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REPORT

Powerfuels and Green Hydrogen (Summary Report)

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Abbreviations

EC	European Commission
EE	Energy Efficiency
EPA	Economic Partnership Agreement
EU	European Union
EUD	EU Delegation
GHG	Greenhouse Gas
IEP	Integrated Energy Plan
IRENA	International Renewable Energy Agency
IRP	Integrated Resource Plan
METI	Ministry of Economy, Trade and Industry (Japan)
PtG	Power-to-Gas
PtL	Power-to-Liquids
PtX	Power-to-X
PV	Photovoltaic
RE	Renewable energy, Renewable electricity
RED	Renewable Energy Directive
RSA	Republic of South Africa
REIPPPP	Renewable Energy Independent Power Producer Procurement Programme
SA	South Africa
SADC	Southern African Development Community
US$	United States Dollar
WITS	University of the Witwatersrand

1 Background and Context

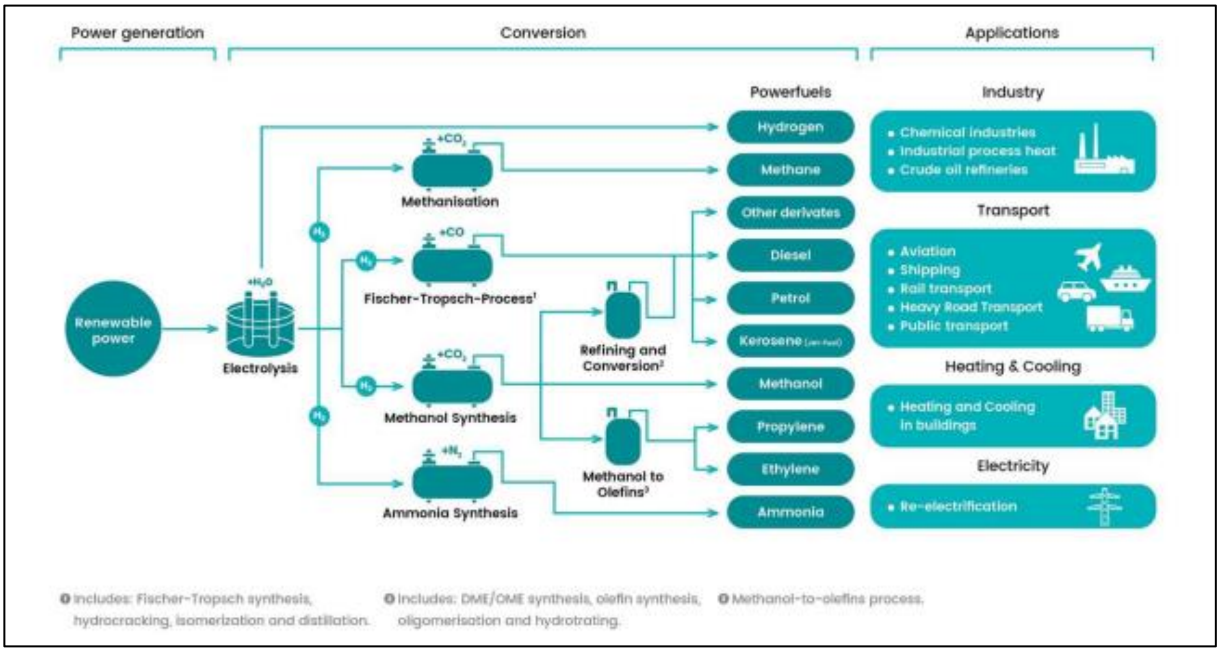
1.1 Introduction

The EU-SA Partners for Growth Programme, which supports the EU Delegation in South Africa, hosted a technical workshop on Powerfuels together with WITS Business School in December 2019. Following on from the successful workshop, this Research Paper has been commissioned by the EU-SA Partnership, as part of informing South African policymakers and companies about Powerfuels' future potential within the South African green energy context.

1.1.1 Powerfuels: A brief definition

Powerfuels are synthetic gaseous or liquid fuels based on renewable hydrogen, which is hydrogen obtained by the electrolysis of water using renewable electricity. Powerfuels comprise pure hydrogen, hydrocarbons and ammonia Figure 1. Powerfuels are thus a renewable alternative to fossil fuels (as their use avoids net emissions of CO_2); and their potential lies in sectors which may be difficult to decarbonise and may not be easily driven directly by renewables-based electricity. In many applications, Powerfuels are thus regarded as a necessary requirement to meet climate goals, alongside renewable energy and energy efficiency.

Figure 1: Different Powerfuel products based on renewable energy



Source: Global Alliance Powerfuels

1.2 Climate policy context

One area of common interest between South Africa and the EU, is support for the Paris Agreement; with both South Africa and EU member states being part of 195 national signatories to the agreement, whose central aim is keeping the rise in global temperature this century well below 2°C above pre-industrial levels, while limiting this temperature increase to 1.5°C.

Within this context, EU heads of state in late 2019 endorsed the objective of achieving a climate neutral EU by 2050; and the European Parliament adopted a resolution supportive of the European Green Deal and the climate neutrality deadline of 2050, shortly thereafter.

As part of this European Green Deal priority, the European Commission presented the Hydrogen Strategy for a climate neutral Europe in mid-2020, which proposes an EU industry plan to reach a cumulative total of electrolyser installed capacity of 40 GW in Europe by 2030, and a further 40 GW "in Europe's neighbourhood" with export to the EU.

Globally, under the Stated Policies Scenario of the International Energy Agency's (IEA) World Energy Outlook, which reflects the impact of existing policy frameworks and current announced policy intentions, energy demand is expected to increase by 27% globally between 2018 and 2040. In Africa, projected demand grows by 60%; based on population growth and anticipated rates of urbanisation.

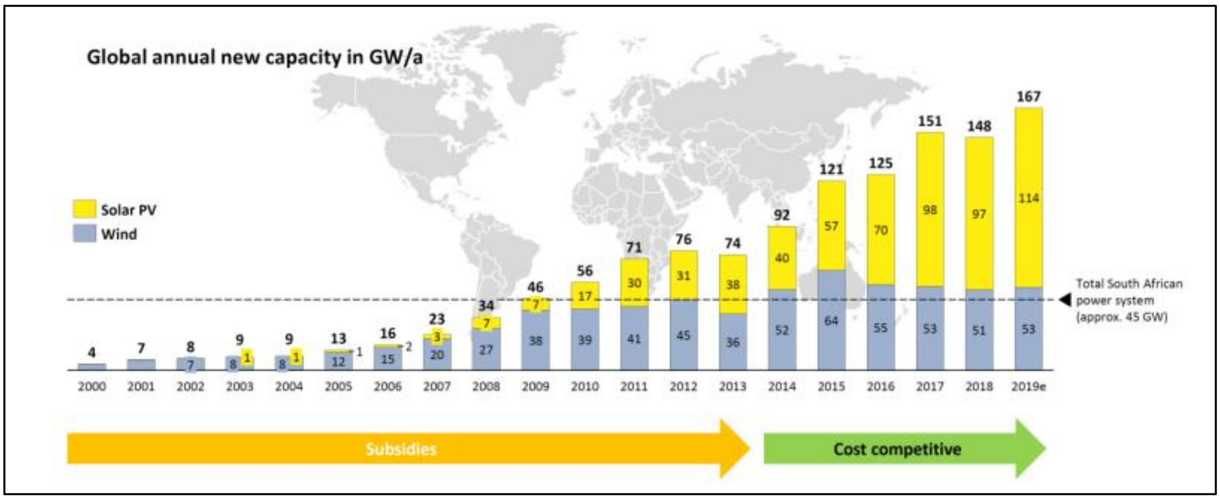
These future increase in energy demand, combined with a simultaneous ambition to decrease GHG emissions, thus urgently requires a decoupling of energy supply from GHG emissions worldwide, and this is only possible if the energy system is transformed according to two principles:

1. Responsible, economical use of valuable resources (energy efficiency or EE),
2. Sustainable, climate-friendly energy sources (renewable energies or RE)

1.3 Renewable power economics

A combination of national policies and subsidies has led to progressive expansion of renewable power capacity being built worldwide from 4 GW/a in 2000 to 74 GW/a in 2013 for solar PV and wind (Figure 2). This has driven down costs to the point that from about 2014, new-build renewable power plants have become competitive with new-build fossil power plants in many areas of the world that have good renewable resources. These favourable market forces have led to a more rapid subsequent rollout of new wind & PV capacity, rising from 92 GW/a in 2014 to 167 GW/a in 2019. In South Africa, bid prices for solar PV and wind have reduced by about 80% and 60% respectively between 2011 and 2015, in each case reaching R0.62/kWh.

Figure 2: New capacity PV and wind added annually since 2000



Source: Bischof-Niemz

1.4 Hard-to-abate sectors

Powerfuels hold particular potential in certain sectors of long-distance transport and industry, where the direct use of renewable electricity is either extremely difficult or not feasible. These sectors have been termed “hard-to-abate”, as they are particularly difficult to decarbonise; and while Powerfuels are part of a bouquet of possible green solutions currently under investigation, their potential is most worthy of extensive exploration.

1.4.1 Heavy-duty, long-distance transport

Here, particular focus falls on two areas:

1. Where current battery-electric technology is limited by lack of long-range capacity and lengthy charging times:
   - Buses and long-haul trucks
   - Commercial aviation
   - Maritime shipping
2. The inordinate cost complexity of electrifying existing transport infrastructure.
   - Rail transport.

1.4.2 Industry

In the industrial sector, specific consideration is being given to four manufacturing processes, which together are responsible for the majority of CO_2 emissions from industry. Indeed, almost 45% of global CO_2 emissions from industry in 2015 resulted from the manufacturing and production of the following:

1. Cement (3 Gt CO_2),
2. Steel (2.9 Gt CO_2),
3. Ammonia (0.5 Gt CO_2),
4. Ethylene (0.2 Gt CO_2) – primarily for production of plastics and related products.

In these four production processes, only 48% of CO_2 emissions came from burning fossil fuels to generate heat, so cannot be decarbonised solely by direct electrification with renewable electricity. Therefore, the role that carbon capture can play as feedstock to produce Powerfuels, together with Powerfuels’ potential to drive decarbonisation of industrial processes, is drawing significant attention.

1.5 Emerging Powerfuels markets

Several large global future markets have emerged specifically for low-carbon Powerfuels – which provide lucrative opportunities for local and EU businesses in South Africa.

1.5.1 Japan

Japan was the first jurisdiction to pursue the explicit importation of Powerfuels as national policy. In this, the motivations behind Japan’s explicitly stated Strategic Road Map for Hydrogen and Fuel Cells, as well as its Basic Hydrogen Strategy, are not driven exclusively by climate considerations, but also by industrial policy. Japan regards fuel cell technology as a key Japanese competence and sees the move towards H_2 as a way to re-industrialise Japan and position Japanese companies for international success. Here, an important component of the strategy has been to demonstrate H_2 and fuel cell technologies at the 2020 Tokyo Olympics (currently postponed due to COVID-19). Japan plans to import H_2 in bulk, beginning at 300 000 tonnes per year in 2030 at a target price of $3/kg, rising to between 5 and 10 million tonnes per year in 2050 at a target price of $2/kg.

1.5.2 The European Union

1.5.2.1 Decarbonising of transportation

Europe too is emerging as an additional Powerfuels market; with the European Commission (EC) already seeking to begin decarbonising transport in the 2009 version of the Renewable Energy Directive (RED). This required EU member states to ensure that a minimum of 10% of energy consumed in transport, was of renewable origin. Subsequent iterations of the RED then also limited the biofuel component of the renewable source mix, due the unintended consequence of the increase in the cultivation of 1st generation biofuels, distorting food prices and changing land use. This then led to further focus on the potential of Powerfuels as part of viable green alternatives; and is particularly important, given current EU climate neutrality targets.

1.5.2.2 Expanded transport decarbonization targets

The 2018 version of the RED (RED II) currently has a 14% minimum renewable energy target for transport to be achieved by 2030; with the relevant act being adopted in early January 2021, and coming into force in June 2021. Notably, many EU member states adopted even higher targets in their National Energy and Climate Plans (NECPs).

1.5.2.3 The European green deal

Recently, the European Green Deal is the most ambitious EU climate policy to date. In addition to the goal of Europe being climate neutral by 2050, the ambition for 2030 is a cut of 50-55% in GHG emissions compared with 1990 levels. This is in contrast with the previously planned 40% cut; and to this end, every EU law and regulation, including the Renewable Energy Directive, will be reviewed in order to be aligned to the new climate goals.

1.5.2.4 The potential for Powerfuels

As part of the European Green Deal, a circular economy action plan will, among other things, examine carbon-intensive industries like steel, cement and textiles, with the objective of preparing for “clean steelmaking” using hydrogen by 2030.

Biofuels and hydrogen will also be promoted in aviation, shipping and heavy-duty road transport where electrification is currently not possible.

1.5.3 EU examples

1.5.3.1 Germany

In mid-2020, the National Hydrogen Strategy (NHS) was passed by the German Federal Cabinet. The NHS concedes that domestic generation will be insufficient to cover all the expected new green hydrogen demand, so most of the hydrogen needed will have to be imported. Some will be sourced from elsewhere in the EU; but of particular importance to South Africa, is the stated intention of Federal Government to systematically develop production sites in partner countries. These should be within the sphere of German development cooperation, and offer great renewable energy potential for Powerfuels production; with South Africa meeting both these requirements.

1.5.3.2 The Netherlands

In April 2020, the Government of the Netherlands published the "Government Strategy on Hydrogen", together with its corresponding policy agenda. The strategy acknowledges that to become a 100% climate-neutral economy by 2050, zero-carbon hydrogen is crucial to integrate and apply; and that there are limits to what can be achieved in the Netherlands using renewable electricity for its production. Thus, with domestic demand for hydrogen expected to increase to approximately 14 Mt per year by 2050, regions where cheap renewable electricity can be generated, become important. And while areas such as Morocco and Portugal are closer, ever-decreasing transport costs will make regions such as Southern Africa more feasible.

1.5.3.3 The ports of Rotterdam (Netherlands) and Antwerp (Belgium)

As global fuel transportation hubs and vibrant industrial zones, both the ports of Rotterdam and Antwerp have expansive green hydrogen ambitions of their own. This ranges from its seamless storage and transportation in and out of these ports, to its onsite manufacture. The national government of the Netherlands has already asked the Port Authority of Rotterdam to map out various options to import hydrogen from abroad, so the port can retain its pivotal role in international transport fuels; while currently, 10-15% of EU hydrogen production takes place in the Port of Antwerp. By now, Belgium also has 613 km of hydrogen pipeline networks – the longest in Europe and second only to the USA with over 2000km of pipeline.

1.5.3.4 France

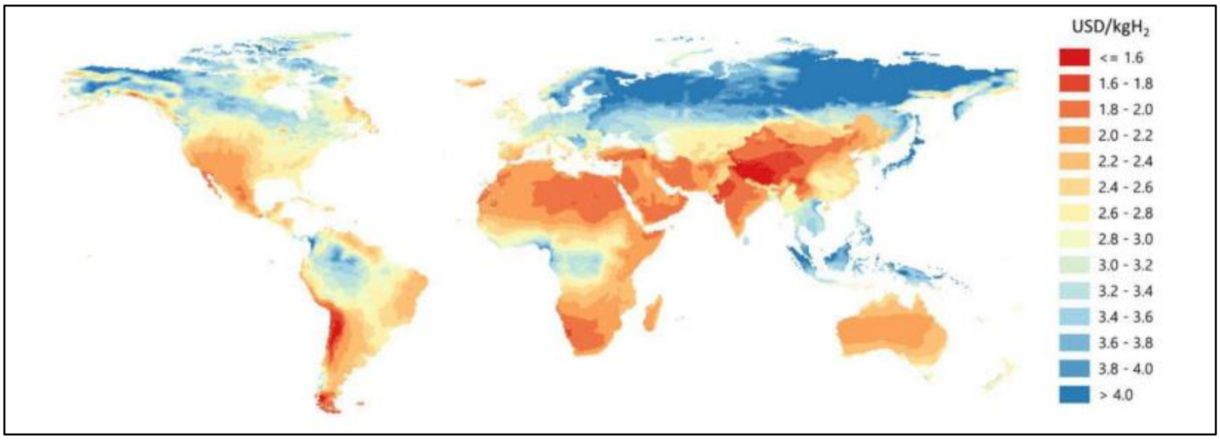
France produces more than 900 kt of industrial hydrogen per year, mostly from fossil fuels. In 2018, a national plan on green hydrogen was adopted to support the transition to green hydrogen, based on the development of its use in three main areas: industry, mobility and energy. France intends to decarbonize industrial hydrogen production by about 10% by 2023, and by between 20% and 40% by 2028. To achieve this, the French government announced plans in September 2020 to use French nuclear power to generate hydrogen; and if the European Union decides that nuclear power counts as "sustainable" for green investments and recovery funding, it would be unlikely that France will import green hydrogen in bulk from overseas for now.

1.6 South African export opportunity

As highlighted, two large economies, the European Union and Japan, have each committed to the bulk import of hydrogen derived from renewable resources. This provides a market for green hydrogen and other green Powerfuels to be generated in South Africa and exported – offering mammoth opportunities for the county and its businesses (both European and South African).

Indeed, future cost assumptions of hydrogen production using renewable electricity, appear to be favourable to South Africa in the long term. Renewable hydrogen may be produced in bulk in South Africa in a cost range of 1.8 - 2.0 USD/kgH2, which meets the Japanese cost target for 2050; while this range is also competitive with most other coastal countries, and beaten only by the Patagonian region and Chile. This shows that South Africa can give rise to a new industry, maximising export opportunities, over and above supplying domestic markets.

Figure 3: Hydrogen costs from hybrid solar PV and onshore wind systems in the long term



Source: IEA and Siegemund

2 Overview of Powerfuels and their applicability to South Africa

2.1 The costs of Powerfuels' production

As introduced in Section 1.1, Powerfuels are based on hydrogen, with green Powerfuels emanating from green hydrogen production. Green hydrogen is obtained by the electrolysis of water, where the electricity used for the electrolysis is obtained from renewable sources. In this, the primary production costs of green hydrogen are made up of three components:

1. The cost of renewable electricity supply

Fortunately, the solar resource of Southern Africa is among the best in the world - exceeded only by the Atacama Desert of Northern Chile - while the South African wind resource is competitive with onshore European wind (offshore wind along the ~2850 km South African coastline would further add to the South African onshore wind resource). This combined wind and solar resource endowment is a permanent competitive advantage, and the reason South Africa is calculated to be able to provide low-cost green hydrogen.

2. The cost of electrolysis

Three types of electrolyser technology exist: alkali electrolyser cells, proton-exchange membranes and solid oxide electrolyser cells; and the cost of electrolysis depends on several technical and financial parameters, such as weighted average cost of capital, CAPEX, efficiency and annual full load hours (FLH).

3. The cost of water supply

Fortunately for South Africa as a water-stressed country, the cost component of seawater desalination for the feedwater per kilogram of hydrogen produced, is less than \$0.02/kg (lower than 1% of the Japanese target cost of \$3/kg). A Powerfuels industry would therefore be better placed to afford the financing of desalination infrastructure than agriculture or other water-consuming businesses, leading to increased water resilience for water-stressed regions in South Africa.

Two additional cost components are relevant:

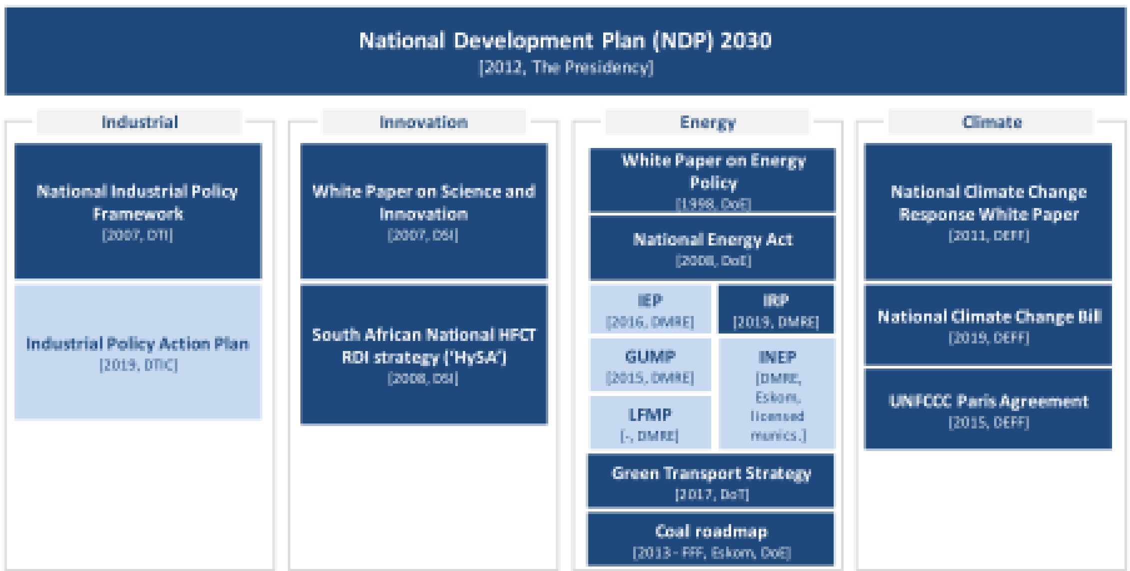
4. **The cost of storing hydrogen**, either as pure hydrogen (as pressurised gas or as cryogenic liquid) or in chemical carriers, such as liquid organic hydrogen carrier (LOHC), ammonia or methanol).
5. **The cost of transportation to markets,** determined by the economics of land-based transportation to ports for exports, necessitate Powerfuels to be produced as close as possible to the port of shipping as waterways for transportation are limited.

3 South African policy and legislative overview

3.1 Overarching policy environment

Guided by the overarching National Development Plan (NDP) Vision 2030, the role that green hydrogen and Powerfuels can play in South Africa, represents the nexus of climate change policy, industrial policy, energy policy and innovation policy, as shown in Figure 4.

Figure 4: South African policy context (specifically focused on hydrogen and Powerfuels)



Note: Light shades indicate draft policy or policy updated periodically. DEFF – Department of Environment, Forestry and Fisheries; DTI/DTIC - Department of Trade, Industry and Competition; DMRE/DoE - Department of Mineral Resources and Energy; DSI - Department of Science and innovation; DoT - Department of Transport; HFCT – Hydrogen and Fuel Cell Technologies; RDI – Research, Development and Innovation; IEP – Integrated Energy Plan; IRP – Integrated Resource Plan; GUMP – Gas Utilisation Master Plan; INEP – Integrated National Electrification Programme; LFMP – Liquid Fuels Master Plan

In this, Chapter 4 of the NDP envisions an energy sector that promotes the following:

1. Economic growth and development through adequate investment in energy infrastructure. The sector should provide reliable and efficient energy service at competitive rates, while supporting economic growth through job creation.
2. Social Equity through expanded access to energy at affordable tariffs and through targeted, sustainable subsidies for needy households
3. Environmental sustainability through efforts to reduce pollution and mitigate the effects of climate change.

Chapter 5 of the NDP also speaks clearly to the need for sustainability and an equitable transition to a low-carbon economy. As part of this, investments into skills, technologies and institutional capacity are highlighted as part of an envisioned shift away from the existing carbon intensive economy, to one of diversified natural resource and mineral usage (including PGMs) - with renewable energy at the core of enabling this transition.

From this, the role of hydrogen as an energy carrier, feedstock or for end-use directly is clear – and especially if produced via low-carbon and clean energy sources like renewable energies.

3.2 Industrial policy

3.2.1 Industrial policy action plan

The National Industrial Policy Framework provides for the development of a rolling action plan in South Africa, called the Industrial Policy Action Plan (IPAP); with the latest iteration of South Africa's IPAP for 2019/20 – 2020/21 including a renewed focus on particular and transversal focus areas.

3.2.2 Local content in public procurement

Most relevant for green hydrogen and Powerfuels would be the positioning of public procurement and local content. Here, parts of particular value-chains in 23 sectors/products are currently designated for local content, whilst simultaneously being subject to public sector preferential procurement policies. And while current requirements are not explicit on green hydrogen or Powerfuels infrastructure directly, they will at least be indirectly, but strongly, impactful considering strong linkages to electrical cables, valves/actuators, working vessels, powerline hardware/structures, transformers, solar PV components, steel products and pumps/motors.

3.2.3 Increased regional trade

There is also opportunity for green hydrogen and Powerfuels in South Africa to offer a springboard into the region and onto the continent, considering South Africa's established capital markets, as well as reputable developmental finance institutions (DFIs) and engineering and industrial capacity.

3.2.4 Expanded industrialisation and export

South African industrial policy is focused on industrialisation, and the country is well aware of the small domestic market relative to international markets. Thus, South Africa has an intentional focus on export opportunities across focus areas. In relation to hydrogen and Powerfuels, focus areas of relevance include automotive, minerals beneficiation, metal fabrication, green industries and electro-technical industries.

3.2.5 Green industries

Following the successful Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) amongst other renewable energy interventions, further localisation is being sought in green industries' value chains for South Africa. There is no explicit positioning of green hydrogen production or Powerfuels at this stage, but the opportunities for green hydrogen and Powerfuels production, domestic use and export to international markets are eminently apparent.

3.3 Climate change policy

The South African government recognises climate change as one of the greatest threats to sustainable development; and that South Africa, along with developing country peers, will be most vulnerable to its impacts. Thus, beyond being a signatory to the Paris Climate Accord, the South African National Climate Change Response White Paper, outlines two key objectives:

1. Effectively managing inevitable climate change impacts through interventions that build and sustain South Africa's social, economic and environmental resilience and emergency response capacity; and
2. Making a fair contribution to the global effort to stabilise greenhouse gas (GHG) concentrations in the atmosphere at a level that avoids dangerous anthropogenic interference.

3.4 Energy policy

The White Paper on Energy Policy, published in 1998, remains the existing guiding document for energy policy in South Africa and outlines South Africa's energy context, objectives and priorities. Then, the National Energy Act of 2008 aims to ensure diverse energy resources are available in affordable quantities to the South African economy, to support economic growth and poverty alleviation.

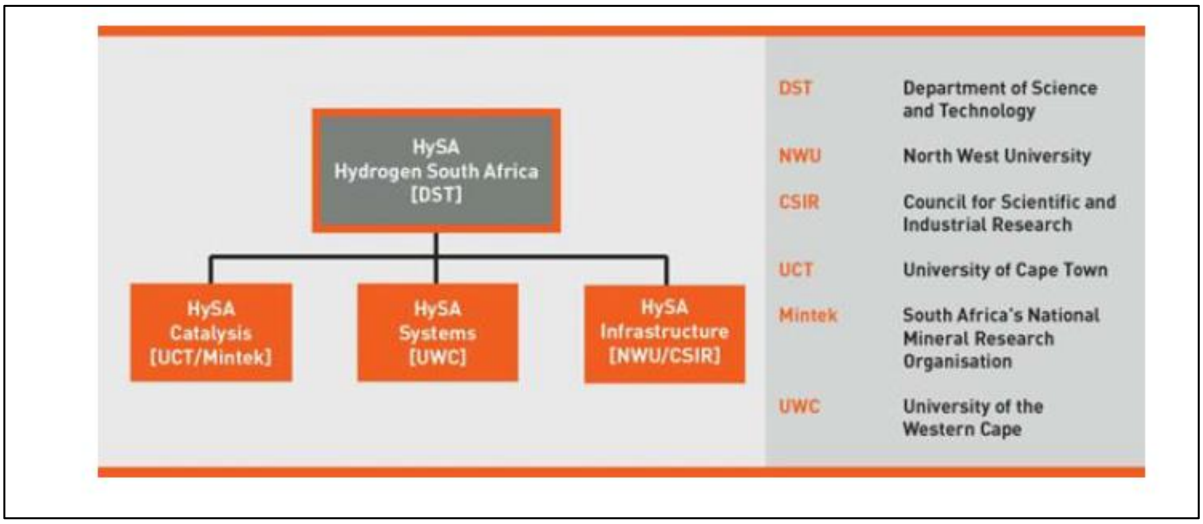
Also, as part of integrated energy planning, the need for a long-term Integrated Energy Plan (IEP) has been defined and is a key strategic planning document dealing with supply, demand, transportation, transformation and storage of energy. Here, in order to drive green hydrogen production and Powerfuels in South Africa, dedicated infrastructure may be necessary to enable hydrogen production from renewables. Fortuitously however, significant new-build allocations for renewables in the form of solar PV and wind in the Integrated Resource Plan (IRP) of 2019, could create the necessary impetus to further expand renewable energy capacity necessary for significant electrolyser capacity to produce green hydrogen.

3.5 Innovation policy and HySA

The South African National Hydrogen and Fuel Cells Technologies (HFCT) Research, Development and Innovation (RDI) Strategy, more commonly known as the Hydrogen South Africa (HySA) strategy, was established in 2008. HySA was established to stimulate and guide innovation of the hydrogen value chain in South Africa, to develop South African intellectual property, human resources, products, components and processes, in a rapidly changing world of hydrogen as an energy carrier and feedstock for industrial processes. HySA's structure is shown in Figure 5.

The ultimate goal of the HySA strategy is to enable South Africa to achieve 25% share of global supply of the PGM based fuel-cell industry, by 2020 or as soon as possible thereafter.

Figure 5: Structure of three centres of competence of HySA and stakeholders



3.6 Hydrogen policy roadmap

The Department of Science and Innovation (DSI) is currently developing a policy roadmap to inform and enable all relevant parties on deploying large-scale hydrogen technologies in South Africa. A specific focus is expected to be placed on green hydrogen, as well as other sources of hydrogen production.

3.7 Concluding comment

Ultimately, while the requisite policy environment across all areas is supportive of Powerfuels, there is a definitive need to shift from an already existing supportive policy environment, to one that is enabling and ambitious. This would empower South Africa to realise the Powerfuels opportunity via initial pilot implementation and roll-out at scale thereafter.

4 Industries in South Africa most likely to benefit from Powerfuels

4.1 Petrochemicals and refineries

There are four conventional oil refineries and two synthetic fuel (synfuel) refineries in South Africa (Figure 6).

Conventional oil refineries use hydrogen to lower the sulphur content of diesel fuel. Some of this hydrogen is a by-product of other refining processes, while the balance is either generated onsite by steam methane reforming, or else purchased from 3rd party suppliers. Thus, if these oil refineries were to instead make use of green hydrogen to desulphurise diesel, the upstream emissions of the resultant diesel would be greatly reduced. This would provide an early customer for green hydrogen, depending on its cost impact on the end product.

With synfuel refineries, while Sasol's ability to switch to green Powerfuels is currently being explored – possibly collaborating with other parties on a pilot plant to convert the concentrated CO_2 stream at Secunda to green Powerfuels for the inland South African market – a possible shorter term opportunity may lie with PetroSA. This is a smaller state-owned synthetic fuels producer located at the coast in Mossel Bay, and is a gas-to-liquids Fischer-Tropsch synthesis plant using offshore natural gas as feedstock. The plant's current size and location, coupled with the depletion of the gas wells it is supplied by, makes it ideal for repurposing to produce Powerfuels aviation fuel for the European market – and cheaper than building new, or repurposing old, refineries in Europe.

Figure 6: Location of the four oil and two synfuel refineries

4.2 Underground mining

Mining houses are already aggressively pursuing Powerfuels (at least hydrogen) in South Africa, as they seek to replace diesel engines with hydrogen fuel cells, as prime movers of underground operations. This is because diesel fumes are carcinogenic and mine ventilation systems must thus limit the concentration of diesel fumes to acceptable levels. This results in as much as 20% of all electricity consumption in underground mines being due to ventilation. Therefore, the replacement of diesel with fuel cell vehicles, means ventilation costs can be reduced by 20%. And while hydrogen fuel and fuel cell systems are more expensive than diesel fuel and engines, the entire system cost is cheaper when the ventilation burden is considered.

Currently, fuel cell-powered vehicles for underground operations, are in various stages of testing and development in South Africa, and include a locomotive, an ultra-low profile fuel cell bulldozer, a hydrogen forklift and the world's largest hydrogen powered mine truck, which is an existing mine haul truck using a fuel cell module, paired with a lithium-ion battery system.

4.3 Banks

Electrolysis infrastructure for the production of green hydrogen, and the RE infrastructure to power it, would be financed by the banking community (local and international). Banking thus has a vested interest in understanding developments in the sector, to ensure a sufficiently riskadjusted approach. This was already demonstrated in 2019, when Nedbank hosted a Hydrogen Fuel Cells conference in Cape Town, in response to questions from its corporate clients regarding the future of hydrogen and fuel cells in South Africa.

4.4 Renewable power developers

The REIPPPP, means that many international renewable power companies, (including European), have established a presence in South Africa and are developing strong supplier and community relationships. Within such a context, a bulk green hydrogen and Powerfuels export programme would require substantial additional RE infrastructure build. This will enable considerable investments by renewable power developers into further RE infrastructure, over and above what is already defined in the IRP 2019.

4.5 Hydrogen infrastructure companies

There are several fuel cell-related companies operating in South Africa; and there may be an opportunity to partner with EU businesses to drive localisation of fuel cell, electrolyser and ancillary infrastructure where it makes sense.

4.6 Gas handling companies

South Africa has a long and illustrious history of subsidiaries of seminal global gas handling giants in the country for decades, which make an immense contribution to the economy, skills development and employment; including Air Liquide (France), Afrox (originally German) and Air Products (USA).

4.7 Transnet port terminals (TPT) and Coega development corporation (CDC)

TPT is a division of Transnet, South Africa’s state-owned freight transport company. It owns and operates 16 terminal operations across seven South African ports; and the bulk export of green hydrogen would provide a source of revenue for the ports concerned (currently envisaged as Saldanha and Coega). Indeed, the CDC has been engaged by the CSIR - South Africa's premier scientific research and development organisation - regarding the feasibility of exporting Powerfuels, which is currently under intense investigation.

4.8 Urban bus transport and long-distance trucking

Moving urban public bus transport from diesel to electrically driven variants (either battery or fuel cell) improves urban air quality, and reduces CO_2 emissions (depending on the source of the electricity charging the batteries or generating the hydrogen). Here, hydrogen buses have some advantages over battery buses, in that they are lighter, have better range and shorter refuelling times, and if powered by green hydrogen, allow cities to achieve critical emissions reductions.

Hydrogen refuelling stations are planned along the N3 highway, connecting Gauteng Province with Durban, to allow hydrogen fuel cell-powered trucks to begin decarbonising heavy goods transport along this busy corridor.

4.9 Steelmaking

A perfect example of existing synergies in this domain, is Saldanha Steel, a mothballed steel plant owned by ArcelorMittal and located at Saldanha. The steelworks could be converted to a Direct Reduced Iron (DRI) steel plant that is supplied by green hydrogen, which is generated at or near the port, to produce “green steel” that could be shipped to Europe. This would provide a new business model for a plant that was unable to compete with cheap Chinese steel supply, and would be synergistic with Saldanha port, now reconfigured for green hydrogen and Powerfuels production and export.

4.10 Cement plants

There are 20 cement plants located in South Africa, all challenged by difficult decarbonisation, as CO_2 is an inevitable product of the process of converting limestone to calcium oxide. Here, over and above the usual options of emitting the CO_2 and paying increasing carbon tax, or sequestering the emitted CO_2, which is expensive and has no economic return; the capture the CO_2 for re-use as a source of feedstock for carbon-neutral hydrocarbon Powerfuels production (such as aviation fuel or methanol), provides a viable alternative, which also offsets losses from the South African carbon tax.

5 Barriers to seizing Powerfuels win-win opportunities

5.1 Legal / regulatory

5.1.1 Construction of RE infrastructure

Producing green hydrogen in the volumes needed to create a Powerfuels export industry, requires large amounts of renewable electricity; and in South Africa, the addition of electricity generation capacity larger than 1 MW, is only possible in accordance with the Integrated IRP 2019 and its resulting Ministerial Determinations.

The IRP however, was not written with such a large increase in renewable electricity demand in mind. Therefore, using renewable allocations under the IRP for hydrogen generation, effectively removes current or planned future renewable supply from conventional grid demand, thus slowing down grid decarbonisation and aggravating energy security concerns.

This also runs directly counter to the German National Hydrogen Strategy, which inter alia states, “attention will be paid to ensuring that an import to Germany of green hydrogen or energy sources based on it, takes place on top of domestic energy production in the respective partner countries and does not impede the supply of renewable energy, which is already inadequate in many cases”; and this would certainly affect South African export opportunities under current RE infrastructure conditions.

These various constraints must be resolved to allow the development of a large-scale Powerfuels export market, particularly to Germany. Furthermore, since a municipality may not contract an IPP directly under current South African legislation, this too will apply to potential hydrogen producers and will require reregulation.

5.1.2 Aviation and maritime fuel

Unlike terrestrial transport, which takes place within defined jurisdictions and may be subjected to national or regional policies (such as mandatory blending of biofuels or CCU fuels, like RED II), aviation and maritime transport take place over international airspace or waters. This makes jurisdiction and compliance management more difficult and will eventually require a global policy framework. Till then, the imposition of individual national quotas of a Powerfuels fraction in aviation fuel, may offer a temporary solution, depending on its cost implications; while shipping would require broad uptake of the new technology in fleets to begin to be viably supplied at ports.

5.2 Market conditions

Powerfuels products will be more expensive than equivalent fossil-based products for the foreseeable future. Also, products from early Powerfuels plants will be more expensive than what is produced by plants built later. To address both issues, there must be certainty that the green Powerfuels produced will be sold at prices high enough to recoup the renewable power and electrolysis investments required.

For South Africa, the fact that Europe has committed to Powerfuels imports, makes exports to there less of a problem; and solutions may take the form of long-term offtake agreement contracts for different Powerfuels products. Domestic consumption however presents cost recoupment and price competitiveness challenges.

5.3 Human and technical capacity

Capacity does no present insurmountable challenge, because the REIPPPP created a renewable electricity market in South Africa, with international companies investing in the local market, creating supply chains and developing human capital. Indeed, human capacity in electrolysis is being developed at HySA (amongst others) and cutting edge chemical engineering capacity exists in various industrial sectors.

5.4 Infrastructure

While PetroSA and Sasol can generate green Powerfuels using their own CO_2 process emissions, a wholesale shift towards green Powerfuels would require an enduring separate CO_2 supply. Most CO_2 emitted in South Africa is generated inland at all the coal-fired power stations, as well as Sasol, ArcelorMittal and cement works (15 of the 20 of which are located inland). Pipelines might deliver CO_2 from these to Sasol, and from there a single pipeline could transport CO_2 to PetroSA. These pipelines do not currently exist, and supply chain infrastructure to deliver finished products to everywhere they are needed, would also require to be addressed.

6 Conclusion

As shown in this research, the ability for South Africa to optimise its Powerfuels potential will depend on various variables, but the presence of the fundamental building blocks required, detailed in this report, bode well for the future and are certainly worth far more exploration and expansion.