in the services sector - but will provide the second highest GDP growth by 2050 of the four modelled scenarios.

4.4 Quantitative Scenario 4: All-inclusive Portfolio

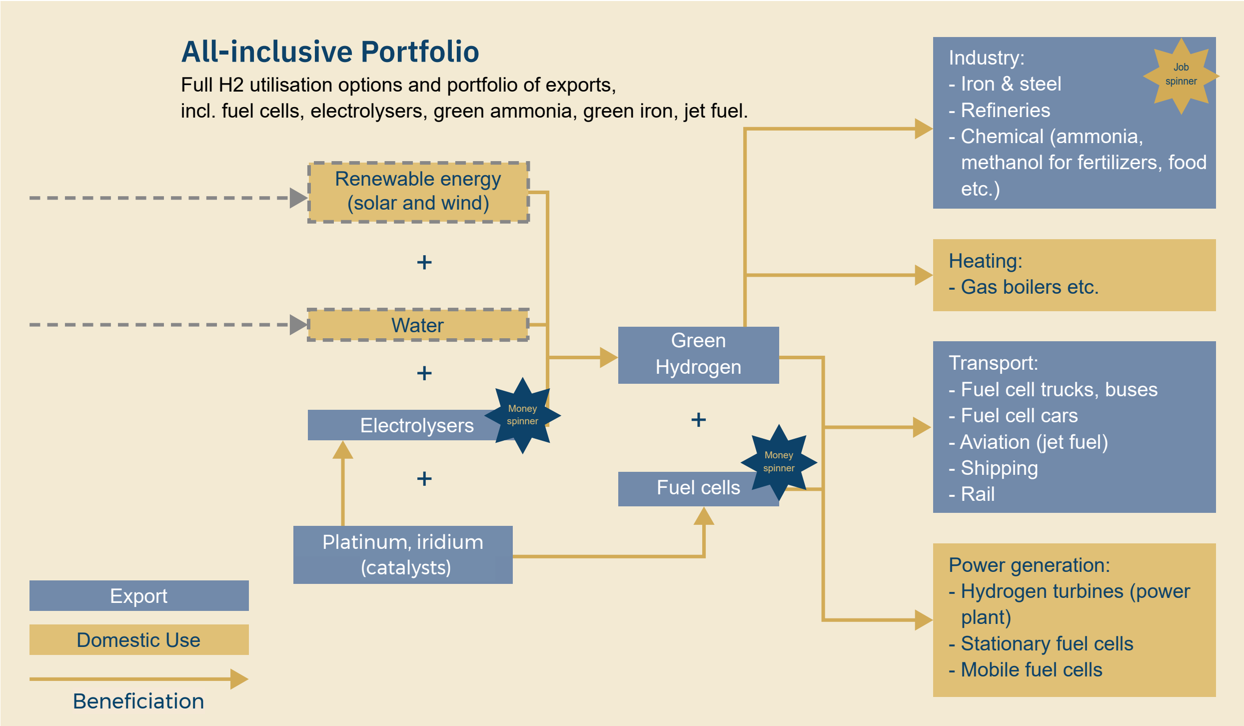


Figure 17 All-inclusive Portfolio

Source: Ahjum et al., "Green Hydrogen and TVET Employment"

The All-Inclusive Portfolio scenario models the impact of a GHE that considers domestic hydrogen utilisation options (including mobility and power generation) as well as a portfolio of exports (including fuel cells, electrolysers, green hydrogen and ammonia, green iron and steel and green jet fuel). The impact of a focus on both domestic utilisation and a portfolio of exports is GDP growth of 118% by 2050 (year-on-year growth of 2.6%) and a total growth worth ZAR 3.5 billion.

Table 13 provides a comparative overview of the number of jobs in the entire South African economy by 2030, 2040, and 2050 based on the All-Inclusive Portfolio scenario. Under this scenario, by 2050 the total number of all jobs for both GHE and non-GHE sectors in the economy at large are forecast at 35.2 million, of which 1.3 million will be TVET related.

Table 13 Number of GHE jobs including GHE TVET jobs in 2030, 2040 and 2050 for selected sectors and the entire SA economy with an All-inclusive Portfolio scenario

Sector	Jobs 2030	Jobs 2040	Jobs 2050	TVET jobs 2030	TVET jobs 2040	TVET jobs 2050
Iron & steel	224 000	581 000	918 000	6 500	16 900	26 600
PGM mining	161 000	188 000	706 000	7 300	8 500	31 900
Power generation[a]	77 000	140 000	212 000	6 000	11 000	16 600
Fuel cells	<1 000	28 000	302 000	<100	900	9 700
Electrolysers	2 000	30 000	283 000	100	1 000	9 100
Ammonia	5 000	34 000	66 000	200	1 500	3 000
GH_2 production	1 000	26 000	52 000	<100	1 200	2 300
SUBTOTAL for GHE sectors[b]	470 000	1 027 000	2 539 000	20 300	41 000	99 200
Compared with South African economy at large						
TOTAL all sectors, (entire SA economy)[c]	**19 899 000**[d]	**26 727 000**[e]	**35 215 000**[f]	**774 000**	**1 035 000**	**1 361 000**

a Numbers for power generation exclude thermal coal power generation, which employs resp. 11 (2030), 6 (2040), and 1 (2050) thousand persons, of which 0.9 (2030), 0.4 (2040), and 0.1 (2050) thousand were TVET-educated in the All-inclusive Portfolio.

b For 2020 we estimate that the mentioned 7 sectors (with power generation excl. thermal coal) employed 327 thousand people, of which 14.6 thousand were TVET-educated (for 2019 these numbers were respectively 388 and 17.4 thousand).

c The Total all sectors jobs refers to the entire SA economy and not only green hydrogen economy jobs. In 2020 the entire South African economy employed about 15.6 million people, of which about 610 thousand were TVET-educated.

d Total all full-time equivalent jobs (including TVET) in the entire South African economy by 2030.

e Total all full-time equivalent jobs (including TVET) in the entire South African economy by 2040.

f Total all full-time equivalent jobs (including TVET) in the entire South African economy by 2050.

Source: Fadiel Ahjum et al., "Green Hydrogen and TVET Employment Prospects: An Assessment in a Context of Ambitious Decarbonisation for South Africa Towards 2050" (Working Paper, SAIIA-UK PACT and University of Cape Town, 2021)

Table 13 also provides a detailed sectoral account of the GHE job numbers by looking at selected GHE sectors (iron and steel, PGM mining, power generation, fuel cells, electrolysers, ammonia, GH2 production) in the entire SA economy in the context of the All-inclusive Portfolio scenario over 2030, 2040, and 2050 windows.

Within the listed GHE sectors, 2.5 million jobs (subtotal for GHE sectors) are expected with the majority (918 000) occurring within the iron and steel sectors. This is followed closely by the PGM sector with 706 000 jobs. The lowest employment contributing GHE sector by 2050 in the All Inclusive Portfolio is forecast to be GH2 production itself with only 52 000 jobs. Of the 2.5 million jobs across all GHE sectors 99 200 (subtotal for GHE sectors) are forecast to be TVET specific within the All Inclusive Portfolio scenario by 2050.

The job gains for the period 2019 to 2050 are forecast at a total of 18.4 million, of which 698 751 are TVET related jobs and 23580 TVET PGM related jobs.

Similar to the previously discussed scenarios, coal mining TVET jobs are forecast to decrease by 6 804, and all job types across the refinery and coal mining sectors by 103 397.

This option requires following a systemic approach, consisting of a medium-term emphasis on domestic use towards 2035, as a catalyst for a strategic long-term, export-oriented economy. Such an economy would be positioned to produce green iron and steel and green ammonia as chief export commodities, along with high-value-added hydrogen fuel cells and electrolysers.

In summary, while all four scenarios demonstrate positive GDP growth and employment gains by 2050, the most significant employment creation and economic impact are seen in the All Inclusive Portfolio scenario.

An All-Inclusive Portfolio that focuses on exporting high-value fuel cells and electrolysers, green steel and ammonia, coupled with domestic hydrogen utilisation, has the potential for gains far exceeding losses (as per Figures 18 and 19). In particular, TVET jobs to be gained across all sectors (including PGM mining) in this scenario far surpass the other three scenarios.

In contrast, Value Added Manufacturing – where South Africa focuses mainly on beneficiating its PGM resources to manufacture and export high-value electrolysers, fuel cells, inverters and a range of battery storage and management components – has the lowest TVET job gain potential and second lowest GDP growth by 2050 of all the four modelled scenarios. This makes a beneficiation-focused South African GHE with no domestic hydrogen utilisation, the least desirable pathway.

Likewise, a domestic-focused GHE under the Status Quo with Domestic Hydrogen Use scenario sees limited economic growth benefits by 2050, while competition for investment resources would lead to a net negative impact in terms of employment in other sectors, such as the services sector.

In contrast, the Business as Usual scenario provides the lowest GDP growth by 2050 but has the second highest potential for total jobs gained.

From the modelling, it is evident that the iron,steel and PGM mining sectors are forecast to do well. These sectors hold the most significant total job and TVET job creation potential for SA. This reflects a high likelihood of growing international demand necessary to catalyse the global transition to Net Zero.

See Table 14 for economic and employment gains and losses per scenario between 2019 and 2050. See Table 15 for TVET job gains and losses in the economy at large, and sub-sectors per scenario between 2019 and 2050.

Table 14 Economic and employment gains and losses per scenario between 2019 and 2050

	GDP growth (ZAR)	GDP growth as a percentage of 2020 GDP	Average annual GDP growth rate	Jobs gained all sectors with net job gains	Jobs lost coal mining and refineries sector with net job losses	Net jobs gained or lost all sectors
Business-as-Usual	2 869 084 515	96%	2,3%	15 212	-100 600	15 111 957
Value Added Manufacturing	2 936 185 148	98%	2,3%	14 853	-100 489	14 752 704
Staus Quo with Domestic Hydrogen Use	3 035 594 743	102%	2,4%	14 928	-104 045	14 824 357
All-inclusive Portfolio	3 533 979 612	118%	2,6%	18 374	-103 397	18 270 774

Source: Compiled by authors (SAIIA)

Table 15 TVET job gains and losses in economy at large and sub-sectors per scenario between 2019 and 2050

	TVET jobs gained all sectors with net TVET job gains	TVET jobs lost coal mining and refineries sector with net TVET job losses	Total TVET jobs gained	PGM TVET jobs gained	Coal mining TVET jobs lost	PGM and coal mining TVET combined job changes
Business-as-Usual	593 198	-8 661	584 536	21 596	-6 600	14 955
Value Added Manufacturing	576 552	-8 648	567 903	27 939	-6 626	21 312
Staus Quo with Domestic Hydrogen Use	582 211	-8 929	573 282	17 432	-6 809	10 622
All-inclusive Portfolio	707 643	-8 892	698 751	23 580	-6 804	16 775

Source: Compiled by authors (SAIIA)

See Figures 18 and 19 for a summary of the economic and employment impacts, by industry, of the different options from 2030–2050. Figure 19 focuses on total employment – a much larger number than TVET employment only. TVET jobs as a percentage of the labour force vary by sector (from over 10% for coal mining to just under 3% for iron and steel), averaging 3.8% of the total workforce. There is little variance between the forecast coal mining and refinery job losses across the four scenarios.

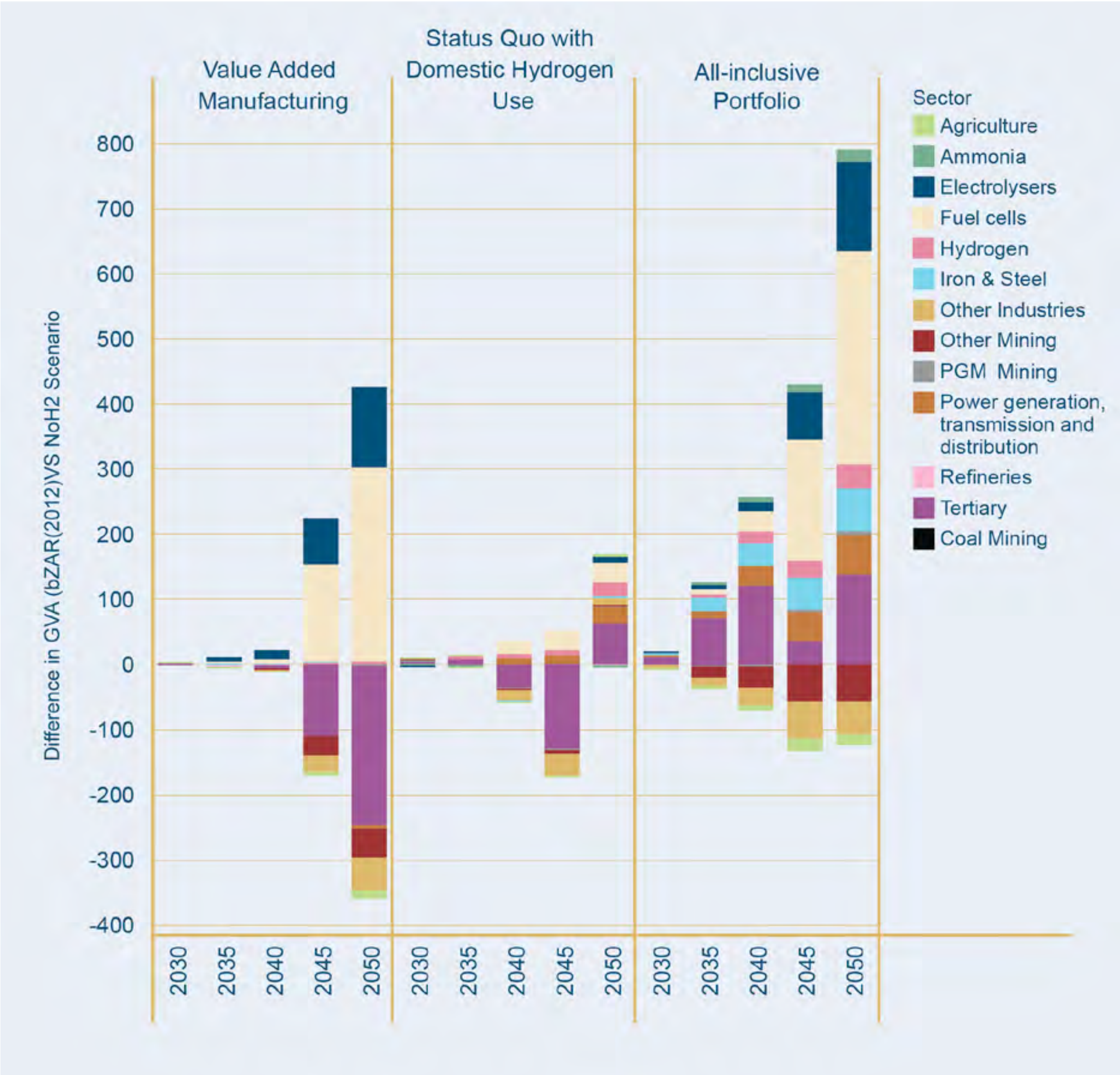


Figure 18 Economic performance by gross value added per scenario relative to Business as Usual

Source: Fadiel Ahjum et al., “Green Hydrogen and TVET Employment Prospects: An Assessment in a Context of Ambitious Decarbonisation for South Africa Towards 2050” (Working Paper, SAIIA-UK PACT and University of Cape Town, 2021)

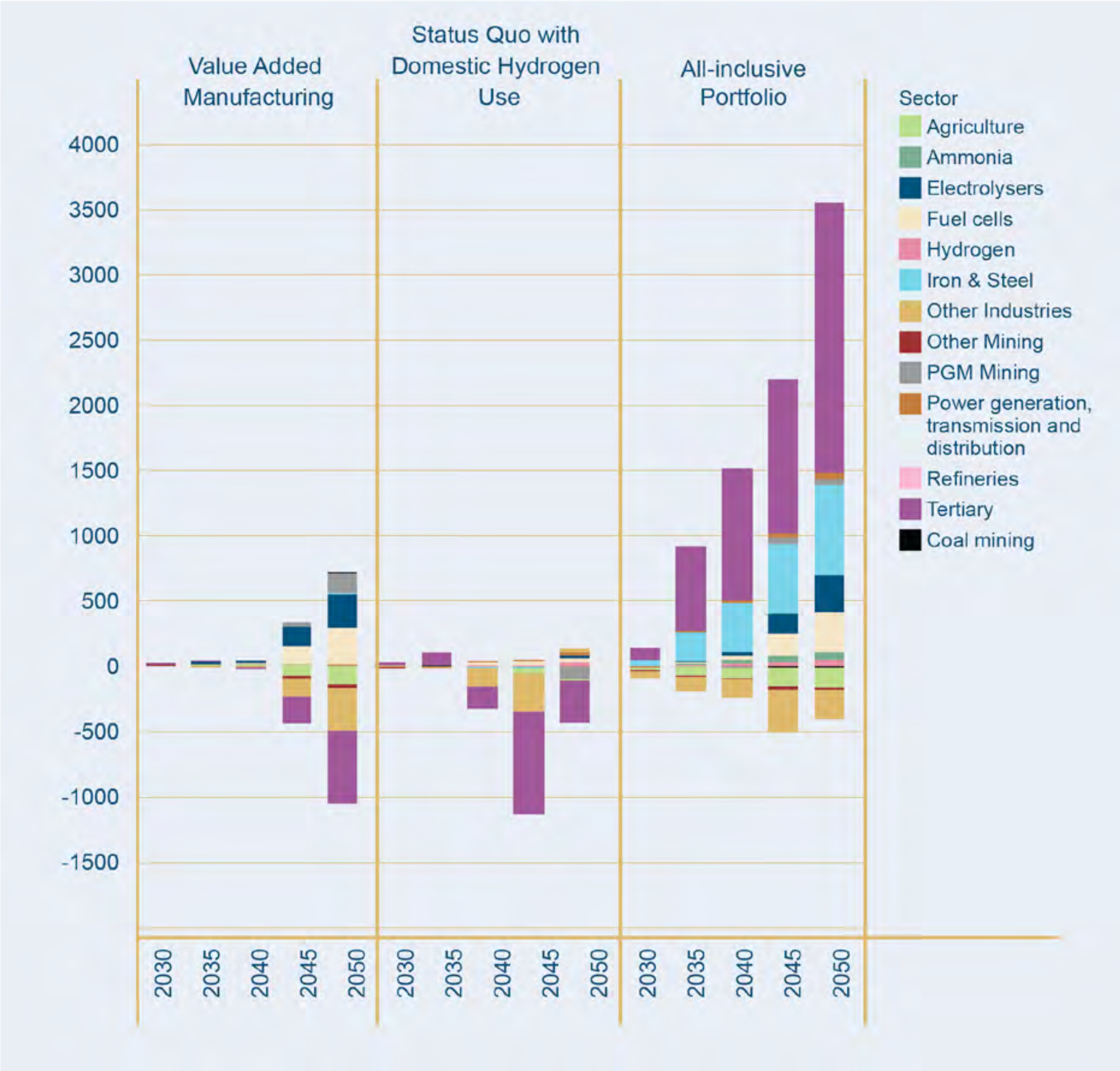


Figure 19 Net employment (full-time equivalent) for different scenarios relative to Business as Usual

Source: Fadiel Ahjum et al., "Green Hydrogen and TVET Employment Prospects: An Assessment in a Context of Ambitious Decarbonisation for South Africa Towards 2050" (Working Paper, SAIIA-UK PACT and University of Cape Town, 2021)

4.5 Options for transitioning workers between industries

The global transition away from fossil fuels will have a major impact across multiple industries. While some industries will decline ('sunset industries'), others will grow. Tables 16-A, 16-B and 16-C consider the potential for transitioning workers, and specifically TVET skilled workers in South Africa, between sunset and growth industries. They estimate both the sunset industry TVET jobs under threat and the potential TVET jobs to be gained in growth industries between now and 2050.

Table 16-A TVET jobs under threat and potential gains in comparative industries, 2020–2030[a]

Sector	Sunset industry	TVET jobs under threat between now and 2030	Growth industry	TVET jobs to be gained by 2030 – Status quo scenario	TVET jobs to be gained by 2030 – All-inclusive portfolio scenario	Comments
Chemicals and petrochemical	Grey H_2, ammonia (NH_3), methanol, refineries	**2 400+** (artisans and technicians at Sasol H_2 production)[b] **+2 000** (refineries)	Green H_2, Green NH_3	**0**	**250 – 300**, consisting of: Green H_2: **<50** Green NH_3: **200 – 250**	Reskill grey H_2 staff before hiring Possibly move green chemicals' timeline forward
Manufacturing	ICE automotive industry	**0**	Fuel cells and electrolyser manufacturing	**0**	**<100** consisting of: Fuel cells: **0** Electrolysers: **50 – 100**	Fuel cells and electrolyser industries in early development – some semi- and high-skilled TVET jobs
Mining	Coal mining	**2 500**	PGM mining	**0**	**0**	Timing mismatch To mitigate, also transition workers to green iron and steel and renewable energy jobs
Manufacturing	Iron, steel and metals	The basic iron and steel sector in South Africa employed just over **29 000** people in 2019, of whom fewer than **1 000** were TVET[c]	Green iron and steel	**1 000**	**2 400**	Green iron and steel are potentially a big future employer of TVET candidates
Energy	Coal-fired power	**100**	Renewable energy, including solar, wind with additional transmission, distribution and storage[d]	**800**	**1 000**	Green H_2 economy requires growth in the renewable energy
2030	Total of the above	**Possibly up to 8 000**	Total of the above[e]	**1 800**	**3 700 to 3 800**	

a All figures except additional ones inserted in table from Fadiel Ahjum and Schers et al., "Green Hydrogen and TVET Employment Prospects: An Assessment in a Context of Ambitious Decarbonisation for South Africa Towards 2050".

b Patel, "South African Industry Demand".

c DTIC, *The South African Steel and Metal Fabrication Master Plan 1.0: Support for the Steel Value Chain* (Johannesburg: DTIC, 2020). TVET estimates ratio from all figures, except additional ones inserted in table from Schers et al., "Green Hydrogen and TVET Skills".

d This includes jobs gained to compensate for loss of jobs in thermal coal-fired power generation.

e The difference in the totals for the five mentioned sunset industry sectors is the number of people already employed in these sectors in 2020 (15.6 million), plus the difference or uncertainty about 2020 versus 2019 job estimates in PGM mining.

SMME's employ about 10 million people (or 75% of the South African labour force).[95] SMMEs are predominantly found in the services sectors (eg, trade, accommodation, transport services, finance, business services) and construction, and to a lesser extent in the manufacturing and agriculture sectors, while being almost absent in mining. About 9% of SMMEs can be found in manufacturing which is comparable to the manufacturing sector's share in total South African employment (approximately 10%).[96] However, determining the size and industry of future TVET jobs in SMMEs is challenging, as they are more likely to be found in industries such as furniture and textile and manufacturing than in petrochemicals and mining. Therefore based on currently available data one can only say that a significant, but difficult to estimate, number of green hydrogen TVET manufacturing jobs will be situated at SMMEs. We expect that industries like fuel cell and electrolyser component manufacturing will be almost entirely made up of SMMEs in the beginning, while industries like chemicals (NH_3, H_2) iron & steel will be dominated by the big companies like Sasol.

Table 16-B TVET jobs under threat and potential gains in comparative industries, 2020–2040[a]

Sector	Sunset industry	TVET jobs under threat between now and 2040	Growth industry	TVET jobs to be gained by 2040 – Status quo scenario	TVET jobs to be gained by 2040 – All-inclusive portfolio scenario	Comments
Chemicals and petro-chemical	Grey H_2 ammonia (NH_3), methanol, refineries	**2 400+** (artisans and technicians at Sasol H_2 production)[b] **+ 2 000** (refineries)	Green H_2, Green NH_3	**450**, consisting of: Green H_2: **450** Green NH_3: **0**	**2 500**, consisting of: Green H_2: **1 200** Green NH_3: **1 300**	Reskill grey H_2 staff before hiring Possibly move green chemicals' timeline forward

95 Small Enterprise Development Agency, *SMME Quarterly Update 3rd Quarter 2020*. (Pretoria: Department of Small Business Development, March 2021)

96 CEIC, *South Africa Employment: Labour Force Survey: Manufacturing*, Statistics South Africa (December 2021)

Manufacturing	ICE automotive industry	**0**	Fuel cells and electrolyser manufacturing	**580**, consisting of: Fuel cells: **580** Electrolysers: **0**	**1 900** consisting of: Fuel cells: **900** Electrolysers: **1 000**	Significant value added for the economy and some semi- and high-skilled TVET jobs
Mining	Coal mining	**5 200**	PGM mining[c]	**260**	**200**	Timing mismatch To mitigate, also transition workers to green iron and steel and renewable energy jobs
Manufacturing	Iron, steel and metals	The basic iron and steel sector in South Africa employed just over **29 000** people in 2019, of whom fewer than **1 000** were TVET[d]	Green iron and steel	**1 900**	**13 000**	Green iron and steel are potentially a big future employer of TVET candidates
Energy	Coal-fired power	**1 000**: By 2018, Eskom employed nearly **50 000** people, of which about 25% in its fleet of coal-fired power stations,[e] to be closed to by 2040 latest, of which respectively an estimated total **4 000** jobs and **1 000** at TVET-level[f]	Renewable energy, including solar, wind with additional transmission, distribution and storage[g]	**4 700**	**5 900**	Green H_2 economy requires growth in the renewable energy
2040	Total of the above	Possibly up to **11 600**	Total of the above[h]	**7 990**	**23 500**	

a All figures except additional ones inserted in table from Fadiel Ahjum and Schers et al., "Green Hydrogen and TVET Employment Prospects: An Assessment in a Context of Ambitious Decarbonisation for South Africa Towards 2050".

b Patel, "South African Industry Demand".

c PGM mining job additions are relative to 2019, due to uncertainty about 2020 job numbers in relation to COVID for this sector.

d DTIC, *The South African Steel and Metal Fabrication Master Plan 1.0: Support for the Steel Value Chain* (Johannesburg: DTIC, 2020). TVET estimates ratio from all figures, except additional ones inserted in table from Schers et al., "Green Hydrogen and TVET Skills".

e Eskom, *Integrated Report* (Johannesburg: Eskom, March 31, 2018).

f As per ratios in Schers et al., "Green Hydrogen and TVET Skills".

g This includes jobs gained to compensate for loss of jobs in thermal coal-fired power generation.

h The difference in the totals for the five mentioned sunset industry sectors is the number of people already employed in these sectors in 2020 (15.6 million), plus the difference or uncertainty about 2020 versus 2019 job estimates in PGM mining.

Table 16-C TVET jobs under threat and potential gains in comparative industries, 2020–2050[a]

Sector	Sunset industry	TVET jobs under threat between now and 2050	Growth industry	TVET jobs to be gained by 2050 – Status quo scenario	TVET jobs to be gained by 2050 – All-inclusive portfolio scenario	Comments
Chemicals and petro-chemical	Grey H_2, ammonia (NH_3), methanol, refineries	**2 400+** (artisans and technicians at Sasol H_2 production)[b] + **2 000** (refineries)	Green H_2, Green NH_3	**1 400**, consisting of: Green H_2: **1 400-** Green NH_3: **0**	**5 300**, consisting of: Green H_2: **2 300** Green NH_3: **3 000**	Reskill grey H_2 staff before hiring Possibly move green chemicals' timeline forward
Manufacturing	ICE automotive industry	**5 000**	Fuel cells and electrolyser manufacturing	**1 500**, consisting of: Fuel cells: **800** Electrolysers: **700**	**18 800** consisting of: Fuel cells: **9 700** Electrolysers: **9 100**	Big value added contribution to the economy and some semi- and high-skilled TVET jobs
Mining	Coal mining	**5 900**	PGM mining[c]	**17 400**	**23 600**	Timing mismatch To mitigate, also transition workers to green iron and steel and renewable energy jobs

Manufacturing	Iron, steel and metals	The basic iron and steel sector in South Africa employed just over **29 000** people in 2019, of whom **fewer than 1 000** were TVET[d]	Green iron and steel	**2 500**	**22 700**	Green iron and steel are potentially big future employers of TVET candidates
Energy	Coal-fired power	**1 000**: By 2018, Eskom employed nearly **50 000** people, of which about 25% in its fleet of coal-fired power stations,[e] to be closed by 2040 latest, of which respectively an estimated total **4 000** jobs and **1 000** at TVET-level[f]	Renewable energy, including solar, wind with additional transmission, distribution and storage[g]	**9 400**	**11 600**	Green H_2 economy requires growth in the renewable energy
2050	**Total of the above**	**Possibly up to 17 300**	**Total of the above**[h]	**32 200**	**82 000**	

a All figures except additional ones inserted in table from Fadiel Ahjum and Schers et al., “Green Hydrogen and TVET Employment Prospects: An Assessment in a Context of Ambitious Decarbonisation for South Africa Towards 2050”.

b Patel, “South African Industry Demand”.

c PGM mining job additions are relative to 2019, due to uncertainty about 2020 job numbers in relation to COVID for this sector.

d DTIC, The South African Steel and Metal Fabrication Master Plan 1.0: Support for the Steel Value Chain (Johannesburg: DTIC, 2020). TVET estimates ratio from all figures, except additional ones inserted in table from Schers et al., “Green Hydrogen and TVET Skills”.

e Eskom, *Integrated Report* (Johannesburg: Eskom, March 31, 2018).

f As per ratios in Schers et al., “Green Hydrogen and TVET Skills”.

g This includes jobs gained to compensate for loss of jobs in thermal coal-fired power generation.

h The difference in the totals for the five mentioned sunset industry sectors is the number of people already employed in these sectors in 2020 (15.6 million), plus the difference or uncertainty about 2020 versus 2019 job estimates in PGM mining.

Sources: Tables 16-A, 16-B and 16-C compiled by authors (SAIIA)

4.5.1 Comparative industries: Refineries vs. green chemicals (H_2 and NH_3)

Figure 20 shows the TVET employment impacts of the phasing-out of refineries and the growth in green hydrogen and ammonia production in an All-Inclusive Portfolio.

The phasing-out of ICE vehicles has a major impact on refineries, with refinery utilisation expected to decline by 85% by 2050, with much of this happening as soon as 2030.[97] The number of jobs created through the production of green hydrogen and green ammonia in an All-inclusive Portfolio forecast could surpass those lost in refineries somewhere between 2035 and 2040, although a lag between the drop in refineries and the growth in green hydrogen and ammonia makes the five or 10 years after 2025 difficult. A potential solution entails moving the green chemical (hydrogen, ammonia, ethylene) manufacturing timeline forward to smooth this transition.[98]

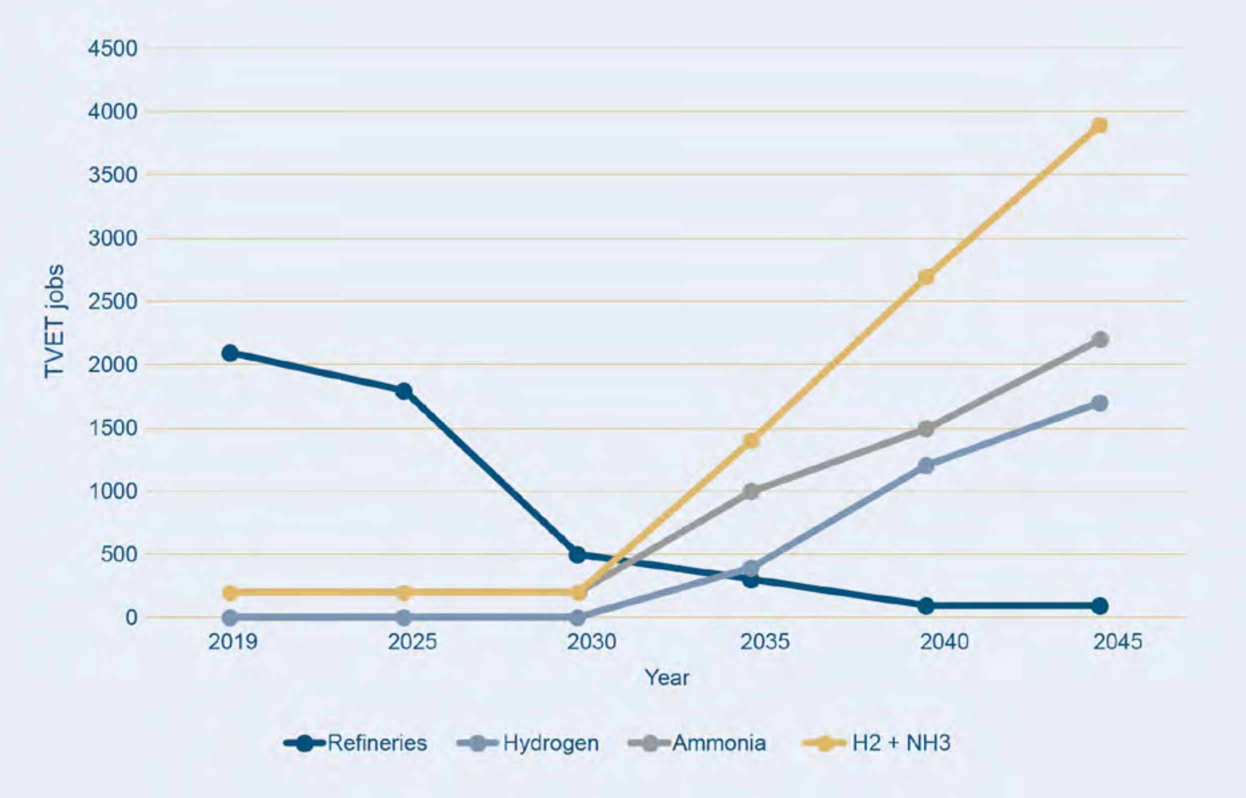


Figure 20 Refineries vs. green hydrogen and ammonia in All-Inclusive Portfolio

Source: Fadiel Ahjum et al., “Green Hydrogen and TVET Employment Prospects: An Assessment in a Context of Ambitious Decarbonisation for South Africa Towards 2050” (Working Paper, SAIIA-UK PACT and University of Cape Town, 2021)

97 Schers et al., “Green Hydrogen and TVET Skills”.

98 Schers et al., “Green Hydrogen and TVET Skills”.

Workers involved in grey hydrogen production could also be transitioned to green hydrogen production, as in the plan for Sasol, for instance. In addition, refinery workers could be transitioned to other green chemicals (outside of the green hydrogen value chain).

There is significant congruence with the Three Horizons Framework (Figure 8), as sunset sectors and industries retire and others begin to grow. The 10 years between 2025 and 2035 will be pivotal in positioning the South African economy to take full advantage of the benefits that could accrue from green hydrogen production and related manufacturing value chains. Upskilling and reskilling will be critical.

4.5.2 Comparative industries: ICE vehicles vs. fuel cells and electrolysers

Figure 21 shows the employment impact of phasing out ICE vehicle manufacturing and the growth of a fuel-cell and electrolyser manufacturing industry by 2045.

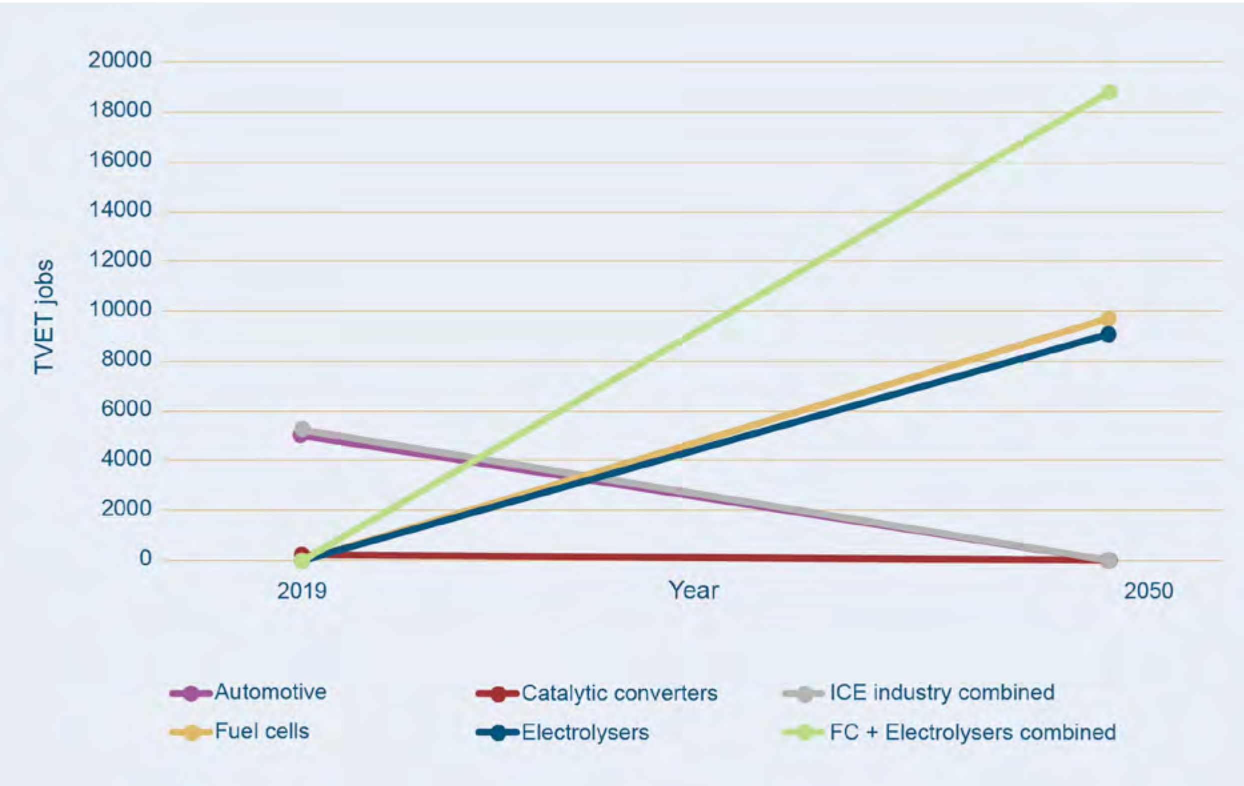


Figure 21 ICE vehicle manufacturing vs. fuel-cell & electrolyser manufacturing in All-inclusive Portfolio

Source: Fadiel Ahjum et al., “Green Hydrogen and TVET Employment Prospects: An Assessment in a Context of Ambitious Decarbonisation for South Africa Towards 2050” (Working Paper, SAIIA-UK PACT and University of Cape Town, 2021)

A global Net-Zero-by-2050 pathway requires that ICE are phased out entirely by 2050, to be replaced by electric or fuel-cell electric vehicles. This has implications for the manufacturing of motorised vehicles, vehicle parts and catalytic converters. In terms of job numbers, fuel-cell and electrolyser manufacturing would surpass the ICE vehicle manufacturing industry for both the All-inclusive Portfolio and the Value Added Manufacturing forecasting options (but not for the domestically focused Status Quo with Domestic Hydrogen Use option).[99]

The TVET jobs created in the fuel-cell and electrolyser industries are, however, in the semi- and high-skilled TVET categories, with negligible numbers in the low-skilled categories. Transitioning workers between the sectors would also require substantial reskilling and upskilling (see the section on skills requirements for more).[100]

It is important to note that there is some uncertainty related to the future of fuel-cell utilisation, as electric batteries continue to make inroads in applications touted for hydrogen, such as light-duty vehicles, trucks, off-grid power and grid balancing.[101]

4.5.3 Comparative industries: Coal mining vs. platinum mining

Jobs gained in platinum mining will surpass those lost in the coal mining sector by 2050 in all scenarios. So too, the boom in PGM mining spurred by international demand for PEM fuel cells and catalysers (a projected two- to eight-fold increase in the demand for platinum) would more than make up for the PGM jobs lost in the production of catalytic converters.[102]

On the mining side, however, there is a lag in terms of timing: the coal sector is projected to decline before the platinum sector is set to boom. To smooth the transition, it is recommended that former coal mining employees are reskilled and upskilled not only for the platinum mining sector but also for jobs in green iron and steel production and renewable energy. In addition to reskilling and upskilling, there will also be a need to train new workers in the skills needed for PGM.[103]

Note: Technological advancement could be a risk to the PGM sector if it leads to the adoption of other catalysts (besides PGM) or more cost-effective, alternative technologies (eg, if electric batteries make inroads in applications touted for hydrogen).

99 Schers et al., “Green Hydrogen and TVET Skills”.
100 Schers et al., “Green Hydrogen and TVET Skills”.
101 Schers et al., “Green Hydrogen and TVET Skills”.
102 Schers et al., “Green Hydrogen and TVET Skills”.
103 Schers et al., “Green Hydrogen and TVET Skills”.

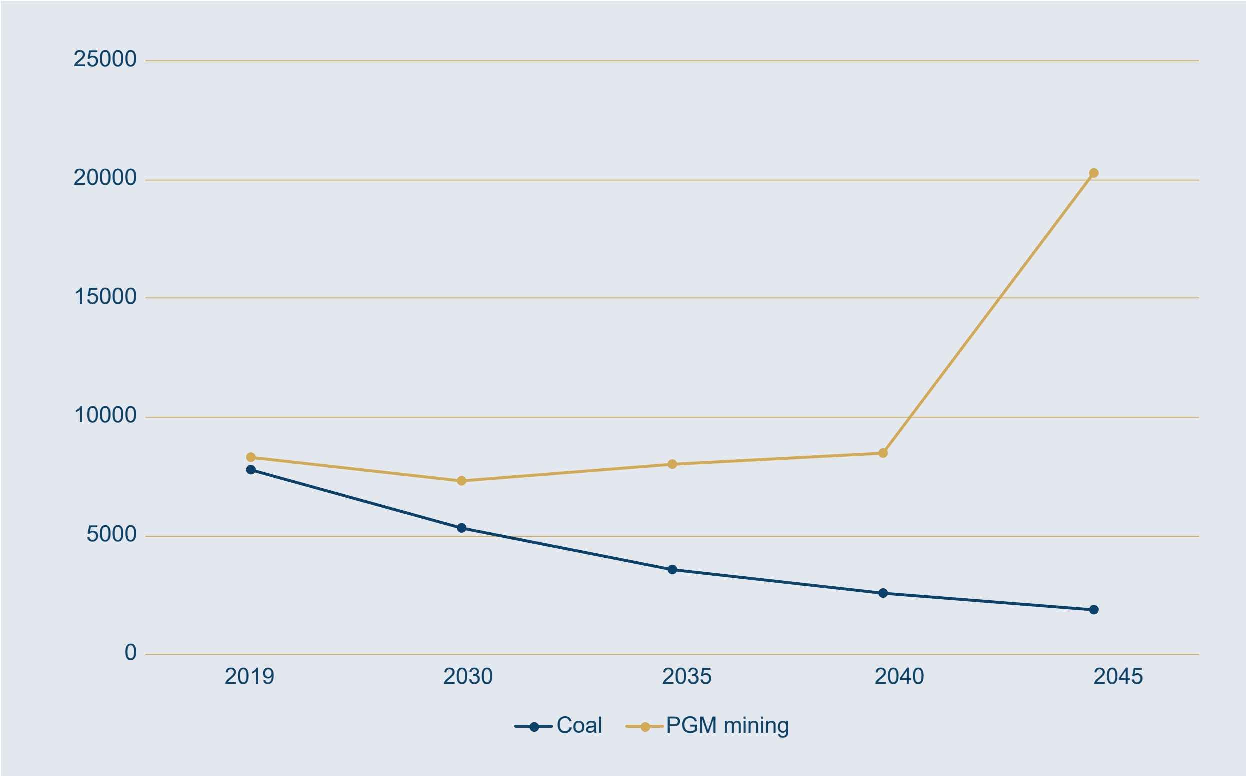


Figure 22 Coal and PGM mining in All-inclusive Portfolio

Source: Jules Schers et al., "Green Hydrogen and TVET Skills' Role in South Africa's Just Transition" (Working Paper, SAIIA-UK PACT and University of Cape Town, 2021)

4.6 Governing the skills transition to a green hydrogen economy

Whereas the previous section considered the potential for transitioning workers between sunset and growth industries, this section focuses on what needs to be done to prepare the South African workforce – and those with TVET skills specifically – for growth sectors related to a GHE.

The South African HSRM makes provision for the development of a framework for reskilling people and preserving jobs in sectors affected by the transition to the hydrogen economy, as well as a skills development plan for a hydrogen-trained labour force (involving the DOL, DHET, DSI and EWSETA). The HSRM considers this a near-term priority (2021–2024),[104] with the implementation of the skills development plan following shortly after (2025–2030). This report could be the starting point for such a framework and plan.

Table 17 summarises key sectors and industries to focus on and by when. It is followed by a more in-depth discussion of relevant emerging and growth industries.

104 DSI, *Hydrogen Society Roadmap*, 49.

In summary, sectors and industries for which skills development should be prioritised in the near term (ie, before 2025) include renewable energy (aligned with the Renewable Energy Master Plan and REDZ, specifically in declining coal-mining areas) and iron and steel, including preparation for a transition to green steel manufacturing (aligned with the Steel Master Plan). The timeline for green hydrogen and ammonia manufacturing could also be pulled forward to the near term.

Table 17 Green hydrogen skills requirements summary

Sector	Sunset industry	Growth industry	Timeline	Comments
Manufacturing	ICE and ICE vehicles	Fuel cells and electrolyser manufacturing, FC vehicles	In the near term (2021–2024) the HSRM prioritises the identification of skills needed and the development of a skills development roadmap for fuel-cell and related H_2 product component manufacturing (involving the DHET with DSI, SANEDI, Hydrogen South Africa (HySA) and the private sector). Skills map to be implemented from 2025 onwards. UCT employment modelling shows the first stirrings of employment in these industries towards 2030–2035, with the bulk of jobs only after 2040.[a] In terms of hydrogen mobility ecosystem, the HSRM sets out plans to scale up the conversion of government fleets and municipal vehicles to use hydrogen as fuel between 2025 and 2030.[b] In the nearer term (2021–2024), the HSRM also makes provision for refuelling station pilots for buses, heavy good vehicles and taxis.[c] Potential to align with pilot training.	New technical skills related to fuel cells, electrolysers, FC vehicles, green hydrogen process and value chain, and occupational health and safety. Digital/ ICT, STEM and soft skills.
Chemical and petro-chemical	Grey hydrogen, ammonia, refineries	Green hydrogen, green ammonia	HSRM makes provision for skills development and training in hydrogen production, certification and safety in the near term (2021–2024).[d] In UCT modelling, green chemical manufacturing is expected to pick up from 2030, although there is a recommendation to move this timeline forward, in part to compensate for the decline in refineries that is already underway.	New technical skills (electrolysis) for green hydrogen and green ammonia, occupational health and safety-related to working with a volatile gas.

Mining	Coal mining	PGM mining	Coal mining jobs are already in decline, while PGM mining jobs are only expected to pick up significantly after 2040. Focus on reskilling coal mining workers as soon as possible, starting with transition to renewable energy skills as per plans for REDZs in coal mining areas.	Reskill, upskill and train PGM mining (known skills). Also reskill or upskill for green steel and renewables. Digital/ICT and soft skills.
Manufacturing	Iron and steel (non-green)	Green iron and steel	Already potential to upscale iron and steel sector and focus on transition to green iron and steel between now and 2030. Another reason for fast-tracking the development of this sector is the fact that the next industry refurbishment cycle is in 2030, so plans need to be in place by then. Align with the HSRM and Steel Master Plan.[e]	Reskill, upskill or train for green iron and steel.
Energy	Coal-fired power stations	Renewable energy, incl. solar, wind	Immediate focus, including aligned with the SAREM and REDZs, specifically those related to just transition initiatives in coal-mining areas, but also to unfolding plans related to the South African GHE.	Reskill, upskill and train for solar and wind energy manufacture, operations, maintenance and distribution.[f]

a Schers et al., "Green Hydrogen and TVET Skills", Table 13.

b DSI, *Hydrogen Society Roadmap*, 44.

c DSI, *Hydrogen Society Roadmap*, 44.

d DTIC, *The South African Steel and Metal*.

e DSI, *Hydrogen Society Roadmap*.

f See, for example, Bambili Advisory, "The South African Hydrogen Economy"; Rassool et al., "Assessment of Local Skills".

Source: Compiled by authors (SAIIA)

New and emerging industries that may take longer to mature include a fuel-cell and electrolyser manufacturing industry, and a green hydrogen mobility ecosystem (including FCEV and refuelling infrastructure). However, it is important to start identifying the skills required and build a skills development roadmap as it can take from 5–10 years to 'ready' the skills system for new value chains and competencies. In other words, the skills system needs to be preparing ahead of the technological development frameworks as lecturers need to be trained, curricula developed and tested, work placements set up, and indeed the model of TVET needs to be reframed, with the necessary funding support, selection of candidates etc. In other words, a *pro-active* approach to skills development should be actively embraced by all partners and put in place in good time. Here, time needed for qualifying artisans etc. also needs to be factored in. There may also already be opportunities for pilot training programmes, building on the lessons from the fuel-cell training led by Bambili Energy (discussed later in the report). Overall, the next 10 years will prove crucial in positioning the country to take advantage of the growing global GHE. For this to be realised, the skills system for this transition must be a more pro-actively advanced GHE.

4.6.1 TVET jobs and skills related to green hydrogen and ammonia production[105]

South Africa currently produces grey hydrogen from natural gas and coal. This is largely for internal (eg, Sasol) or domestic use. Hydrogen is used to produce methanol and ammonia, which is then used for fertilizers, fuels, explosives and other chemicals. Hydrogen is also used in steel production, platinum refining, glass manufacturing and food processing.

Sasol, Afrox and Air Liquide have all indicated an interest in introducing green hydrogen production to their processes. Sasol has indicated that many roles already exist within grey hydrogen production processes that are applicable to a green hydrogen transition, and hence internal labour will be retrained and reskilled for green hydrogen before new labour is hired. The roles span process jobs (eg, operators, controllers, foremen), maintenance positions (eg, machinists, welders, electricians), logistics jobs (eg, forklift drivers, stock control) and support positions (eg, lab assistants). Firms already have detailed expertise related to managing and handling gaseous and liquified material at scale (including safety protocols), water and brine treatment systems, and operating electrolytic systems for the production of chemical products.[106] As mentioned earlier, it is also possible to transition TVET staff from refineries[107] (both industries work with explosive feedstock), although that will require some reskilling.

Technicians and artisans in existing hydrogen production processes are trained with a combination of TVET and in-house training. For example, two TVET colleges near Sasol cater respectively for chemical technical training and maintenance, fitting and other mechanical technical requirements.[108] The firms interviewed for this study are optimistic about hydrogen training programmes. They flagged programmes that require upgrading, including electrical, plumbing, construction and metalwork, as useful. Training is followed by in-house training in chemical operations to familiarise employees with production processes and plant operations.[109]

105 Patel, "South African Industry Demand"; Bambili Advisory, "The South African Hydrogen Economy".
106 Patel, "South African Industry Demand".
107 Schers et al., "Green Hydrogen and TVET Skills".
108 Bambili Advisory, "The South African Hydrogen Economy"; Patel, "Industry Demand".
109 Patel, "South African Industry Demand".

Table 18 Firms indicating an interest in green hydrogen production

Firm	Details	Location
Sasol	Produces about 2.7m tonnes of grey hydrogen/year, for which it employs ~2 400 technicians and artisans, split 2:1 between Secunda and Sasolburg. April 2021: Announced partnership with Toyota to assess feasibility of green H_2 mobility ecosystem. April 2021: Announced a collaboration between Sasol, Linde, Enertrag and Navitas to bid for the production of SAF for export to Germany. July 2021: Joined H_2 Council (CEO-led initiative).	Secunda and Sasolburg
Eskom	Plans to decommission and repurpose its existing coal fleet and power stations – in line with the just transition narrative – including consideration of a move towards green hydrogen. Views green hydrogen as a promising, but early-stage technology still associated with substantial capex and opex costs, and estimates that it will only be cost-feasible from 2030 onwards. Is currently at a research and development (R&D) stage with the development of its green hydrogen activities, and anticipates finalising its hydrogen strategy in 2022. Was eagerly awaiting policy direction in the Hydrogen Society Road Map, launched on 17 February 2022, and is exploring potential projects in the Richards Bay region, given the proximity to ports. Looking to expand Sere Wind Farm on the Cape West Coast to solar PV and to couple that with electrolysers for green hydrogen production. Is still considering its positioning in the green hydrogen value chain, including whether it will confine itself to green hydrogen production for energy when wind and solar conditions are not optimal or whether it wants to venture further downstream into hydrogen products such as ammonia and fertilizers.	Richards Bay, Cape West Coast
Afrox	Produces hydrogen for sale in the domestic market. Linde, its parent company, has significant experience in producing grey, blue and green hydrogen internationally. April 2021: Announced a collaboration between Sasol, Linde, Enertrag and Navitas to bid for the production of SAF for export to Germany.	Pelindaba
Air Liquide	Aims to produce 50% H_2 by carbon-free processes by 2020 (has a South African presence).	Alberton (Greater Johannesburg)

Source: Muhammed Patel, "South African Industry Demand for Green Hydrogen Technician and Artisan Skills" (Working Paper, SAIIA-UK PACT and Trade and Industrial Policy Strategies, 2021)

The demand for technical and vocational skills in green chemicals production includes roles in mechanical fields (eg, machinists, mechanical fitters), electrical fields (eg, site electricians), logistics (eg, logistics planners, stock control officers, tanker drivers), production (eg, hydrogen lab technicians, electrolytics systems operators) and maintenance (eg, on-site technicians, welders). The roles span process (eg, operators, controllers, foremen), maintenance (eg, machinists, welders, electricians), logistics (eg, forklift drivers, stock control) and supportive positions (eg, lab assistants).[110]

Even where jobs have familiar or recognisable titles, its specifications may change. For example, Figure 23 shows how a position with the same title (in this case, maintenance technician) may differ in the case of grey and green hydrogen production.

4.6.2 TVET jobs and skills related to fuel-cell and electrolyser manufacturing[111]

Fuel cell and electrolyser manufacturing is a new industry that stands to grow significantly in the coming decades. South Africa has a strategic advantage in PEM electrolysis systems, which use metals such as platinum and iridium as electrodes. Table 17 summarises existing firms in the space.

In the all-inclusive portfolio scenario, by 2050 the number of TVET jobs in the fuel-cell and electrolyser manufacturing sector (18 800) will be roughly double. The number currently employed in the vehicle manufacturing sector is 5 000.[112] There is potential to transition workers who work on the production of catalytic converters and other ICE vehicle parts to electrolysers and fuel cells,[113] although that will require reskilling and upskilling. In addition, it will be necessary to train new workers for a growing industry. As this is a fairly new sector in South Africa, there is a strong link between R&D and industry. In the R&D and design phase, most of the jobs require tertiary degrees. At the production stage, there are roles for semi- and high-skilled TVET workers in manufacturing, operations, maintenance and logistics.[114]

Examples of required skills include[115]

- **new technical skills** related to fuel cells, electrolysers, green hydrogen value chain added to STEM curricula (consider exchange agreement);
- **occupational health and safety** related to working with a volatile gas like hydrogen and related applications;
- **digital/ICT skills**, for example, collecting, organising and storing data; using digital tools to operate lab equipment; or working with CNC systems; and
- **soft skills**, including communication, teamwork, problem solving, emotional intelligence and critical thinking.

110 Patel, “South African Industry Demand”.
111 Patel, “South African Industry Demand”.
112 Schers et al., “Green Hydrogen and TVET Skills”.
113 Schers et al., “Green Hydrogen and TVET Skills”.
114 Patel, “South African Industry Demand”.
115 Patel, “South African Industry Demand”; Bambili Advisory, “The South African Hydrogen Economy”.

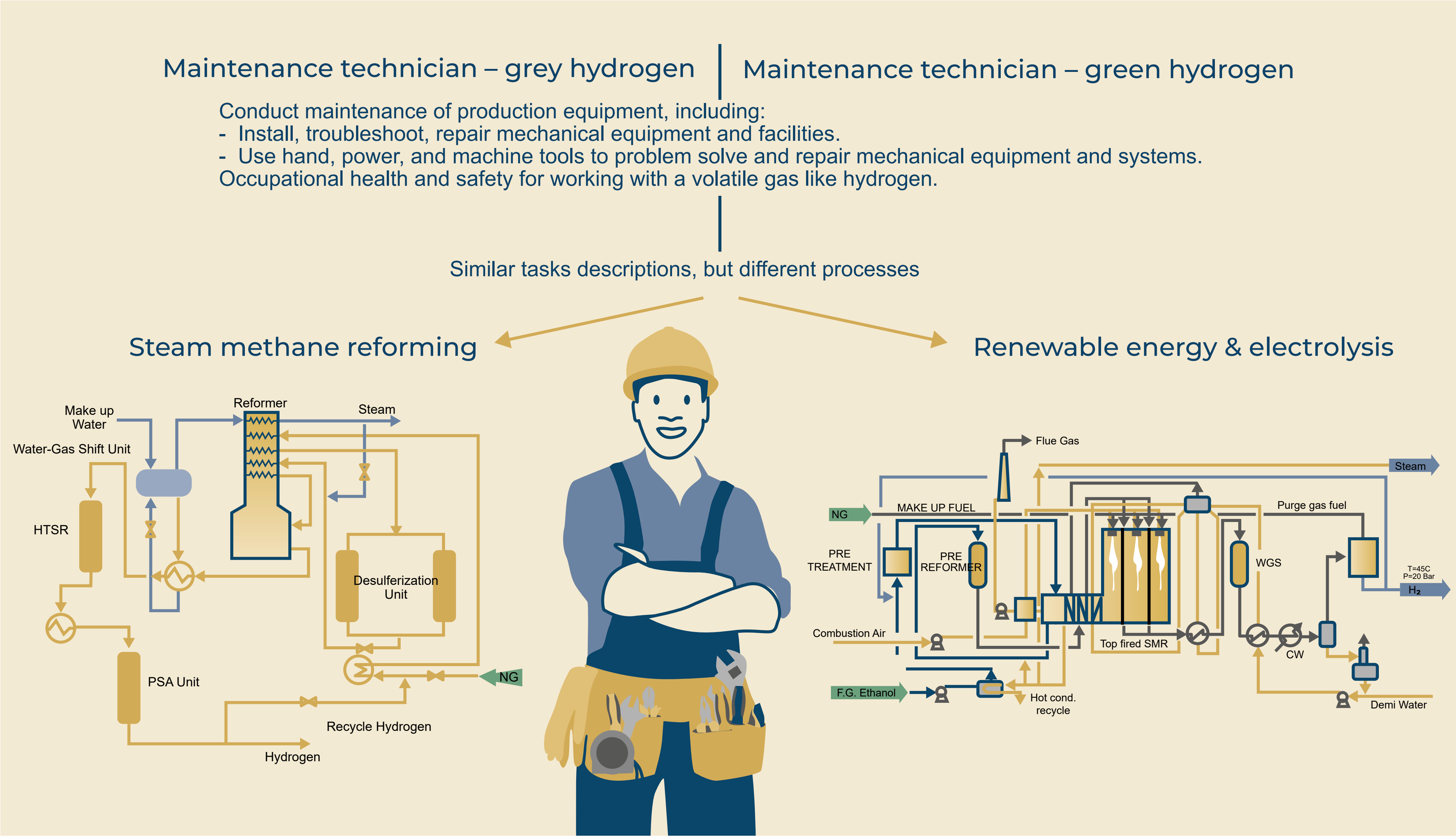


Figure 23 Maintenance personnel: Grey and green hydrogen

Source: Muhammed Patel, "South African Industry Demand for Green Hydrogen Technician and Artisan Skills" (Working Paper, SAIIA-UK PACT and Trade and Industrial Policy Strategies, 2021)

Table 19 Fuel cell and electrolyser manufacturing firms in South Africa

Firm	Products	Location
HyPlat	Membrane electrode assembly (MEA) for fuel cells and electrolysers, catalysts	Cape Town & Johannesburg
Isondo Precious Metals	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	Johannesburg

Source: Muhammed Patel, "South African Industry Demand for Green Hydrogen Technician and Artisan Skills" (Working Paper, SAIIA-UK PACT and Trade and Industrial Policy Strategies, 2021)

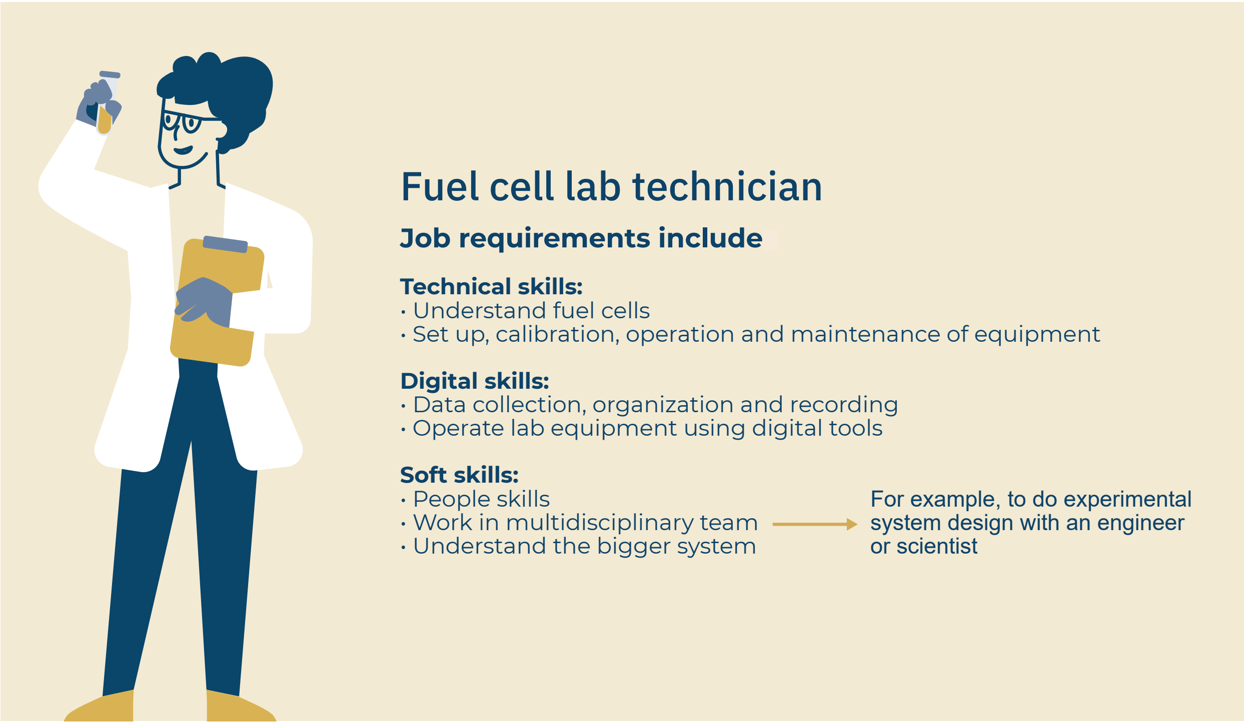


Figure 24 Fuel cell lab technician

Source: Compiled by authors (SAIIA)

Currently, the demand for skills related to fuel-cell and electrolyser manufacturing is oriented towards highly skilled labour (Masters and PhD level) with roles focusing on the design and development of systems and processes. However, increasing demand for artisans and technicians is anticipated at the manufacturing/assembly and operations stages. Examples of positions include electrolyser stack assembly technicians, coating technicians, gas diffusion layer technicians, systems integration technicians, fuel-cell sealers, field service technicians, fuel-cell stack assembly technicians, chemical lab assistants, CNC operators, production operators, fuel-cell laboratory technicians,[116] and health and safety officers. Many of these are new jobs that require new skills. The job depicted in Figure 24 shows an example of a new position (a fuel-cell lab technician) associated with this emerging field.

4.6.3 TVET jobs and skills related to FCEV manufacturing

A global Net-Zero-by-2050 pathway requires that ICE vehicles be phased out entirely by 2050, to be replaced by FCEV. Most light-duty vehicles would likely be replaced by battery-electric vehicles, with fuel cells restricted to heavy freight (HCV6-9). By 2045, it is projected that fuel-cell technology will dominate the heavy freight segment of the transport market, with 170 000 to 190 000 trucks and other heavy freight vehicles in operation. Note that this is an optimistic upper bound of hydrogen demand in road transport, as battery-electric technology may impact this segment.[117]

Current industry plans in preparation for this transition include a partnership between Sasol and Toyota to explore the development of a green hydrogen mobility ecosystem. This would begin with the development of a mobility corridor for hydrogen powered heavy-duty, long-haul fuel-cell trucks along with refuelling infrastructure. One pertinent example is the N3 route between Johannesburg and Durban. Sasol also 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.[118]

It is important to note that the local FCEV industry will be relatively small, with limited job creation potential (projected at just over 1 000 TVET jobs for the fuel cells). A local FCEV industry will also create jobs related to FCEV manufacturing and the running of hydrogen refuelling infrastructure. In addition to heavy-duty long-haul transport, the HSRM also plans to promote the use of FCEVs in long-haul passenger travel (eg, buses, taxis), mining (eg, mining trucks, forklifts), rail, shipping and aviation.[119]

Technical and vocational positions in a hydrogen mobility ecosystem could include roles such as automotive testers and packers, test cell mechanics, heavy duty vehicle test technicians, bus assemblers, fuel-cell and liquid hydrogen safety officers, fuel-cell installation technicians, refuelling technicians and fuel-cell systems managers.[120]

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116 Patel, “South African Industry Demand”.

117 Ahjum et al., “Green Hydrogen and TVET Employment”.

118 Patel, “South African Industry Demand”.

119 DSI, *Hydrogen Society Roadmap*.

120 Patel, “South African Industry Demand”.

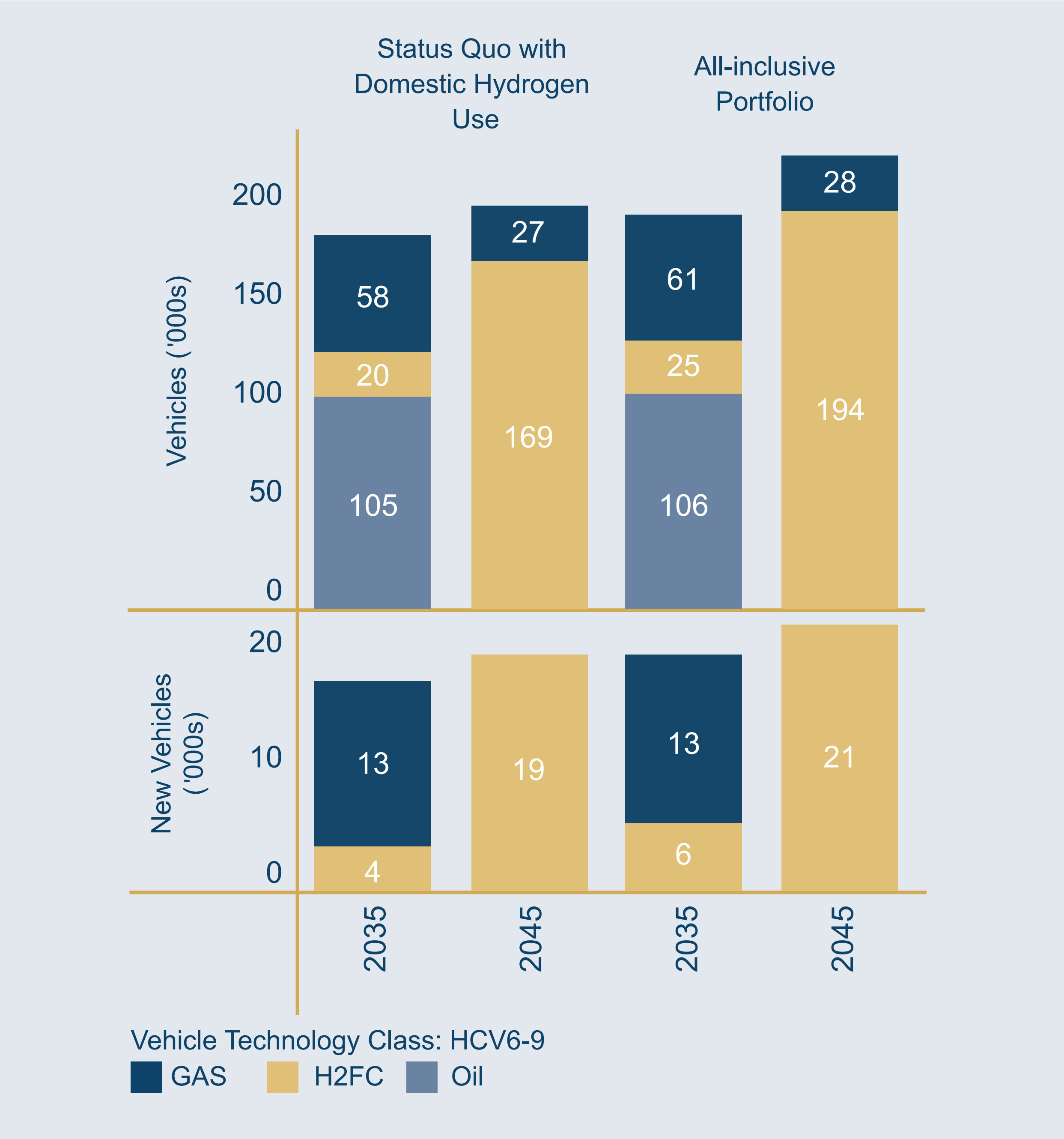

Figure 25 Portfolio of technology options for heavy class vehicles (HCV6-9)

Source: Jules Schers et al., "Green Hydrogen and TVET Skills' Role in South Africa's Just Transition" (Working Paper, SAIIA-UK PACT and University of Cape Town, 2021)

While some of these roles would be new, others may sound familiar. However, even the familiar ones may require new or updated skills. For example, Figure 26 shows how a position with the same title (in this case, mechanical fitter) may differ in the case of ICE vehicle and FCEV manufacturing.

Figure 26 Mechanical fitter: ICE vehicles vs. FCEVs

Source: Compiled by authors (SAIIA)

4.6.4 TVET jobs and skills related to platinum group metals mining

Platinum is one of the key materials used for the electrodes in electrolysers that produce hydrogen, as well as for PEM in fuel cells. A rise in demand for platinum for fuel cells would more than make up for the loss related to phasing out catalytic converters. An optimistic case would see platinum demand increase as much as eight-fold (provided that South Africa maintains its dominance in the sector and that platinum-catalysed PEM remains the preferred technology in fuel cells). A more modest case would still see platinum demand double. This means that the growth in platinum mining jobs would also surpass the losses in coal mining jobs by 2050 in all scenarios.[121]

This will result in an increased demand for TVET skills in PGM mining, especially from 2030 onwards as the sector starts to boom. The skills for this sector are mostly known, although there may be a need to upskill or update curricula in the context of technological changes in the mining sector (eg, related to digital and 4IR technologies and their impact on the sector). Moreover, the platinum sector already has systems for integrated in-house training for TVET graduates.[122]

The demand for skills in the platinum mining sector can be met in part by transitioning workers from other mining sectors that are in decline, including the coal mining sector. This would require some reskilling, although many of the jobs would be similar. There is also potential to build on the existing in-house training programmes to help reskill these workers. However, there is a mismatch in timing: the coal sector will decline before the platinum sector booms. An alternative strategy is therefore required for the coal mining sector between 2022 and 2030.[123]

What about the coal miners?

To ensure a just transition for workers in the coal mining industry, it may be necessary to consider industries that require skill sets that are a bit more distant, but which nevertheless require strong mechanical, teamwork and logistics skills. For example, lower-skilled workers from the coal mining industry could be deployed to the construction, operation and maintenance environments in other sectors. There is also room for general upskilling and reskilling in digital literacy and mathematics. Specifically, and related to the broader hydrogen economy, there may be potential to reskill and upskill former coal mining employees not only for the platinum mining sector but also

121 Schers et al., "Green Hydrogen and TVET Skills".
122 Schers et al., "Green Hydrogen and TVET Skills".
123 Schers et al., "Green Hydrogen and TVET Skills".

for jobs in renewable energy generation[124] and iron mining for a growing green steel sector.[125] This would require a more detailed study of the requirements for upskilling and reskilling, as well as a careful analysis of the age profiles of these labour forces, and workers' willingness to move.[126]

4.6.5 TVET jobs and skills related to green iron and steel

Green hydrogen offers the potential for greening hard-to-abate industries such as steel production. Currently, steel production in South Africa uses coal-fired power as an input and coking coal for the reduction of iron ore. Greening the industry would require replacing coal-fired inputs with renewables, and replacing the use of coking coal. Using green hydrogen for the reduction of iron ore is the most promising technology on that front. In order to green the full chain, it is important to consider green iron ore mining by replacing energy inputs with renewables, mining vehicles with green alternatives (eg, hydrogen fuel cell or electric), and transport with green freight (eg, rail or fuel-cell trucks).

In 2019, the basic iron and steel sector employed just over 29 000 people (down from just under 45 000 in 2010),[127] of whom an estimated 2.9% (or 844 in 2019) were at the TVET level. An expanded view of the metals sector that includes basic iron and steel as well as precious and non-ferrous metals, casting of metals, structural and fabricated metal products and metalwork service activities added up to just under 152 000 jobs in 2019 (of which around 4 400 were TVET ones if the same ratio of 2.9% is applied).

Modelling shows significant job creation potential for an export-oriented green iron and steel sector. By 2050, this industry could be responsible for as many as 918 000 jobs, of which 26 600 would be TVET-related. This is also one of the first sectors that could benefit from growth in the global GHE, resulting in around 6 500 TVET jobs by as early as 2030 (up from about 3 900 today), 11 800 by 2035 and 16 900 by 2040.[128] Another reason for fast-tracking the development of this sector is the fact that the next industry refurbishment cycle is in 2030, so plans need to be in place by then.[129]

Should South Africa actively develop this sector (see additional considerations below), there may be some potential to reskill and upskill workers from coal mining to growth industries such as iron mining and green steel production. This would, however, require

124 Note plans to locate REDZ in areas where coal and gold mining is in decline, including Emalahleni in Mpumalanga. See, for example, Creamer, "Renewables Sector's Just Transition".

125 For example, iron ore deposits are located 400 to 600km away from the coal fields in Mpumalanga.

126 Schers et al., "Green Hydrogen and TVET Skills".

127 DTIC, *The South African Steel and Metal Fabrication Master Plan 1.0*.

128 Schers et al., "Green Hydrogen and TVET Skills".

129 Bambili Advisory, "The South African Hydrogen Economy"."

more detailed study, including the upskilling or reskilling requirements, the profiles of these labour forces, and workers' willingness to move.[130] Whereas there may be some overlap in the skills required for coal and iron mining, South Africa's iron and coal fields are far from each other. When it comes to green steel production, the skills required include hydrogen production and the handling of smelting metals – something that would likely first absorb existing workers in steel production. However, if the industry were to grow as projected, there would soon be a need for additional workers. These additional positions could be filled either by workers transitioned from elsewhere or by new entrants to the workforce.

Growing South Africa's green steel sector would involve engaging players such as ArcelorMittal.[131] ArcelorMittal South Africa accounts for at least 75% of domestic steel production in the country and 100% of the virgin iron ore production, with operations that use iron ore and blast furnace technology (the coal-based technology to be replaced by green hydrogen) located near Johannesburg, Vanderbijlpark and Newcastle. The global parent company, ArcelorMittal, has new plans for green steel projects using green hydrogen. These are all based in Europe, likely influenced by climate commitments in the EU. The company is also present in emerging markets, but has so far not stated any explicit plans for green steel production using green hydrogen in these locations.[132] A few smaller manufacturers use scrap metals and electric arc furnace technology. In a development that is indicative of difficulties in the sector, the only other player that used iron ore and blast furnace technology – Evraz Highveld Steel and Vanadium – has wound down operations following business rescue.[133] ArcelorMittal South Africa is using its facilities to process the steel from Vanderbijlpark.

Globally, there has been an oversupply of steel, with only the lowest-cost producers (eg, Russia and formerly Ukraine) breaking even on exports over the steel cycle. South Africa has also been at a significant cost disadvantage on several fronts, including coking coal inputs, logistics, labour and capital. For example, coking coal contributes 27% to the cost of steel production. South Africa imports 50% of the supply from Australia. In terms of logistics, South Africa is at a geographic disadvantage in both rail (for inland transport from iron mines in the Northern Cape to steel producers and then to port) and shipping (it is far from most markets, apart from regional ones).[134] Some of these dynamics may change – for example, the current process based on coal and

130 Schers et al., "Green Hydrogen and TVET Skills".

131 Hilton Trollip, Bryce McCall and Chris Bataille, "How Green Primary Iron Production in South Africa Could Help Global Decarbonization", *Climate Policy* 22, no. 2 (2022): 236–247.

132 See, for example, LeadIt, "Green Steel Tracker", https://www.industrytransition.org/green-steel-tracker/.

133 See: Evraz Highveld Steel and Vanadium Limited. http://www.evrazhighveld.co.za/.

134 Kumba Iron Ore, The South African Iron and Steel Value Chain (Centurion: AngloAmerican, 2011).

coking coal may be replaced with the process based on hydrogen reduction. There may also be opportunities in the region or further afield in specific subsectors. This all needs to be weighed carefully and considered in the context of the South African Steel and Metal Fabrication Master Plan,[135] together with the significant job creation potential. The master plan does mention that by 2050 the industry should be 'green' – an inclusion that supports the general trend towards greening the industry – and even notes that the hydrogen economy looks favourable for this.

4.6.6 TVET jobs and skills related to renewable energy

For hydrogen to be classified as green, the energy inputs need to be clean or renewable. Growth in the GHE would therefore require an expansion of green energy production – specifically wind and PV solar – in South Africa. The energy requirements for different GHE options, as well as the employment implications, are summarised in Figures 27 and 28. As would be expected, the additional energy requirements and the employment impacts are largest in the All-inclusive Portfolio scenario.

As mentioned previously, there is an opportunity to transition workers from the coal mining and coal-fired power sectors to the renewable energy sector. Whereas coal-fired energy relies on a more centralised model, renewable energy is decentralised, providing potential for democratisation of energy at the community level and securing livelihoods through selling electricity onto the grid. There are already plans to locate REDZs in coal and gold mining areas that are in decline (eg, Emalahleni in Mpumalanga), to assist with a just transition.[136] Transitioning workers from coal mining or coal-fired power generation to renewables will require reskilling and upskilling.

Specialised skills required in the renewable energy sector include ones related to solar and wind component manufacture and distribution, project development, construction and installation, and operation and maintenance. Cross-cutting skills include ones related to occupational health and safety, quality assurance, and certification and compliance. In addition, most jobs in these fields require social and soft skills (eg, teamwork, conflict management, problem solving, communication and diplomacy), digital skills (eg, related to equipment and systems control) and baseline STEM skills in engineering and/or technology.[137] For more details on skills and jobs related to renewable energy, see GreenCape's assessment of local skills for the South African renewable energy value chain.[138]

135 DTIC, *The South African Steel and Metal Fabrication Master Plan 1.0*.

136 Creamer, "Renewables Sector's Just Transition".

137 Bambili Advisory, "The South African Hydrogen Economy".

138 GreenCape, *Assessment of Local Skills*.

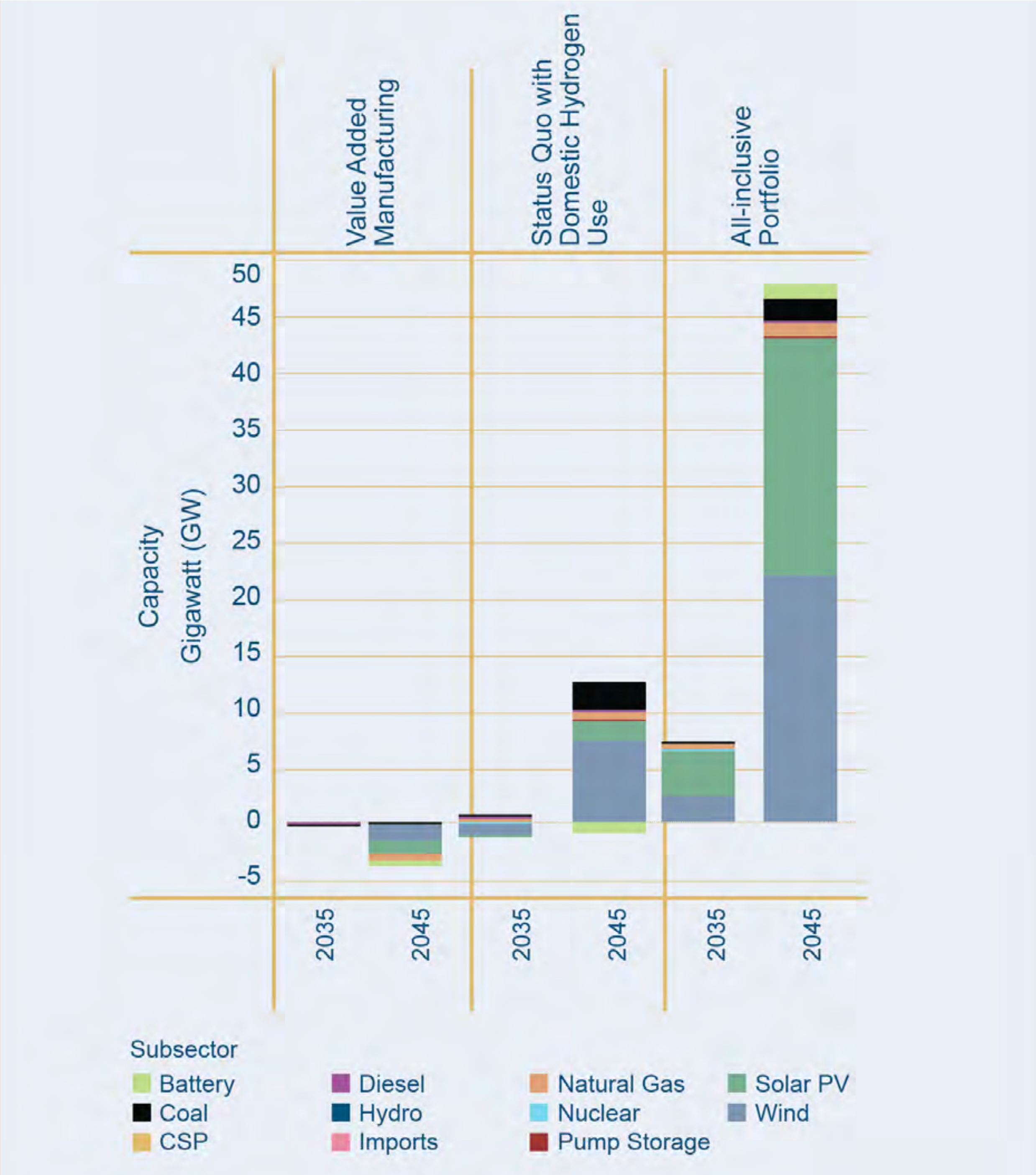

Figure 27 Power sector capacity requirements for different green hydrogen economy options

Source: Fadiel Ahjum et al., "Green Hydrogen and TVET Employment Prospects: An Assessment in a Context of Ambitious Decarbonisation for South Africa Towards 2050" (Working Paper, SAIIA-UK PACT and University of Cape Town, 2021)

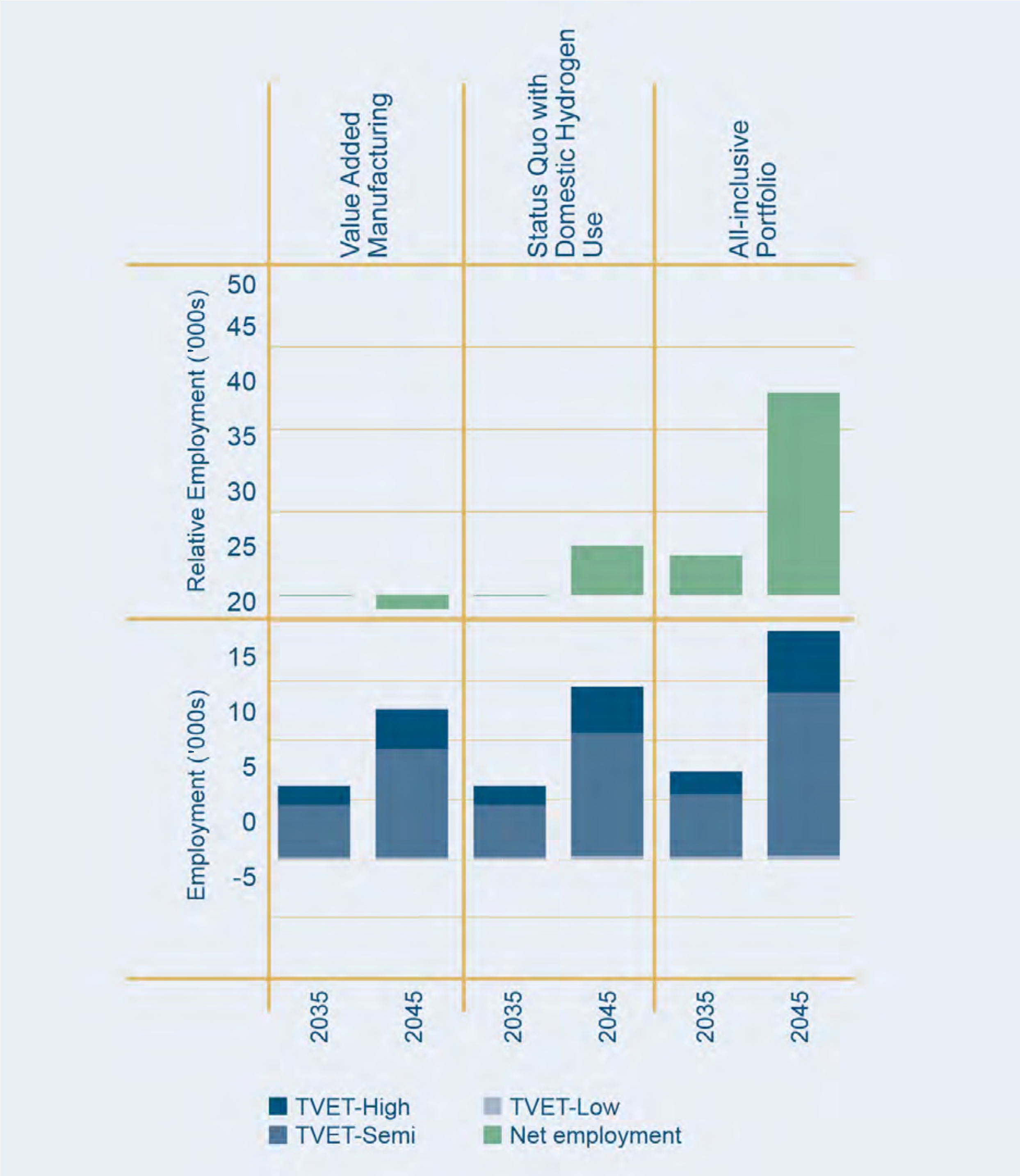

Figure 28 TVET employment in the power sector for different green hydrogen economy options

Source: Fadiel Ahjum et al., "Green Hydrogen and TVET Employment Prospects: An Assessment in a Context of Ambitious Decarbonisation for South Africa Towards 2050" (Working Paper, SAIIA-UK PACT and University of Cape Town, 2021)

SECTION C

POLICY RECOMMENDATIONS AND STRATEGIC ACTIONS FRAMEWORK

Image credit: Department of Science and Innovation, Pretoria: Group of TVET graduates trained in operations and maintenance of stationary hydrogen fuel cells at 1 Military Hospital in cooperation with the Department of Defence and Bambili Energy

5 Policy recommendations

This section details strategic actions and policy recommendations for a range of identified domestic stakeholders, with the aim of producing innovative and anticipatory responses to the changing role of TVET in the South African GHE. The recommendations are aligned with the vision, objectives, outcomes and levers of change detailed in the Theory of Change for the Green Hydrogen TVET skills transition section of this report. They also seek to cultivate the 'seeds' or 'pockets of the future' described through the Three Horizons framework, to a desired, demand-led TVET ecosystem.

The 11 identified target stakeholders for policy recommendations and strategic actions are (1) the Presidency; (2) the Treasury; (3) DHET; (4) DSI; (5) DTIC; (6) DMR; (7) TVET management and educators; (8) energy and water SETAs; and (9) private sector industry; (10) trade unions and trade union federations; and (11) civil society organisations.

The recommendations are categorised according to three implementation timelines: (1) short term (2022–2025); (2) medium term (2026–2036); and (3) long term (2037–2050). The medium-term timeframe (2026–2036), in particular, is identified as a key window. Significant disruption is expected in this timeframe, as several industrial players have indicated a commitment to supplement fossil-fuel-based production with green hydrogen in the next five to 10 years. This timeframe is, therefore, pivotal in positioning the South African economy and skills ecosystem to take full advantage of the benefits that could accrue from green hydrogen production and related manufacturing value chains.

Table 20 Theory of Change for the green hydrogen TVET Skills Just Transition components in relation to policy and strategic action recommendations

Vision	A just and inclusive green hydrogen TVET ecosystem that cultivates a transversal skills commons, and fosters economic wellbeing and ecological resilience by 2050						
Objectives	Just transition	Reduced GHG emissions	Transversal skills commons	Skills development investment	Reduced inequality and poverty	Improved balance of TVET college payments	Improved skills governance
Outcomes	Transformative quality and relevant training and education	Fostering socio-ecological systems resilience	Inclusive economic wellbeing	Excellent physical and technological infrastructure	Effective partnerships for enhanced social mobility	Adequate and sustained TVET financing	Institutionalised anticipatory governance
Levers of change	Local and international demand for green skills (including GH_2 skills) and pre-emptive domestic energy policy	Compliance and regulation	Enabling TVET infrastructure and policy supports GH_2 skills development	Skills competitiveness, innovation culture and skilled workforce	Attractive career development & skills investment environment	Corporate targets for green skills development through CoS	International commitments for peer learning and VET exchange programmes
Outputs	Labour market development/ skills development business cases	Favourable and integrated policy, fiscal measures, and regulatory environment	Financial framework that provides access to demand-led skills development	Gender equality in skills development drawing on socially excluded communities	National and international partnerships	Demonstration of CoS pilot projects, including industrial clusters	Research, development and innovation toward a transversal skills commons

Source: Compiled by authors (SAIIA)

GESI

Gender equality and social inclusion are central to, prioritised and integrated throughout the policy recommendations. Owing to the complex nature of reversing the ever-increasing trends of gender inequality and social exclusion of marginalised communities in South Africa, a multi-faceted approach is recommended to promote the GHE TVET Skills Just Transition.

- ### Nano/micro education for broader social inclusion

Systemic changes to educational outcomes considering gender equality and social inclusion include creating nano/micro education model to complement the current fixed three-year curricula. A modular approach to skills development enables flexible forms of PSET provisioning by stacking customisable qualifications beyond selected categories and can result in the achievement of a qualification over time. It allows for more flexible responses to skills demands in the labour market, given the extent of time involved in development of new qualifications. It should, however, be built on a sound base of knowledge progression which ties modules to learning pathways. This approach supports post-disciplinary education, with the primary focus being on education platform ecosystems building meaningful and demand-led skills capabilities. Students, especially economically marginalised groups, have flexibility to create a collection of shorter courses towards a qualification, while still being able to access the traditional learning pathway framework to build core knowledge. This may alleviate demands of upfront tuition costs and dedicated study time, allowing greater accessibility while still responding to a rapidly changing industrial and skills environment and increasing employability. It also allows workers to upskill and/or reskill themselves while remaining in employment, provided there is adequate support for the learning pathway decision-making, especially within the context of severe education disadvantage.

- **Digitalisation for increased accessibility**

The proposed digitisation of the TVET college system curricula increases accessibility beyond the brick-and-mortar facilities owing to the adoption of digital tools such as augmented reality (AR) and virtual reality (VR). These education toolkits mimic in-person learning and doing-by-hand and are built on open-source digital infrastructure, creating an augmented experiential education system (education metaverse). This Virtual Learning Environment system enables a new era of distance-learning tools with computer-generated simulations integrating the real world (AR) or that are entirely self-contained (VR). All students (including those negatively affected by gender equality and social inclusion dimensions) benefit from setting their pace of learning as they access the education metaverse through AR and VR tools. Geographical location is no longer a barrier, because all students access the same digital classroom remotely (the upstream activities to produce green energy are ideally suited to rural and peri-urban areas, creating the demand for green skills in those areas). AR and VR tools also surpass language barriers, as students can learn in their mother tongue, while AR is particularly accessible via mobile phone. Digitisation thereby offers a means to eliminate barriers to entry, decentralise skills (in line with supply/production), offer ‘on-demand’ education, and attract more students to TVET institutions, often via mobile phone. However, the COVID-19 pandemic has shown that unless strong cultures of digital praxis are already in place, an over-dependence on digital learning approaches serves to widen the digital divide rather than narrow it. Therefore, an integrated approach with both gradual digital praxis and contextualised, physical learning is recommended.

- **Strengthening skills–employment linkages for women in the GHE**

While female participation and qualification rates within the South African TVET ecosystem are high, women (particularly racially marginalised women) still face exclusion from the labour market, with current and historically lower rates of employment. Social mobility within employment is also lower for women than for men, with management and decision-making opportunities remaining elusive. There is therefore a need to foster collaboration between government stakeholders and private industry to strengthen the linkage between skills and employment for marginalised women towards goals of broader social inclusion. Examples are targeted skills building programmes and industry-based apprenticeships to encourage equal access to promotions, management and leadership roles.

- **Support for re-orientation of TVET skills ecosystem**

Given the current constraints and low base from which the TVET college system is emerging (eg, low throughput figures) provision for adequate support for the re-orientation of the TVET skills ecosystem to meet the needs of the GHE is critical. This may be achieved through course (re)design for transformative learning and changed praxis, both in content and structure. In particular, considerations for course (re)design must be aimed at providing support for technology enhanced learning as well as building communities of practice along the skills value chain in the GHE.

Monitoring and Evaluation

The monitoring and evaluation of implemented policy and strategic actions will be critical to ensuring the achievement of intended objectives, outcomes and GESI towards the fulfilment of the broader vision. Guiding questions to consider are:

- Is the policy or action being implemented as intended?
- What can be improved?
- Are objectives and outcomes on track to be delivered?
- Which groups in society are impacted by the policy or action?

Table 21 Strategic actions and recommendations towards a just transition

Objective: Just transition			
Outcome: Transformative, quality, and relevant training and education systems for enhanced mobility			
Action	**Champion**	**Supporting entities**	**Monitoring progress**
Short term 2022–2025			
Develop a clear 'Green Skills Masterplan' for the GHE which articulates detail of the re-skilling, up-skilling and new skills occupational demands/or workstreams to guide short-term, medium-term and longer-term skills planning and alignment with the GHE TVET Just Transitions Strategy (this document), the Hydrogen Society Roadmap for South Africa, NDP and SDGs. Proactively integrate this into skills system planning instruments and tools (eg, OFO, TVET curriculum guidelines and funding formulas, NSF programme planning etc.)	DHET	DSI, DTIC, private sector industry, SETAs, TVET management, trade unions and trade union federations, civil society organizations	• Development and implementation of Green Skills Masterplan for the GHE and HSRM • Policy and regulatory framework developed
Implement selection criteria for TVET colleges to participate in green specialisation programmes	DHET	DTIC, DSI, private sector industry, SETAs, TVET management, trade unions and trade union federations, civil society organisations	• Increase in number of TVET green specialisation programmes
Adapt the OFO to include green skills (re-skilling and new skills) required for the Just Transition (GHE and RE)	DHET	DTIC, DSI, private sector industry, SETAs, TVET management, trade unions and trade union federations	• Development and implementation of revised OFO framework
Develop a multi-stakeholder visioning document reflecting a shift from a narrow focus on education for jobs towards a systemic understanding and broader framing of economic wellbeing in policy to reimagine the TVET's role and operating mechanisms (eg, via communities of practice/skills ecosystem models along the skills value chain (low, medium, high) and along the GHE Valley in alignment to the UNESCO-SADC Higher Education and TVET Strategic Framework	DHET	DSI, DTIC, SETAs, TVET management, trade unions and trade union federations, civil society organisations	• Development of multi-stakeholder visioning document on education for economic wellbeing and re-imaging TVET ecosystem to be aligned to UNESCO-SADC Higher Education and TVET Strategic Framework

Develop and implement TVET teacher training programmes pro-actively (with sufficient time for substantive re-training) based on industry and workplace training for mentors to ensure fit-for-purpose accredited training over a set period of time, to ensure teaching materials remain up to date with changes in technological advances Involve Higher Skills sector partners where relevant	SETAs	DHET, DTIC, DSI, private sector industry, TVET management, private sector, trade unions and trade union federations, civil society organisations	• Development of TVET teacher training programmes and implementation
Enhance career and programme guidance for TVET students to ensure direction of study aligns with current and future demand for industry employment and an understanding of the just transitions emerging	DHET	DHET, DTIC, DSI, private sector industry, TVET management, trade unions and trade union federations, civil society organisations	• Revised TVET career and programme guidance framework
Design and implement new pathways for apprentice training oriented towards the GHE with clear learning pathways and diversified modalities for achievement of the learning pathways	SETAs	DHET, DTIC, DSI, private sector industry, TVET management, trade unions and trade union federations, civil society organisations	• Increase in number of apprentice training pathways and participants
Design and implement intermediate technical skills interventions, aligned to emerging OFO requirements and new learning pathways to build a pipeline of skills for emerging industries.	DHET	Industry, TVET Management, SETAs	• Implementation of intermediate technical skills interventions
Medium term 2026–2036			
Develop and implement a framework for reskilling and upskilling to preserve jobs in sectors affected by the energy transition with clear communication tools and orientation programmes for affected workers	DHET	DSI, DTIC, private sector industry, SETAs, TVET management, academia, civil society organisations, Presidency, trade unions and trade union federations	• Development and implementation of upskilling/reskilling framework • Increase in number of diversified sector orientated communication tools and orientation programmes

Develop and implement novel skills training programmes on digital, soft, STEM, climate change and GH_2 skills that help to strengthen transformative learning capability	DHET	DSI, DTIC, private sector industry, SETAs, TVET management, academia	• Development of novel and transversal skills training programmes • Increased number of TVET programmes and graduates incorporated in curricula with digital, soft, STEM, climate change and GH_2 skills
Implement comprehensive monitoring and evaluation of green specialisation programmes to ensure they are fit for purpose	DHET	DSI, DTIC, private sector industry, SETAs, TVET management, academia	• Revising and updating monitoring and evaluation framework and processes for green specialisation programmes
Harmonise the South African TVET Ecosystem Strategic Framework with regional education and training approaches to ensure alignment between national and regional skills and training objectives and strategies such as the UNESCO-SADC Higher Education and TVET Strategic Framework	DHET	DTIC, SETAs, TVET management	• Undertaking of harmonisation/alignment analysis of South African TVET Ecosystem Strategic Framework and relevant regional strategies
Long term 2037–2050			
Design and implement nano/micro credentialing systems for CoS or TVET ecosystemTVET ecosystem to enable stacking of credentials and for broader social inclusion within clear learning pathways that lead to meaningful career opportunities	DHET	DSI, DTIC, private sector industry, SETAs, TVET management, academia	• Development and implementation of alternative, nano/micro credentialing system
Design and implement translocal digital tools such as AR and VR for the TVET learning context where relevant, and consider other modalities that complement these learning approaches, in order to cater for diverse learning approaches and needs	DHET	DSI, DTIC, private sector industry, SETAs, TVET management, academia, private sector	• Increased use of translocal digital TVET learning tools
Design and implement a well-articulated, flexible, shared credentialing (“jukebox”) education model (whereby courses can be selected and taken across collaborative institutions [CoS] with the same credentialing) as a means to eliminate barriers to entry, decentralise skills (in line with supply/production), offer ‘on-demand’ education and attract more students to TVET institutions	DHET	DSI, DTIC, private sector industry, SETAs, TVET management, academia, labour unions and labour union federations, civil society organisations	• Development and implementation of alternative, shared credentialing (jukebox) model

Source: Compiled by authors (SAIIA)

Table 22 Strategic actions and recommendations toward reduced GHG emissions

Objective: Reduced GHG emissions			
Outcome: Fostering socio-ecological systems resilience			
Action	**Champion**	**Supporting entities**	**Monitoring Progress**
Medium term 2026–2036			
Collaborate with technical experts and the high skills TVET sector to develop training content aimed at a green energy transition	DHET	DSI, DTIC, private sector industry, SETAs, TVET management, trade unions and trade union federations	• Establishment of industry-TVET curriculum collaboration platforms
Design and implement industrial policy measures stimulating the GH_2 market in South Africa and create demand for infrastructure and technicians/artisans	Presidency	DSI, DHET, DTIC, private sector industry, trade unions and trade union federations, civil society organisations	• Development and implementation of policy measures to stimulate domestic GH_2 market • Lowered GHG emissions to 112 Mt CO_2-eq.
Long term 2037–2050			
Grow industry GH_2 skills demand and increase job absorption rate in line with the Hydrogen Society Roadmap and the National Development Plan 2030	DTIC	DSI, DHET, private sector industry, SETAs, Presidency, trade unions and trade union federations	• Increased TVET-industry job absorption rate • Lowered GHG emissions to 70 Mt CO2-eq.

Source: Compiled by authors (SAIIA)

Table 23 Strategic actions and recommendations for transversal skills commons

Objective: Transversal skills commons			
Outcome: Inclusive, economic wellbeing			
Action	**Champion**	**Supporting entities**	**Monitoring Progress**
Short term 2022–2025			
Articulate and brand TVET colleges as central to a just transition in South Africa	DHET	DTIC, SETAs, TVET management, civil society organisations, Presidency, trade unions and trade union federations	• Development of relevant communication plan and products
Update the Integrated Resource Plan (2019) to reflect the changing economics of GH_2 production; subsequent iterations of the IRP should be developed and aligned with the SAREM in order to coordinate investments into renewables capacity and GH_2	DMRE*	DHET, DTIC, DSI, private sector industry	• Revised Integrated Resource Plan with incorporation of GH_2 opportunities and alignment with SAREM
Establish an overarching body to coordinate relevant stakeholders in the quadruple helix around the H_2 economy, ensuring a smooth and just transition	Presidency	DSI, DHET, DTIC, DMRE, TVET management, SETAs, academia, civil society organisations, industry	• Establishment of overarching, multi-stakeholder coordinating body
Medium term 2026–2036			
Design and implement CoS orientated incentives consisting of capital grants and low interest/concessional loans in order to reduce the up-front costs of investment into the manufacturing of electrolysers and fuel-cell and H_2 production	DTIC	Presidency, Treasury, DSI, private sector industry	• Development and implementation of policy/incentives framework • Increased number of GH_2 CoS grants and incentives in place
Finalise the SAREM to ensure harmony between renewables generation and the potential for beneficiation through power-to-X technologies used to produce GH_2 and ammonia	DTIC	DMRE, DSI, private sector industry	• Finalisation of SAREM with incorporation of GH_2 opportunities
Provide further support and traction to GH_2 production through exemptions on electricity taxes and/or redirecting fossil fuel subsidies towards GH_2 production	DMRE	DTIC, Treasury, private sector industry	• Increase in domestic GH_2 production and related SMME's • Increase in GH_2 supportive subsidies • Decrease in fossil fuel subsidies

Design export promotion incentives in order to support the growing demand for GH_2 internationally and incentivise hydrogen production proximal to key ports such as Saldanha Bay, Durban, Boegoebaai, Richards Bay and Coega	Presidency	DSI, DHET, DMRE, DTIC, private sector industry, civil society organisations	• Implementation of an export-orientated policy/incentives framework • Number of export incentives in place
Long term 2037–2050			
Utilise CoS to elevate the TVET college status and perception, thereby making it an attractive option for higher education for new entrants and working adults	DHET	DSI, DTIC, industry, SETAs, TVET management, academia, civil society organisations, Presidency, trade unions and trade union federations	• Increased TVET enrolment figures • Increased TVET job absorption rate • Increased apprenticeships/work-based learning students/graduates at SMMEs and large corporations

Note: DMRE = Department of Mineral Resources and Energy

Source: Compiled by authors (SAIIA)

Table 24 Strategic actions and recommendations toward skills development investment

Objective: Skills development investment			
Outcome: Excellent physical and technological infrastructure			
Action	**Champion**	**Supporting entities**	**Monitoring Progress**
Short term 2022–2025			
Adjust the CoS model for increased flexibility, allowing qualifying TVET colleges and interested industry partners to partner on selected GH_2-related specialisations in specific locations	DHET	DSI, DTIC, private sector industry, SETAs, TVET management, trade unions and trade union federations, civil society organisations	• Revised CoS framework/model • Increased number of SMMEs accepting adapted CoS model for internships
Implement formal and informal innovation platforms to leverage learner agency	DSI	DHET, DTIC, private sector industry, SETAs, TVET management, civil society organisations	• Establishment of learner-led innovation platform
Create dialogue platforms for ongoing feedback from industry towards TVET curricula development or SETA conduit	DHET	DSI, DTIC, private sector industry, SETAs, TVET management, trade unions and trade union federations	• Establishment of dialogue platforms • Increase in job absorption rate of TVET graduates
TVET colleges to optimise process efficiencies across the value chain	SETAs	DHET, private sector industry, SETA	• Increased TVET enrolment and throughput rates
Establish, optimise and scale CoS for greater alignment of college supply and workplace demand, creating pathways for apprentice training, ideally located proximal to the planned H_2 hubs in Cape Town, Johannesburg, Durban and Limpopo	DHET	DSI, DTIC, private sector industry, SETAs, TVET management, trade unions and trade union federations DSI, DTIC, private sector industry, SETAs, TVET management, trade unions and trade union federations	• Increased job absorption rate of TVET graduates proximal to planned H_2 hubs
Investigate feasibility and implementation of available digitisation tools (3D labs) to enable increased access and mitigate physical limitations	DHET	DSI, DTIC, private sector industry, SETAs, TVET management, academia, civil society organisations	• Completion of TVET digitisation feasibility study
Enable collaborative planning (through a working group) across the GH_2 value chain to map South Africa's (green) skills supply in relation to current and future demand	DHET & SETAs	DSI, DHET, DTIC, private sector industry, academia, civil society organisations, Presidency, trade unions and trade union federations	• Establishment of GH_2 working group on skills anticipation and skills foresight

Source: Compiled by authors (SAIIA)

Table 25 Strategic actions and recommendations toward reduced inequality and poverty

Objective: Reduced inequality and poverty			
Outcome: Effective partnerships			
Action	**Champion**	**Supporting entities**	**Monitoring Progress**
Short term 2022–2025			
Establish Occupational Team Convenors (OTCs) to promote employer participation by redefining partnerships to increase TVET-industry alignment and employment absorption rate	DHET	DTIC, private sector industry, SETAs, TVET management, trade unions and trade union federations, civil society organisations	• Increased number of TVET-industry apprenticeships • Increased job absorption rate for TVET graduates • Increased apprenticeships/work-based learning students/graduates at SMMEs and large corporations
Empower SETAs (combined with industry associations and subject matter experts) to assess and re-orient their respective sectors in terms of the GH_2 opportunities available within the sector	DHET	DSI, DTIC, private sector industry, SETAs, trade unions and trade union federations, civil society organisations	• Industry awareness of relevant SETA policies and incentives for GH_2 • Increased number of GH_2 related SMMEs (particularly women and youth-led)
Develop a communication plan to promote public awareness, community engagement and readiness of H_2 energy sources across all sectors	DSI	DHET, DTIC, DMRE, private sector industry, academia, civil society organisations, Presidency	• Developed communication plan • Industry awareness of relevant policies and incentives for GH2 • Increased number of GH_2 related SMMEs (particularly women and youth-led)
Strengthen skills-employment linkages to ensure higher absorption of women in the GHE labour market (to match high TVET throughput rates of women) through increased collaboration and targeted skills-building programmes and industry-based apprenticeships	SETAs, industry	DHET, DTIC, private sector industry, TVET management, trade unions and trade union federations, civil society organisations	• Increased job absorption rate for TVET women from historically vulnerable backgrounds • Number of women-led SMMEs involved

Medium term 2026–2036			
Provide support to SMEs to become “lead employers’ and “host employers’ to optimise CoS workplace training opportunities	DTIC	DHET, private sector industry, SETAs, trade unions and trade union federations	• Increased number of TVET-industry apprenticeships
Long term 2037–2050			
Leverage the demographic dividend by establishing international partnerships to scale up training required for the GH_2 export economy	Presidency	DSI, DHET, DTIC, TVET management, SETAs, academia, civil society organisations, private sector industry, trade unions and trade union federations	• Number of international commitments, potential partners and investors engaged • International market demand for South African GH_2 production

Source: Compiled by authors (SAIIA)

Table 26 Strategic actions and recommendations towards an improved balance of TVET college payments

Objective: Improved balance of TVET college payments			
Outcome: Adequate and sustained financing			
Action	**Champion**	**Supporting entities**	**Monitoring Progress**
Short term 2022–2025			
Revise national TVET budget allocation to achieve the desired outcomes	Treasury	Presidency, DHET, TVET management, SETAs	• Year-on-year increase in national annual funding allocation towards TVET ecosystem • Increased number of regional commitments, potential partners and investors engaged
Ensure that the TVET ecosystem commits and allocates an adequate budget to state-of-the-art training equipment, so the physical and technological infrastructure is conducive to training fit-for-purpose and up-to-date graduates	DHET	DSI, DTIC, private sector industry, SETAs, TVET management, private sector	• Year-on-year increase in TVET college ecosystem spending on physical, technological infrastructure and intellectual property
Medium term 2026–2036			
Integrate GH_2 specialisation programme into college funding norms	DHET	DSI, DTIC, private sector industry, SETAs, TVET management	• Increase in national annual funding allocation towards GH2 specialisation programme
Long term 2037–2050			
Innovate funding model of TVET education to secure multiple, transparent and adequate funding streams	DHET	DSI, DTIC, private sector industry, SETAs, TVET management, academia, civil society organisations, Presidency, Treasury	• The establishment of novel funding streams towards the TVET ecosystem • Increased number of regional and international commitments, potential partners and investors engaged

Source: Compiled by authors (SAIIA)

Table 27 Strategic actions and recommendations towards improved skills governance

Objective: Improved skills governance			
Outcome: Institutionalised anticipatory governance			
Action	**Champion**	**Supporting entities**	**Monitoring Progress**
Short term 2022–2025			
Improve TVET-learner-industry feedback loops through networks, learning loops and incentives	SETAs	DHET, DTIC, DSI, private sector industry, TVET management, trade unions and trade union federations, civil society organisations	• Increased job absorption rate for TVET graduates • Increased number of TVET-industry apprenticeship placements
Create an H2 industry body to regulate quality standards of the CoS and ensure apprenticeship placements through rigorous selection and matching processes	Industry	DHET, DSI, DTIC, SETAs, TVET management, trade unions and trade union federations, civil society organisations	• Increased number of TVET-industry apprenticeship placements • Established industry CoS regulatory body to ensure quality standards and apprenticeship placements
Implement data collection, reporting and tracking tools	TVET management	DHET, private sector industry, SETAs, trade unions and trade union federations, civil society organisations	• State-of-the-art skills matching and tracking methods • Increased and improved skills matching and tracking
Implement regulation and internal controls to manage the educational outcomes of OTCs in alignment with UNESCO-UNEVOC and Cedefop best practice	TVET management	DHET, private sector industry, SETAs	• State-of-the-art skills matching and tracking methods • Increased and improved skills matching and tracking • Adopted skills governance framework in alignment with UNESCO-UNEVOC and Cedefop best practice
Create a marketing and advocacy plan for GH2 use in the electricity sector (main and micro-grid)	DMRE	DSI, private sector industry, civil society organisations, trade unions and trade union federations, civil society organisations	• Adopted marketing and advocacy plan • Increased GH2 uptake in the electricity sector

Develop departmental skills foresight capabilities to improve anticipatory skills governance and proactive policy planning, for example, through collaboration with the Centre for Public Sector Innovation (CPSI), to ensure the development of the policies and regulations for skills anticipation and matching (competencies and qualifications) in the future GHE	All	All	• Developed departmental skills foresight and skills anticipation capabilities • Increased number of departmental capabilities to conduct foresight-informed policy planning • CPSI established departmental anticipatory governance implementation programmes • Increased capabilities in skills matching
Medium term 2026–2036			
Develop GHE-oriented skills foresight programmes and pilot projects	DHET	DSI, DHET, DTIC, private sector industry, trade unions and trade union federations, civil society organisations	• Established skills foresight programmes and pilot projects
Shift college culture and manage skills supply towards anticipatory and demand-led delivery ecosystem	TVET management	DSI, DTIC, private sector industry, SETAs, academia, civil society organisations, trade unions and trade union federations, civil society organisations	• Increased enrolment and job absorption rate for TVET graduates • State-of-the-art skills governance • Anticipatory and demand-led TVET ecosystem • Improved economic wellbeing

Source: Compiled by authors (SAIIA)

6 Conclusion

A just transition towards a green hydrogen TVET skills ecosystem that enables a transversal skills commons, and foster economic wellbeing and ecological resilience by 2050 is achievable. The current juncture requires South Africans to re-envision knowledge and reimagine the purposes of education and the organisation of learning, particularly in providing quality post-school education and training. The desired futures for the TVET skills transition also present opportunities to embrace digitally enhanced sustainable development within the post-schooling institutions' core functions and build societal capacity for transformative change.

The aim is for marginalised communities to have the autonomy, capacity, resources and skills to become architects of their destinies, while at the same time supporting social cohesion and individual well-being. These attributes are critical to ensuring beneficial planetary, human and economic outcomes. Education and skills development institutions are ideally suited to do the required social knitting to create more robust and more resilient communities, by providing support and mitigating and removing barriers that prevent individuals from living active and connected lives.

Funder

Research consortium partners

Key stakeholders and primary beneficiaries represented on steering committee

Appendix A: Research approach and methodology

This report constitutes a synthesis of seven research outputs (see Figure 1) produced throughout the project lifespan, with the aim to consider opportunities, leverage points and risks relating to the South African TVET ecosystem, rooted in a systems innovation approach. A systems innovation approach is by its very nature radical, as it directly influences both the architecture of a system and its component parts. The Organisation for Economic Co-operation and Development notes it is 'a horizontal policy approach that mobilises technology, market mechanisms, regulations and social innovations to solve complex societal problems in a set of interacting and interdependent components that form a whole "socio-technical system'.[139] For this reason is it also deeply political, as it tackles head-on path dependency, institutional inertia, market power, accepted technological trajectories and political power.

This approach requires government to be entrepreneurial and innovative, but also recognises that government cannot manage such complex transitions on its own. Hence, apart from sound political leadership, a systems innovation approach needs to be inclusive and framed within a common, long-term societal vision over a 20- to 30-year time-horizon. This requires a very specific type of governance that achieves broad-based cultural acceptance and legitimacy as the rationale and benefits of the choices are continuously made clear to society. While business is a key driver of innovation, especially to support greater efficiencies, the way in which technology choices is exercised is central to systems innovation.

This was one of the key dilemmas facing the authors in proposing a roadmap and policy path(s) going forward. Favouring one system's innovation over the other implies very specific skills attributes in society and infrastructure decisions with broad and far-reaching implications for the types of technologies that the region should seek to adopt. These are expensive choices with significant long-term implications, because of their high sunk costs and the recognition that we are living in a fast-changing world. At the same time, one has to recognise that systems innovation entails not only winners but also losers. The report addresses the possible winners and losers through the just transition lens.

139 Organisation for Economic Co-operation and Development, Working Party on Innovation and Technology Policy, *Draft Synthesis Report on System Innovation* DSTI/STP/TIP (Paris: OECD, 2014).

The research methodology is best characterised as following a mixed-method approach. The seven research streams used a variety of research methods, including economic value chain analysis, integrated quantitative economic modelling or forecasting, and methods from the field of futures studies. The data sources include qualitative stakeholder interviews, content analysis, desktop research and evaluation of a TVET-level hydrogen fuel-cell maintenance and installation training course. The report draws together findings from seven research streams or working papers, detailed below.

- **Workstream 1:** Bambili Advisory, "The South African Hydrogen Economy: A TVET-Industry Skills Gap Analysis" (Working Paper, SAIIA-UK PACT, 2021)
- **Workstream 2:** Jules Schers et al., "Green Hydrogen and TVET Skills' Role in South Africa's Just Transition" (Working Paper, SAIIA-UK PACT and University of Cape Town, 2021)
- **Workstream 3:** Muhammed Patel, "South African Industry Demand for Green Hydrogen Technician and Artisan Skills" (Working Paper, SAIIA-UK PACT and Trade and Industrial Policy Strategies 2021)
- **Workstream 4:** Muhammed Patel and Deon Cloete, "TVET Skills in the South African Green Hydrogen Economy: A Policy Review" (Working Paper, SAIIA-UK PACT and TIPS, 2022).
- **Workstream 5:** Bambili Advisory, Anthony Gewer and Suzanne Smit, "Towards a Just Skills Transition in South Africa: Exploring the role of a TVET hybrid Centre of Specialisation for the Green Hydrogen Economy" (Working Paper, SAIIA-UK PACT and NBI, 2021).
- **Workstream 6:** Fadiel Ahjum et al., "Green Hydrogen and TVET Employment Prospects: An Assessment in a Context of Ambitious Decarbonisation for South Africa Towards 2050" (Working Paper, SAIIA-UK PACT and University of Cape Town, 2021).
- **Workstream 7:** Deon Cloete, Ndeapo Wolf and Letitia Jentel, "Futures of TVET Skills: A Green Hydrogen Strategic Framework" (Working Paper, SAIIA-UK PACT, 2022)

The report makes use of quantitative forecasting and scenarios. The Energy Systems Research Group at UCT modelled the climate, economic and employment impacts of different green hydrogen futures, along with four scenarios depicting different choices related to domestic use of hydrogen and an export orientation. In addition, the research made use of qualitative futures-informed methods such as the 2x2 Scenario Matrix and the Three Horizons Framework. The Three Horizons Framework helps us make sense of and plan for major transitions – in this case, the shift from a carbon-based economy to a green one – as well as their impacts across industries, the world of work and the education system that prepares the workforce for this new world. Together, these approaches help us prepare for an uncertain world by identifying alternative futures (some more desirable than others) and providing pathways to help role players shape a desirable future.

Importantly, the approach has been participatory from the start. A participatory approach is required not only to make sense of a complex and changing landscape but also to shape a desirable future. A steering committee consisting of the funder, research consortium partners and primary beneficiaries guided the work throughout the research process.

- The study was funded with generous support by the UK PACT programme.
- Research consortium partners: the Futures Programme at SAIIA (research consortium lead), Bambili Advisory, the Energy Systems Research Group at UCT, Trade & Industrial Policy Strategies (TIPS) and the NBI.

  Representatives from key government stakeholders: DSI, DHET, South African National Energy Development Institute (SANEDI) and EWSETA.

Limitations of the study

Limitations of the integrated energy-economic modelling methodology and its quantitative scenarios:

The Energy Systems Research Group at UCT concluded that more detailed assessments of the requirements for up- or reskilling are still needed based on the quantitative modelling. To narrow down uncertainty and to be better able to quantify training requirements, additional research would be needed, beyond current labour statistics.

Obviously, the results presented in this study have been obtained within the limitations of the methodology applied. Modelling is an exercise that, by definition, tries to simplify our complex reality, which also means that models are necessarily constrained in the extent to which they can represent that reality. For instance, the intertemporal 'central planner' perspective of our energy-systems modelling methodology means that the timing of new technologies might be a few years different from how various public or private actors would decide to invest in new capacity. This means that impacts for the period beyond 2035, when new capital starts to get a more significant role in shaping the energy system in comparison to its well-described present-day capital stock, could take place a few years earlier or later. This is inherent methodological uncertainty.

Other limitations are that due to how technology choice operates in the energy systems model the heavy-duty class hydrogen fuel-cell vehicles were assumed dominant for class 6-9 HCVs, with little competition from other technologies. However, battery electric vehicles also could be a future option within this category to some extent, while, on the other hand, the penetration of hydrogen fuel-cell vehicle technologies in lower (smaller) vehicle classes, such as HCV2-5, might be bigger than our model predicts, eg, depending on local circumstances (grid access, etc.). These opposite model biases hopefully cancel each other out with respect to the future need for hydrogen fuel cells. The Energy Systems Research Group at UCT also assumed, in line with International Energy Agency forecasts, that platinum-based PEM fuel cells and PEM electrolysers would remain the dominant technologies in their fields. However, these fields could still experience strong technological developments, while the future metal prices of the diverse mineral resources necessary for competing technologies are also uncertain.

Finally, the Energy Systems Research Group assumed TVET shares in sectoral labour forces would remain constant. This is a reasonable assumption in view of the trend of the TVET labour share in South Africa's labour force over the past decade. However, we do not know the reason behind the trend: (a) It might be possible that there is a constant outflow from this category to the lower and higher tertiary education categories, if people who initially had TVET-education as their highest degree decide to continue their education and become employed at the level of higher diplomas or degrees. (b) More importantly, the fact that someone has a certain type of education does not guarantee that the job the person occupies requires that level of education specifically. It could both be higher (with possibly some on-the-job training), or lower, if well-educated people crowd out less-educated workers in the labour market. Our results for future TVET employment should therefore rather be considered indicative of future trends in terms of growth or decline within a sector, rather than precise predictions. To narrow down uncertainty or to be able to better quantify training requirements, additional research would be needed, eg, through detailed surveys of sectoral or company labour forces or with detailed enquiries with human resources managers of leading companies in each sector.

Appendix B: Stakeholder engagement

Partner inception workshop

The partner inception meeting was held on 17 March 2021. The aim of this meeting was the preparation of consortium members for the start of the project, outline the project approach, develop a project timeline and set deadlines for key deliverables, and develop a stakeholder engagement plan to monitor stakeholder engagement throughout the project life cycle. The consortium members,[140] including SAIIA, presented their proposed project deliverables:

- The UCT Energy Systems Research Group presented two papers that would provide the basis for SAIIA policy briefs, proposed research design and expected findings;
- TIPS presented its impact analysis of GHE development;
- KPMG presented an overview of the Hydrogen Society Roadmap; and
- Bambili Advisory presented its TVET gaps analysis and evaluation synthesis report.

Visioning workshop

A multi-stakeholder visioning workshop was held on 11 May 2021 to foster public–private partnership dialogue and create a preferred South African just labour transition future that imaginatively captures the values and ideals of all stakeholders in alignment with the South African HSRM.

Key objectives of the visioning workshop included:

- to introduce UK PACT and project research scope to key stakeholders in government and industry;
- to create a participatory platform that enables key stakeholders in the just labour transition and GHE to share their insights and critically engage with a wider audience; and
- to align project research scope with industry outputs to ensure that our research is relevant in the broader just labour transition, just energy transition and GHE conversation.

140 NBI joined as a research consortium partner in October 2021.

The workshop was attended by 79 people, comprising representatives from SANEDI, EWSETA, TVET Colleges South Africa, DHET, DTIC, DSI, SASOL, Anglo American, HySA and Eskom (in addition to research consortium partners). Four breakaway brainstorming sessions were held during the workshop based on four key industries (mining, transportation, power generation, and industrial and manufacturing processes). Outcomes from the breakaway sessions highlighted the importance of a just labour transition, despite many unknowns involved in the future hydrogen economy.

Research scoping and partner meetings

Monthly meetings were held between SAIIA and individual project partners throughout the project lifespan (February 2021 – April 2022) to ensure the achievement of project milestones, discuss research design and findings and ensure alignment with budgetary and scoping considerations.

Partner stakeholder interviews

Individual research consortium partners carried out a range of stakeholder interviews to inform their research outputs over the project's duration (February 2021 – April 2022). This was to ensure research relevancy and ground findings through a participatory approach.

Consultation with funder

A monthly meeting was held between UK PACT (the funding partner for this project) and SAIIA throughout the project (February 2021 – April 2022) to measure and management progress of project milestones and ensure alignment with budgetary and scoping considerations.

Government consultations working group

Throughout the project lifespan (February 2021 – April 2022), SAIIA met with government stakeholders on a weekly basis to discuss project progress and present research outputs for primary input. The meetings were chaired by SAIIA and were attended by beneficiary representatives from the DSI, DHET, EWSETA, DTIC, SANEDI and UK PACT, alongside our consortium partners. In chairing the weekly consultations, the project secured regular participation of all beneficiaries, thereby ensuring better stakeholder engagement, communication of key themes, research design and findings, and the novelty of the project contributions and recommendations.

Roundtable stakeholder workshop series

SAIIA and project partner NBI conducted individual and collective research stakeholder dialogues, which culminated in a series of three 'roundtable' discussions titled 'Towards a Just Labour Transition: Exploring the role of a TVET Hybrid Centre of Specialisation for the Green Hydrogen Society.' The meetings were held on 2–4 and 9 November 2021 and were attended by government departments, industry stakeholders, SETAss, academics and training centres, where key research questions were addressed and workshopped. The platform-initiated discussions on the just labour and energy transitions in South Africa while specifically targeting PSET through the TVET college system. A key focus was also pathways for connecting TVET with industry to enable employment opportunities and the development of skills for the future GHE.

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