GREEN HYDROGEN
SOUTH AFRICA

Green hydrogen investment

Profiles for South African Industrial Development and Special Economic Zones

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GREEN HYDROGEN INVESTMENT

Profiles for South African Industrial Development and Special Economic Zones

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RESPONSIBLE INSTITUTIONS

Green Hydrogen South Africa (GHSA): GHSA is a multi-stakeholder initiative that promotes South Africa as a leading green hydrogen producer and investment destination of choice. It is led by The Department of Electricity and Energy of South Africa and home of the South African Green Hydrogen Summit (SAGHS).

H2.SA: H2.SA is a project of the German Development Cooperation with South Africa. It is commissioned by the German Federal Ministry for Economic Cooperation and Development (BMZ) and implemented by the *Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH* in close cooperation with The Department of Electricity and Energyof South Africa. H2.SA's main objective is to promote a South African green and sustainable hydrogen economy. Working closely with its partners from Government, private sector, and civil society, H2.SA provides expertise, resources, and builds capacity for a secure and sustainable energy future that holds opportunities for all South Africans.

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ACRONYMS

	Organisation
AED	United Arab Emirates dirham
AMSA	ArcelorMittal South Africa
AUD	Australian Dollar
BIB	Bipartisan Infrastructure Bill
BPO	Business Process Outsourcing
CAPEX	Capital Expenditures
CBAM	Carbon Border Adjustment Mechanism
CCA	Customs Controlled Area
CCS	Carbon Capture and Storage
CDC	Coega Development Corporation
CHIETA	Chemical Industries Education and Training Authority
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CSP	Concentrated Solar Power
DOE	Department of Energy
DTIC	Department of Trade, Industry and Competition
EA	Environmental Authorisations
EBRD	European Bank for Reconstruction and Development
EC	European Commission
EGI	Electricity Grid Infrastructure
EIA	Environmental Impact Assessment
ETS	Emissions Trading System

ACRONYMS

	Organisation
EU	European Union
FDI	Foreign Direct Investment
FTZ	Free Trade Zone
GCCA	Generation Connection Capacity Assessment
GDP	Gross Domestic Product
GW	Gigawatt
ha	Hectares
ICT	Information and Communication Technology
IDZ	Industrial Development Zones
IRA	Inflation Reduction Act
ISES	Integrated Sustainable Energy Strategy
JET IP	Just Energy Transition Investment Plan
KIP	Kathu Industrial Park
km	Kilometres
kV	Kilovolt
KZN	Kwazulu-Natal
LCOE	Levelised Cost of Electricity
LCOH	Levelised Cost of Hydrogen
LNG	Liquefied Natural Gas
m	Metres
MERSETA	Manufacturing, Engineering and Related Services Sector Education and Training Authority

ACRONYMS

	Organisation
MICT SETA	Media, Information and Communication Technologies Sector Education and Training Authority
Ml	Megalitres
Ml/d	Megalitre per day
MoU	Memorandum of Understanding
Mt	Million tonnes
NC	Northern Cape
NCEDA	Northern Cape Economic Development Agency
NCT	Ngqura Connecting Terminal
NEMA	National Environmental Management Act
NEMISA	National Electronic Media Institute of South Africa
NGHS	National Green Hydrogen Strategy
NMBLP	Nelson Mandela Bay Logistics Park
OPEX	Operational expenditures
PEM	Proton Exchange Membranes
PGM	Platinum Group Metal
PICC	Presidential Infrastructure Coordinating Commission
PPA	Power Purchase Agreement
PtX	Power-to-X
PV	Solar Photovoltaic
RBCT	Richards Bay Coal Terminal
RBIDZ	Richards Bay Industrial Development Zone

	Organisation
RD&I	Research, Development and Innovation
REDZ	Renewable Energy Development Zone
REIPPPP	Renewable Energy Independent Power Producer Procurement
RFNBO	Renewable Fuels of Non-Biological Origin
SBIDZ	Saldanha Bay Industrial Development Zone
SDG	Sustainable Development Goal
SETA	Sector Education and Training Authority
SEZ	Special Economic Zone
SIP	Strategic Integrated Project
SMME	Small, Medium, and Micro Enterprise
SOEs	State Owned Enterprises
STEM	Science, Technology, Engineering, Math
TNPA	Transnet Ports Authority
TPT	Transnet Port Terminal
TWh	Terawatt hour
U.S.	United States
UAE	United Arab Emirates
USA	United States of America
VAT	Value Added Tax
WWTW	Wastewater Treatment Works

CHAPTER 1

Introduction

1. INTRODUCTION

Globally, countries have committed to reducing their greenhouse gas emissions. Part of the response includes decarbonising the hard-to-abate sectors such as steel, iron, cement, petrochemicals, shipping, and heavy road transport. These hard-to-abate sectors contribute to approximately 30% of global emissions, and this share is expected to double under business-as-usual scenarios (Eugenia Filmanovic, 2022). Green hydrogen and related green hydrogen products are recognised as a critical intervention that can be used to decarbonise the hard-to-abate sectors. The global market for green hydrogen is forecasted to be 300-320 million tonnes (Mt) green hydrogen by 2050 with the EU and Japan looking to import 11-15 Mt per year and 5-10 Mt per year, respectively by 2050 (DTIC, 2022a). Against this backdrop, countries globally seek to develop green hydrogen and hydrogen-related products for domestic consumption and export markets to support global decarbonisation efforts.

Although South Africa does not have an explicit regulatory framework for developing a hydrogen economy, several pilot projects have been implemented within the confines of existing energy, infrastructure, health and safety, and environmental regulatory frameworks. The country is actively pursuing the development of a green hydrogen economy and is positioning itself to be a major producer and exporter of green hydrogen, producing between 4-8 Mt per year and 2-6 per year for the export and domestic markets, respectively (DTIC, 2022a).

In February 2022, the South African government launched the Hydrogen Society Roadmap (HSRM) and, in November 2022, released the Green Hydrogen Commercialisation Strategy for South Africa (GHCS) for public comment. The HSRM and the Green Hydrogen Commercialisation Strategy are the first proactive steps taken by the government to leverage opportunities presented green hydrogen. They reflect several government priorities, including:

- The commitment to decarbonise the fossil fuel-dependent South African economy in line with net zero ambitions,
- Developing local green hydrogen industrial capabilities,
- An effort to stimulate socio-economic development,
- A way to leverage the country's resources (land, renewable energy, and critical mineral resources).

South Africa has several factors that can cement its position as a significant player in the global green hydrogen economy. These include expertise in the Fischer-Tropsch process, abundant resources (land and renewable energy), and major production capacity of platinum group metals (PGMs), a key input for hydrogen applications, production and export of green hydrogen and green ammonia, manufacturing of hydrogen fuel cells, electrolysers, and membrane electrode assemblies, the manufacturing of fuel cell electric vehicles, and low-carbon solutions for mass transportation and hydrogen-powered ecosystems.

The government's strategy involves creating local and international demand for green hydrogen and hydrogen-related products. A key enabler for developing projects in South Africa that will compete against other global players to service the export markets is the establishment of green hydrogen projects in the country's Special Economic Zones (SEZs). SEZs are instrumental in accelerating the growth of the green hydrogen industry and act as catalysts for innovation, investment, and export-orientated development. SEZs will play a crucial role in developing South Africa's green hydrogen economy and will provide a conducive environment for the development, production, and export of green hydrogen and hydrogen-related products.

For this study, four SEZs (Coega Industrial Development Zone, Richards Bay Industrial Development Zone, Freeport Saldanha, and Boegoebaai[1]) are profiled as initial preferred locations for green hydrogen development for exports and domestic consumption. The selection of these four SEZs emanated from an analysis of the SEZs and their applicability in the green hydrogen economy. Furthermore, an assessment of the SEZs' progress towards realising green hydrogen initiatives was also used to determine which SEZs to select. It is recommended that the same exercise be conducted for other SEZs so that a clearer picture of the South African competitive advantage in the global green hydrogen landscape is achieved. The Investment Profiles aim to highlight the synergistic effect between the SEZs for the export of South African green hydrogen and hydrogen-related products. They further seek to expedite export pilot projects to position South Africa as a preferred and reliable provider of green hydrogen to key markets, leveraging trade relationships and government support.

1. *No current SEZ but under consideration in view of green hydrogen activities at site.*

CHAPTER 2

Methodology

2. Methodology

The methodology used to compile the Investment Profiles involved synthesising secondary data through a literature review (public and those shared by the SEZs). The literature reviewed focussed on the aspects in the figure below, for the four selected SEZs.

1. Overview of the IDZ/SEZ
    - Locality, towns nearby, population etc.
2. Economic activities of the IDZ/SEZ
3. GH_2 vision / growth vision
4. Technical specifications (available & planned)
5. Regional opportunities and constraints
6. Social-environmental considerations
    - Environmental and Social Governance
    - Environmental management and monitoring approach
    - Social, community and development programmes
    - Environmental planning and constraints
7. South African regulatory framework / policy environment
8. Market potential/value proposition – what makes IDZ/SEZ unique for business opportunities?
    - Product(s) / bundle of products
    - Value to customers / problems solved for customers / needs satisfied
    - Possible market demand share of product (domestic and international)
    - Available resources (renewable energy, water, land)
9. Customer Segments
    - Different segments of target customers: for whom does IDZ/SEZ create value
10. Financial information / Finaacial Projections or Revenue Streams
    - Financial status and potential profitability in the future
11. Potential competotors
    - What makes selected IDZ/SEZ better positioned than global competitors
12. Key off-taker requirements and how are they are or will be met (e.g. H_2GA)
13. Gap analysis – ancillary infrastructure neede to accommodate GH_2

Figure 1: Scope of work Investment Profiles

Following the conclusion of the literature review, in-person bilateral consultations and site visits were arranged with the SEZs. On the following dates:

- Freeport Saldanha – 5 July 2023 in Saldanha,
- NCEDA – 6 July 2023 in Kimberly,
- COEGA – 11 July 2023 in Gqeberha and,
- RBIDZ – 12 July 2023 in Richard's Bay.

The consultations complemented the literature review by sourcing information that could not be accessed through publicly available sources. Relevant personnel in the selected SEZs who are involved in decision-making around the development of the green hydrogen economy in and around the SEZs were engaged. The consultations further included sharing the draft profiles with the SEZs to assess their accuracy, completeness, and relevance in positioning South Africa's SEZs as ideal locations for developing green hydrogen projects.

CHAPTER 3

What are Special Economic Zones?

3. What are special economic zones?

SEZs are geographically located areas for targeted economic activities that seek to promote economic growth and exports (SARS, 2023). In South Africa, there are four sector-specific or multi-product categories of SEZs, which are defined as follows, according to the SEZ Act No 16 of 2014 (DTIC, 2014).

- Free Ports: a duty-free area adjacent to a port of entry where imported goods may be unloaded for value-adding activities within the SEZ for storage, repackaging or processing, subject to customs procedures,
- Free Trade Zone: a duty-free area offering storage and distribution facilities for value-adding activities within the SEZ for subsequent export,
- Industrial Development Zone (IDZ): a purpose-built industrial estate that leverages domestic and foreign fixed direct investment in value-added and export-oriented manufacturing industries and services,
- Sector Development Zone: a zone focused on developing a specific sector or industry by facilitating general or specific industrial infrastructure, incentives, and technical and business services primarily for the export market.

Currently, the country has 11 SEZs located in different provinces, as depicted in Figure 2.

Figure 2: Location of South Africa's 11 existing SEZ's and the planned Boegebaai SEZ (CSIR, 2023)

SEZs play a vital role in boosting South Africa's economy by encouraging foreign direct investment (FDI), enhancing export competitiveness, creating employment opportunities, and fostering technical advancements.

Some of these SEZs have competitive advantages for the development of green hydrogen projects, including:

- Good wind and solar resources potential,
- Proximity to port infrastructure,
- Enabling ease of access to the export markets, which is a key enabler in supporting the development of a green hydrogen economy,
- Proximity to Renewable Energy Development Zones (REDZs) for COEGA (Stormberg and Cookhouse), Freeport Saldanha (Komsberg and Overberg) and Boegoebaai (Springbok). REDZs are geographical areas for the development of renewable energy projects. The benefits of renewable energy projects being located in a REDZ include

shortened Environmental Authorisation (EA) processes (DFFE, 2021). The REDZs seek to improve the efficiency of the environmental assessment processes to facilitate the development of solar photovoltaic (PV), wind and associated infrastructure in areas of low to medium environmental sensitivity. South Africa currently has 11 REDZs located in various provinces, as shown in Figure 3 below where they are overlayed onto the electricity grid infrastructure corridors where investment in transmission infrastructure is planned (CSIR, 2019).

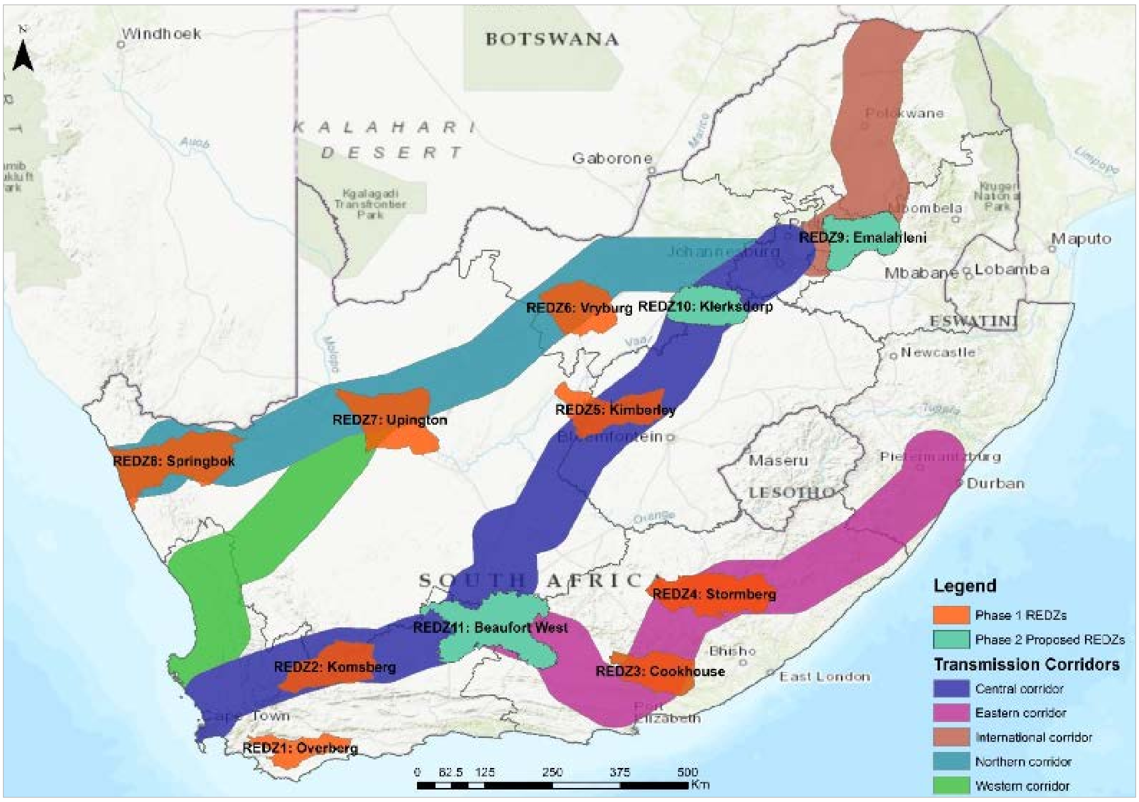


Figure 3: Renewable Energy Development Zones in South Africa (CSIR, 2019)

Additionally, providing incentive schemes for businesses operating within the SEZs creates an enabling environment for further development of green hydrogen production capabilities. These will be expanded on in each of the selected SEZ profiles in Section 6 and include incentives such as (DTIC, n.d.):

- A reduced corporate tax rate of 15% for qualifying businesses,
- Accelerated depreciation allowance of 10% for buildings,
- Customs duty and value added tax (VAT) exemptions on imported materials and goods used in the production process,
- Employment tax incentive for employers employing low-salaried employees (below South African Rand (ZAR) 60,000 per year), and
- 12i tax allowance – tax allowance on new industrial projects and upgrades or extensions to existing ones.

To date, these incentives offered in SEZs have attracted renewable energy development companies, gas solutions companies, steel mills, cement plants, and fuel cell electric vehicle component manufacturers, which demonstrates that they can be leveraged for the development of the green hydrogen economy (Metcalfe et al., 2020).

CHAPTER 4

South African Regulatory Framework/ Policy Environment

4. South African regulatory framework/policy environment

South Africa does not currently have a regulatory framework that explicitly supports the development of a hydrogen economy. To date, pilot projects have been implemented within the limits of the country's existing energy, environmental, health, and safety regulatory frameworks.

However, the HSRM and the GHCS are currently the main national green hydrogen policies and strategies in South Africa. Both have ambitious targets that centre around creating green hydrogen export markets and decarbonising various economic sectors.

The HSRM seeks to "serve as a national coordinating framework for a South African hydrogen economy. It ultimately aims to contribute to the growth and development of the South African economy and the creation of sustainable green jobs while moving the country towards secure and low-cost sustainable energy, promoting broader national competitiveness" (DSI, 2021). The HSRM identified six priority actions for a South African green hydrogen economy:

1. Hydrogen production, storage and distribution,
2. Creation of an export market,
3. Decarbonisation of transport,
4. Decarbonisation of energy-intensive industry,
5. Enhanced and green power sector, and
6. Centre of excellence in manufacturing.

The HSRM further mentions several catalytic projects, including ambitions for a Boegoebaai SEZ focused on green ammonia production, the Platinum Valley Initiative (Hydrogen Valley) targeting the decarbonisation of heavy-duty transport, and Sustainable Aviation Fuels (SAF) utilising existing Fischer-Tropsch facilities.

The GHCS is a comprehensive strategy which outlines the commercial opportunity and development approach for a viable green hydrogen industrial sector, able to service both exports as well as stimulate domestic demand and the right behaviour to meet sectoral decarbonisation targets (DTIC, 2022b). This may be explicitly realised through:

- Production and export of green hydrogen into future global green energy trading markets,
- Production and domestic use of green hydrogen to decarbonise South Africa's economy, and
- Development of industrial capability in the manufacturing and supply of equipment used in the global green hydrogen value chains.

The GHCS notes that South Africa has a significant commercial opportunity to develop a new green energy sector that drives economic growth and development, energy security, and the transition to a low-carbon economy and society.

Furthermore, the GHCS foresees the rollout of the South African green hydrogen economy in the short-to-medium term as focussed on compression and fuel cells for mobility (including heavy and industrial mobility), transport and fuels (for shipping, aviation and in the form of ammonia) and for industrial application in chemicals and metal furnaces (see Figure 4) (DTIC, 2022b).

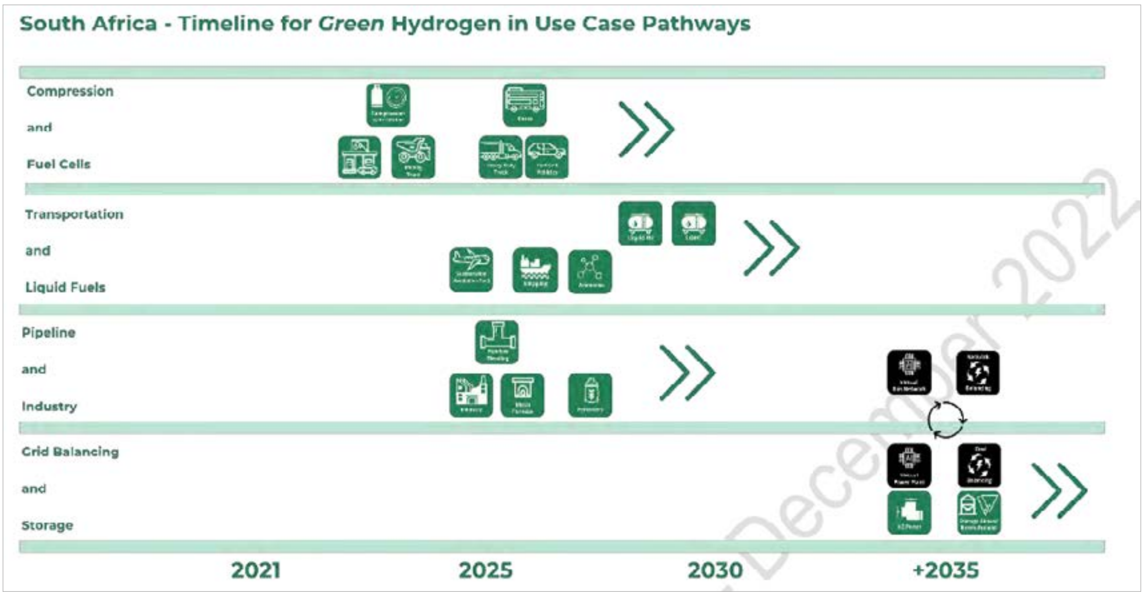


Figure 4: Indicative green hydrogen commercialisation roadmap (DTIC, 2022:21)

Lastly, South Africa's Just Energy Transition Investment Plan (JET IP) aims to "establish an ambitious long-term partnership to support South Africa's pathway to low emissions and climate-resilient development, to accelerate the just transition and the decarbonisation of the electricity system, and to develop new economic opportunities such as green hydrogen and electric vehicles amongst other interventions to support South Africa's shift towards a low carbon future." The JET IP identifies three priority sectors, which include green hydrogen. The plan estimates that between 2023-2027, the sector's investment needs are at ZAR 319.01 billion, which includes ZAR 3.7 billion for project feasibility and ZAR 109.3 billion for capital cost investment for the green hydrogen and green ammonia sub-sectors (The Presidency, 2022).

Explicit regulatory and policy enablers are, however, required to initiate a South African hydrogen economy. Barriers that must be overcome include electricity grid availability and reliability, renewable energy availability, opaque standards, targets and strategies at the sector level, and lack of hydrogen transport and storage regulation. The government will need to develop green hydrogen regulatory objectives that will drive green hydrogen development in a coordinated manner, starting with the introduction of green hydrogen regulations under section 19(1) of the National Energy Act and the development and introduction of green hydrogen standards for production, storage, refuelling, transportation and end-use.

CHAPTER 5

Key off-taker requirements

5. KEY OFF-TAKER REQUIREMENTS

Standards and certification are essential for ensuring product reliability, safety, interoperability, and sustainability and facilitate the tradability and fungibility of equipment and products. Without adequate standards, products could not meet safety and quality requirements, especially in the energy industry where safety is paramount.

In June 2023, the European Commission (EC) adopted two acts related to the certification of green hydrogen in the EU as part of its REPowerEU plan to promote renewable hydrogen production and reduce dependence on fossil fuels. This model is emerging as a potential for the USA (Iaconangelo, 2023) and given that South Africa has identified green hydrogen as a potential driver for sustainable economic growth and energy transition and has developed the HSRM and GHCS to become the producer and exporter of green hydrogen, compliance with the acts is therefore necessary for exporting green hydrogen to the EU.

The acts set out several provisions for the certification of hydrogen, including the criteria for determining the carbon footprint of hydrogen production and the procedures for verifying compliance with sustainability criteria. These conditions are additionality, temporal correlation, and geographic correlation for green hydrogen produced from renewable energy plants with direct electricity connections to Power-to-X (PtX) product plants and those that use grid-tied electricity solutions. Figure 5 depicts the two options and the associated conditions that need to be met.

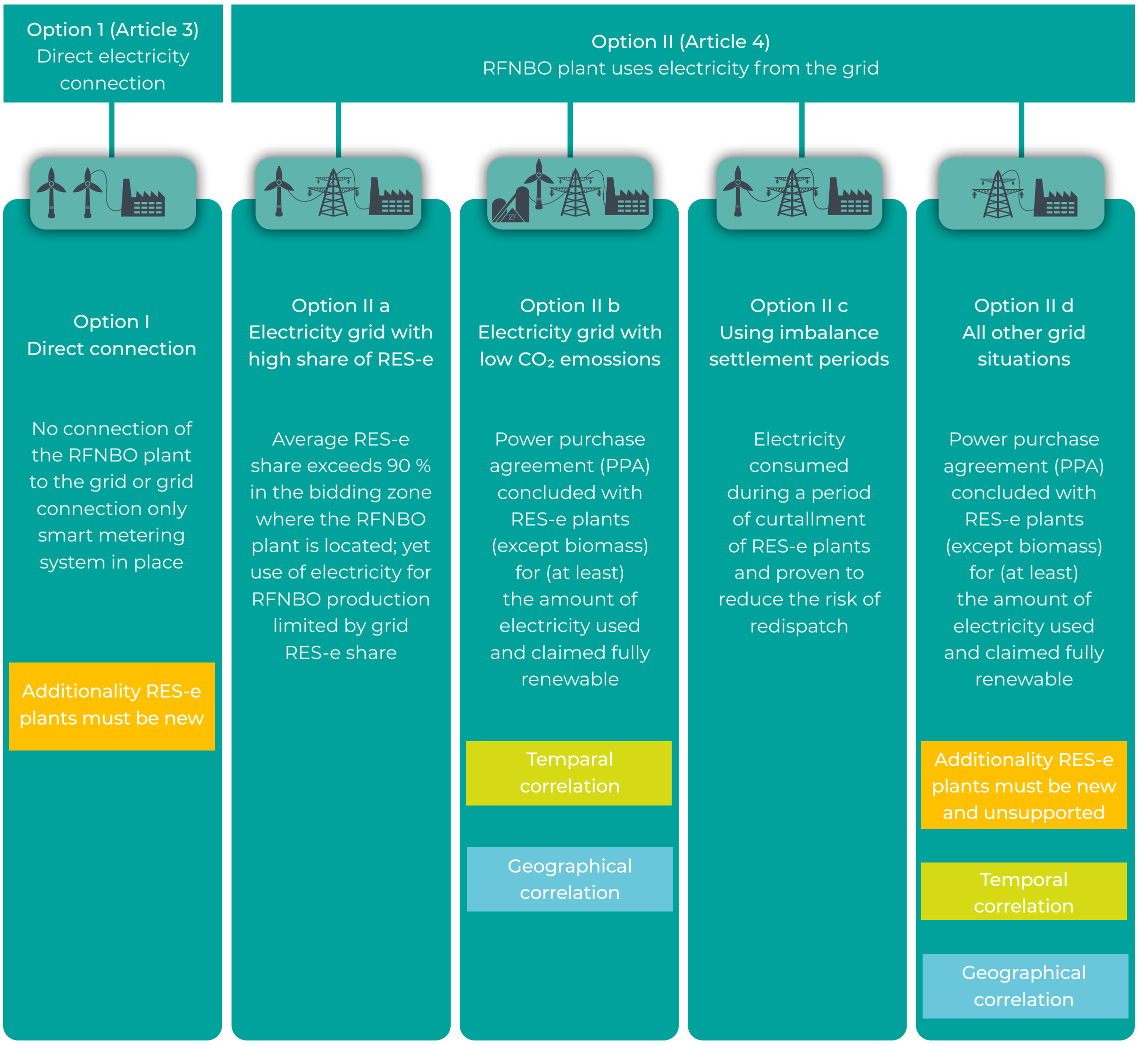


Figure 5: Requirements under the direct electricity connection and use of grid-tied electricity (Piria et al., 2023)

Additionality requirement: The principle of additionality should incentivise the deployment of additional and new renewable electricity generation capacity. This reduces the risk of renewable electricity used to produce PtX products being unavailable for other uses. To comply with the additionality requirement, the following requirements must be met:

- The Renewable Fuels of Non-Biological Origin (RFNBO) producers must conclude power purchase agreements (PPAs) with renewable energy producers. The amount of electricity covered by those PPAs must be equivalent to the amount used for the RFNBO production, which is claimed to be fully renewable.

- The renewable energy production installation must not have come into operation earlier than 36 months before the hydrogen plant. This ensures that the green hydrogen is produced from new, 'additional' and not from pre-existing renewable energy capacity.
- The renewable energy production installation must, in principle, have not received operational or investment subsidies.

Temporal correlation requirement: The principle of temporal correlation should incentivise the production of PtX products to take place at times when it supports the integration of renewable electricity production into the electricity system. This reduces the risk of PtX production triggering additional fossil-based electricity generation. To achieve the additionality requirement, the following requirements must be met.

- The production of RFNBO (PtX products) should take place during the same hour as renewable electricity production that is contracted by the PPAs.
- Use of renewable electricity from a new storage asset that (i) is located behind the same network connection point as the electrolyser or the installation generating renewable electricity and (ii) has been charged during the same one-hour period in which the electricity under the renewables power purchase agreement has been produced; or,
- The production of RFNBO (PtX products) should take place during the same hour period in which the clearing price of electricity resulting from single day-ahead market coupling in the bidding zone is lower than or equal to EUR 20 per MWh or lower than 0.36 times the price of an allowance to emit one tonne of carbon dioxide equivalent.

Geographical correlation: The principle of geographical correlation should incentivise the production of PtX products occurring in areas of the grid with high shares of renewable electricity generation. This helps to limit the risk of PtX product production, causing additional stress to the electricity grid. Under the geographic correlation requirement, the renewable energy production installation and hydrogen plant should, in principle, be in the same bidding zone or the off-shore bidding zone that is interconnected to a bidding zone (if any).

Another requirement that needs to be considered is the European Union's (EU) **Carbon Border Adjustment Mechanism (CBAM)**, which aims to contribute to the EU's climate neutrality objectives and encourage partner countries to decarbonise their production processes by levelling the playing field in carbon pricing between the EU and third-country producers. The CBAM requires importers of certain carbon-intensive goods to pay a levy on their imports corresponding to the charge imposed on comparable domestic industries under the EU emissions trading system (ETS), thus extending the carbon price paid by EU firms to foreign producers of the same goods (L. B. Jones et al., 2023).

To ensure that traded hydrogen will contribute to decarbonisation, different countries, which are potential markets for South Africa's green hydrogen exports, have set or are discussing setting **certification thresholds** for the imported hydrogen and hydrogen derivatives. The type of certification, the degree of implementation as well as the level of ambition differs substantially between countries with thresholds ranging from:

- 28.2gCO_2eq/MJ in the currently discussed EU threshold,
- 33gCO_2eq/MJ for US draft standard,
- 36.4gCO_2eq/MJ for EU´s CertifHy voluntary scheme, and
- 41gCO_2eq/MJ and ca. 42gCO_2eq/MJ for the suggestion of the China hydrogen alliance and the currently discussed Korean certification threshold (Siele & Dörr, 2023).

Implementing the EU acts and complying with CBAM, certification thresholds, and other key off-taker requirements from other potential export markets presents challenges and requires a strong policy and regulatory framework, investment protection, infrastructure development, and building a skilled workforce. South Africa must address these considerations to capitalise on the opportunities presented by the EU green hydrogen market and accelerate the development of their green hydrogen industries (Feris, 2023).

CHAPTER 6

Selected special economic/industrial zones

6. Selected special economic/ industrial zones

6.1 Coega IDZ

6.1.1 Overview

Coega IDZ (established in 1999) is located in the Nelson Mandela Bay Metropolitan Municipality in the Eastern Cape province. Nelson Mandela Bay is one of the two metropolitan municipalities in the province and incorporates the towns of Gqeberha (formerly Port Elizabeth), Kariega (formerly Uitenhage) and Despatch (NMBM, 2023). The municipality has a population of approximately 1.2 million people and is an export and manufacturing hub.

Coega IDZ is South Africa's largest and oldest SEZ and is strategically located near the deep-water Port of Ngqura and the Port of Port Elizabeth with container, bulk and break-bulk terminals, and the Port Elizabeth International Airport (~26 kilometres (km) away). The ports provide opportunities for export-based manufacturing (NMBM, n.d.). The IDZ has 9300 hectares (ha) of prime, serviced industrial land, which is divided into 14 customised zones (some fully functional) for heavy, medium and light industries (see Figure 6) (Coega, 2023d).

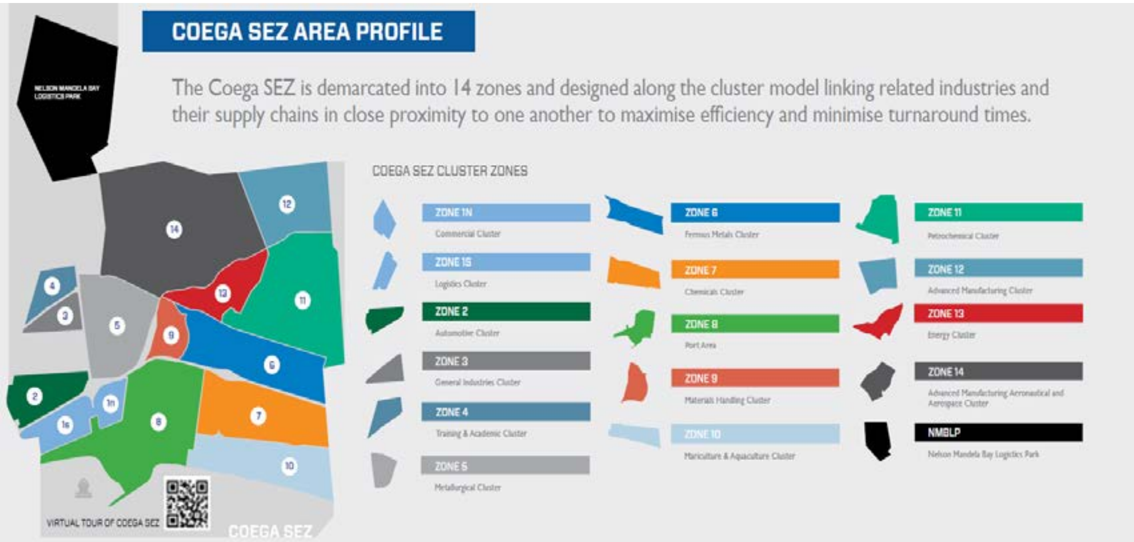


Figure 6: COEGA IDZ Zones (Coega, 2023c)

The IDZ, therefore, has easy access to rail, national road, sea and air transport networks and seeks to attract local and foreign investment. Key industries within the IDZ include:

- Metals/Metallurgical,
- Automotive,
- Business process outsourcing (BPO),
- Chemicals,
- Agro-processing,
- Logistics,
- Trade solutions,
- Energy, and
- Maritime.

In addition to the zones, the Coega IDZ also operates the Nelson Mandela Bay Logistics Park (NMBLP) in Kariega (formerly Uitenhage). The logistics park provides services and infrastructure to the automotive manufacturing industry, and this consequently assists manufacturers in reducing automotive manufacturing costs and improves suppliers' competitiveness (Coega, 2023c).

6.1.2 Economic Activities

COEGA IDZ's focus sectors include automotive, chemicals, metals, energy, agro-processing, aqua farming and maritime. The description of each sector is as follows (Coega, 2023c):

- **Automotive:** The IDZ is the major distribution and processing hub for automotive manufacturing in Southern Africa. The custom secure areas in the IDZ allow automotive industry investors to warehouse, pack, unpack, and assemble vehicles or components in a custom secure zone, with the benefit of a suspension on VAT and import duties.
- **Chemicals:** The IDZ has identified opportunities for aluminium sulphate, lactose, polystyrene, butadiene, PET polymer, and biodiesel based on South Africa's chemical sector demand.
- **Metals:** IDZ offers the opportunity to beneficiate metal resources. Zone 6 and zone 5 have been allocated for the beneficiation activities, manufacturing and production of ferrous and non-ferrous metals (see Figure 6). Further opportunities include iron and carbon steel smelting and manufacturing, stainless steel manufacturing, stainless-steel rolling-mills; ferromanganese smelting, copper smelting and manufacturing, zinc smelting, direct reduce iron and hot briquette iron manufacturing, manganese smelting and cement production.

- **Energy:** To attract and sustain investments, Coega IDZ plans to support the development of various gas, nuclear, and renewable projects.
- **Maritime:** To contribute to the region's maritime industry's growth and take advantage of its proximity to a deep-water Port of Ngqura, Coega IDZ has identified opportunities in marine services (i.e., onshore services and facilities that service off-shore maritime activities). Most vessel traffic at the Port of Ngqura is from containers, which account for approximately 75% of vessels, followed by bulk carriers and tankers. The energy demand of ships departing the Port of Ngqura is approximately 2.9 terawatt hours (TWh)/year and this requirement could be replaced by green ammonia. Figure 7 below shows the energy requirements of the vessels departing the Port of Ngqura.

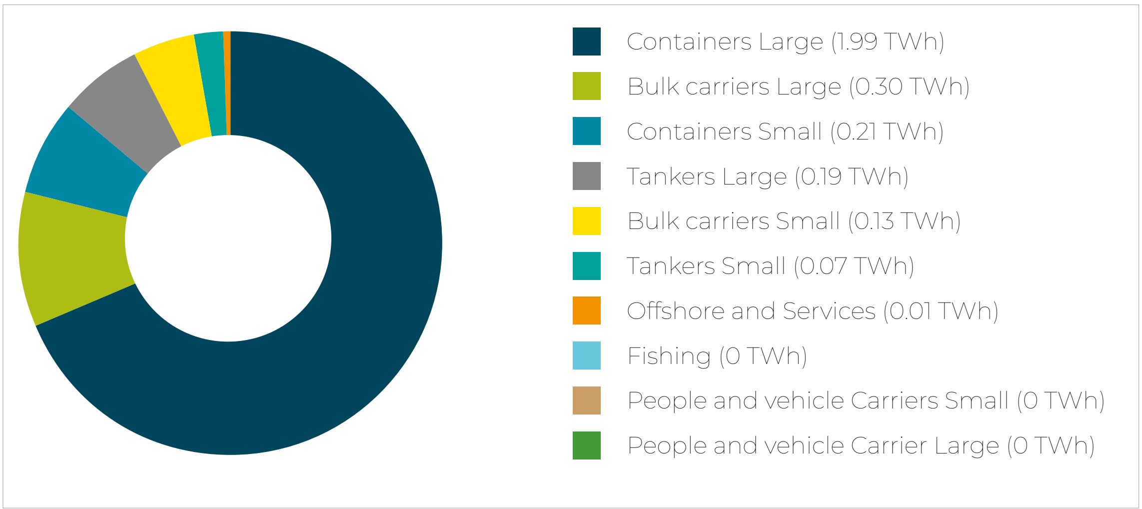


Figure 7: Energy requirements of the vessels departing the Port of Ngqura (Ricardo & EDF, 2021)

- **Agro-processing and aqua farming:** For agro-processing, the IDZ has identified opportunities in the processing and distribution of agricultural products. While for aquaculture farming the IDZ has identified the production of species such as abalone, finfish, seaweed, tilapia, trout and oysters as an opportunity to contribute towards the growth of the sector.

6.1.3 Green hydrogen vision

The Coega IDZ currently has no green hydrogen strategy but plans to host investments that will export green ammonia and those seeking to produce fertilizer from green ammonia for the agricultural sector in the Eastern Cape. Coega is also home to a sizeable industrial industry which includes fast-moving consumer goods (FMCG) and pharmaceutical companies and provides an option for local deployment of hydrogen as part of domestic demand growth (Coega MoM,2023).

The IDZ has a gazetted Strategic Integrated Project (SIP) that aims to produce green ammonia (DPWI, 2022b). The SIP is a Hive Energy project (UK-based company), which will be implemented in partnership with Linde, to produce 950,000 tonnes of green ammonia per year by 2027 (Hive Energy, 2022b). The planned project infrastructure includes solar power (1,445 MW), battery energy storage systems, 400 kilovolt (kV) transmission lines between the Dedisa substation and the production plant, and a bulk liquid storage tank, among others, as depicted in Figure 8. The total project cost is estimated to be USD 5.8 billion and will be financed through investments (Hive Energy, 2022b). Additionally, the full four phases of the project are expected to generate over ZAR 300 billion and ZAR 216 billion of FDI and direct tax revenues, respectively (Hive Energy, 2021)

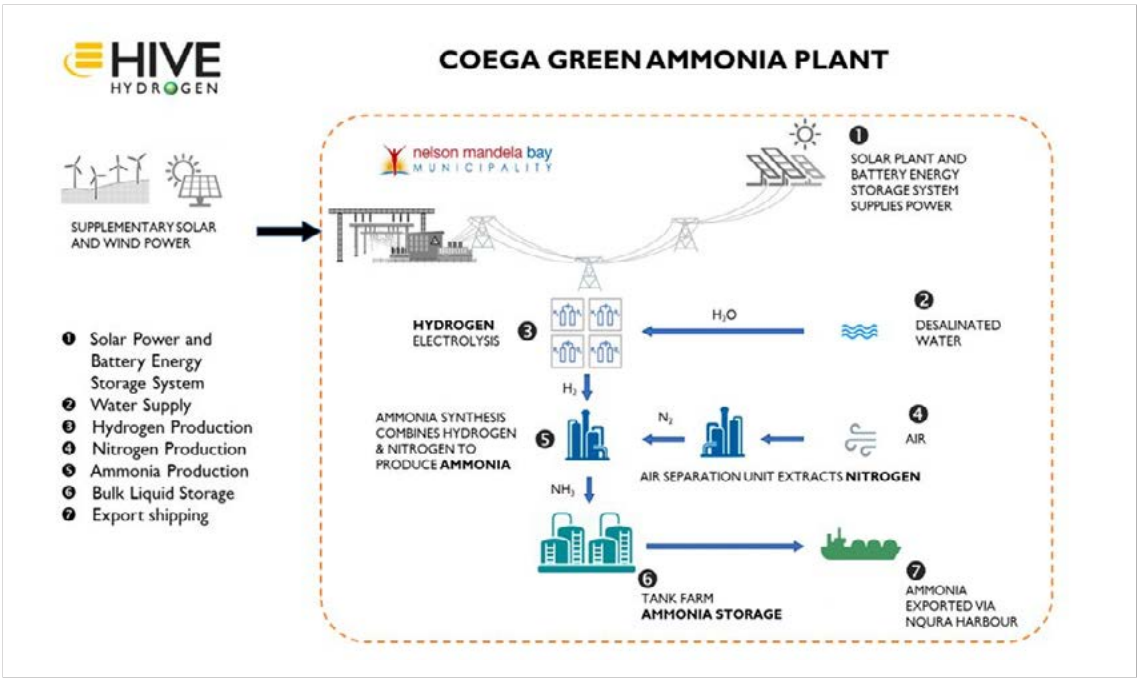


Figure 8: Hive Energy Green Ammonia Project Vision (Hive Energy)

For projects to qualify as a SIP, the following criteria needs to be adhered to (ISA, 2023):

- Significantly contribute towards economic or social development,
- Substantially contributing to any national strategy or policy relating to infrastructure development; or
- Have a monetary value of at least ZAR 400 million per year, for a minimum of three consecutive financial years, or a total project value of at least ZAR 1 billion (DPWI, 2022a).

SIPs, like large-scale wind, solar PV, and electricity grid projects developed within REDZs, enjoy streamlined environmental approval processes, reducing the time from 107 days to just 57 days.

6.1.4 Technical specifications (available and planned)

Coega IDZ has the following infrastructure to support the energy sector and possible new sectors (Coega, 2023c):

- Roads,
- Bulk water,
- Bulk sewer networks,
- Electrical substations,
- Overhead power lines,
- Main substations,
- Peaking power plant,
- Electrical cable,
- Potable water pipelines, and
- Telecommunications sleeve networks.

6.1.5 Regional opportunities and constraints

6.1.5.1 Opportunities

- **Resource potential:** Solar PV and wind energy are anticipated to be the main RE sources used for the generation of green hydrogen and green ammonia, respectively in South Africa, due to the excellent resource potential for both sources across the country (Figure 9). Currently, South Africa has solar PV and onshore wind installed capacities of 3,346 and 5,074, respectively (DMRE, 2024). During daylight hours, a combination of solar and wind resources in South Africa has the potential to produce hydrogen at a capacity of almost 100%. In the evening, wind generation has the potential to produce hydrogen at the capacity factor of ~30%, which exceeds the international norm of ~22% (TIPS, 2020).

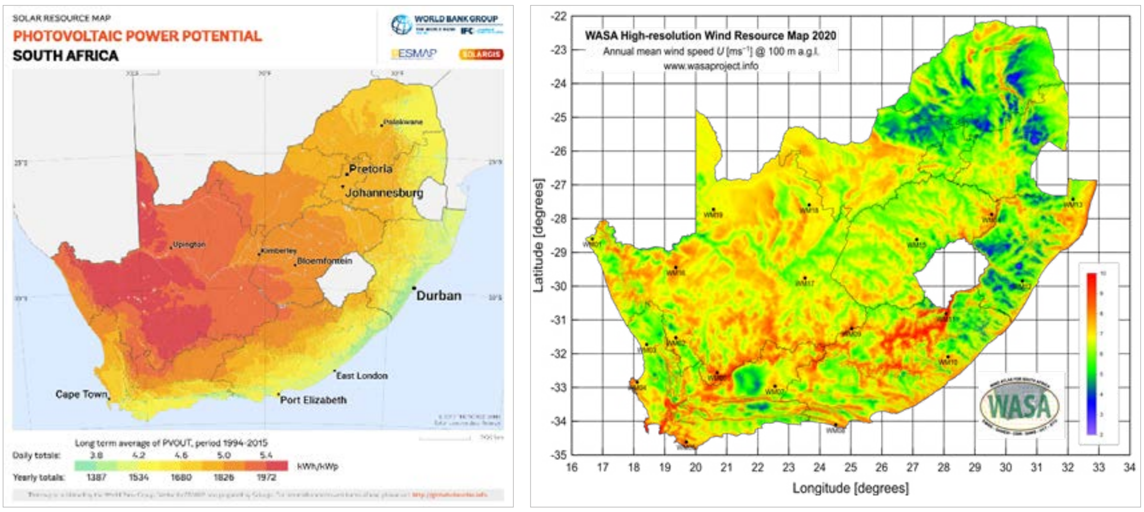


Figure 9: South African solar (left) and onshore (right) resource (DMRE et al., 2020; Solargis, 2023)

The Eastern Cape has one of the best wind resources in the country hosting more than 15 of South Africa's 22 operational wind farms (Global Africa Network, 2021a). The region has an average annual wind speed of 5.76 m/s at 10 metres (m) above the ground (Mukumba & Chivanga, 2023; World Bank, Wind DTU, et al., 2023). However, the solar resource potential in the Eastern Cape is relatively lower when compared to other provinces such as the Northern Cape, north-west and Western Cape, where the bulk of solar farms are located (World Bank, ESMAP, et al., 2023). Additionally, initial analyses show that South Africa has tremendous potential to establish an off-shore wind industry given its extensive coastline and off-shore wind resources (see Figure 10). This map shows the estimated technical potential for fixed (49 GW) and floating (852 GW) off-shore wind in South Africa in terms of installed power capacity within 200 km of the shoreline (World Bank, 2021).

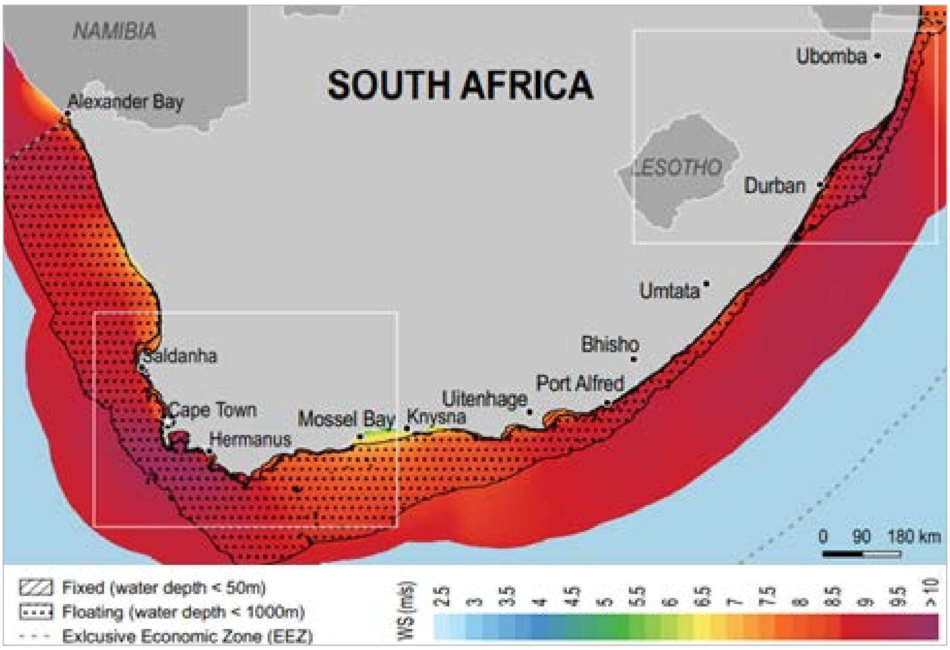


Figure 10: South Africa off-shore wind resource potential (DTU et al., 2022)

- **REDZs and strategic transmission corridor:** Coega IDZs proximity to the Cookhouse and Stormberg REDZs and the eastern corridor offers an advantage that incentivises the financing and construction of renewable energy plants.
- **Existing road, rail, port infrastructure:** Coega IDZ is a strategically connected area, with the N2 providing access to both the Eastern Cape and KwaZulu-Natal (COEGA, 2023). The Ngqura Connecting Terminal (NCT) benefits from four railway lines, accommodating up to 50 wagons, which link to the main railway line heading towards Gauteng. Additionally, the main railway traverses the Coega IDZ, and efforts are underway to refurbish the railway line between East London and Coega (Transnet, 2022a).

  Furthermore, Coega's proximity to the deep-water Port of Ngqura makes it feasible for exports (DTIC, 2022b). Port of Ngqura with a maximum permissible draught of 15,5-17,5 metres has a 4-berth container terminal and handles just over 6 million tonnes of cargo per year (Transnet, 2018a). However, the port infrastructure should be expanded to accommodate zero carbon fuel production (i.e., green hydrogen and green ammonia), so it can be used to supply the domestic market and the fuel can be exported as a commodity (Ricardo & EDF, 2021). The port of Port Elizabeth has a permissible draught of 12 metres, has 12 berths, and handles just over 5 million tonnes of cargo per year.

  Transnet National Ports Authority (TNPA) is advancing the implementation of its recovery plan at its ports of East London, Ngqura and Port Elizabeth to improve operational efficiencies and enable efficient utilisation of port infrastructure. For the port of Ngqura which is regarded as the transhipment and energy hub, two of the six hydraulic mooring units have been delivered and operationalised to improve operations and reduce shipping delays (Eastern Cape Industrial & Business News, 2024; Freight News, 2024; SA News, 2024a).

- **Skills:** Coega IDZ focus sectors require STEM (Science, Technology, Engineering, Math) skills. To enhance skills development, Coega Development Corporation (CDC) established the Coega Skills Development Centre, which offers short courses, apprenticeships and learnerships in welding, electrical, engineering, fitting and turning; fitting and machining among others (Coega, n.d.). Additionally, the IDZ offers training to service investor needs – the programmes are funded by various Sector Education and Training Authorities (SETA's) (Coega, 2023a).
- **Existing industries:** Salt manufacturing company, Cerebos, based in Coega IDZ, operates a desalination plant which can support large-scale green hydrogen production. The Hive project will require 3.4 megalitres per day (Ml/d) (Barradas, 2023b) and is planning to source water from Cerebos for the first phase of the project (Hive Energy, 2022a).
- **Water Supply:** The CDC has received a coastal waters discharge permit which flows from an Environmental Impact Assessment (EIA) process, whereby the CDC was granted Environmental Authorisation on 27 September 2021. This enables the organisation to move forward with the proposed coastal-dependent industries, including projects for power provision, desalination and aquaculture. These projects include two 1,000 MW liquefied natural gas (LNG) power stations, a land-based aquaculture development zone, and a desalination plant with a maximum capacity of 60 Ml/d.
- **Electricity supply:** The IDZ is looking to reduce reliance on Eskom for power supply. In 2023, CDC announced the approval of the Coega IDZ Energy Strategy which is in line with South Africa's Integrated Resource Plan 2019. The strategy outlines available options to manage the energy supply, energy demand, efficient usage, current future energy technologies, investments while taking into consideration the environmental impacts, demand and supply balance, and costs (Coega Energy, 2023). Additionally, Coega has plans to develop 183 MW of wind, 12 MW solar PV and biomass electricity generation projects (Coega, 2023c).
- **Manufacturing and local content:** Coega IDZ is home to one of the country's three local assembly plants for solar PV modules, Seraphim Solar Cells, which operates in Zone three and has the capacity to provide approximately 750 MW/year.

6.1.5.2 Constraints

- **Electricity:** The current energy crisis in South Africa and the unpredictability of future energy costs remains a challenge (CDC, 2022a). The Generation Connection Capacity Assessment (GCCA) report further indicates that the grid is constrained in areas where renewable energy projects have largely been developed in South Africa. This includes the Eastern Cape, Western Cape and Northern Cape (Eskom, 2022).
- **Aging infrastructure:** There is a need to upgrade and maintain the existing aging infrastructure. The CDC is however constrained by lack of funding (CDC, 2022a).

6.1.6 Social- environmental considerations

Approximately 30% of COEGA IDZ is considered natural open space, which is managed and protected through rehabilitation, plant species rescue, and alien invasive plant control. The IDZ's operations comply with relevant overarching South African environmental legislation, including the National Environmental Management Act (NEMA), and the CDC is certified in terms of ISO 9001, ISO 45001, and ISO 14001. The IDZ implements several environmental and social programmes aimed at conserving and enhancing the health of ecosystems and people within the IDZ and beyond (see Figure 11).

Energy efficiency and saving
- Efforts to reduce electricity consumption.

Water efficiency and quality
- Water savings, harvesting, quarterly quality monitoring.

Biodiversity programmes
- Landscaping and rehabilitation.
- Open Space Management.
- Alien Invasive Plant control.
- Plant rescue.
- Spatial planning.
- Heritage – the "origin of manufacturing".

Waste management
- Recycling and reuse.

Emissions and air quality
- Carbon footprint monitoring.
- Ambient air quality monitoring.

Occupational **Health** and **Safety**
- Integrated Safety, Health, Environmental and Quality (SHEQ) management system based on international standards.
- Clinic which provides health services to employees, investors and operators.

Employment, training and **development**
- Employee upskilling and capacity development.

Local community initiatives
- Maths and Science Programme.
- Internship Programme.Disability Affirmation Programme.
- Disability Affirmation Programme.

Environmental approval support
- Dedicated environmental / sustainability team available to facilitate environmental assessment and other approval processes.

Figure 11: Summary of Coega SEZs social-environmental sustainability initiatives (CDC, 2022b)

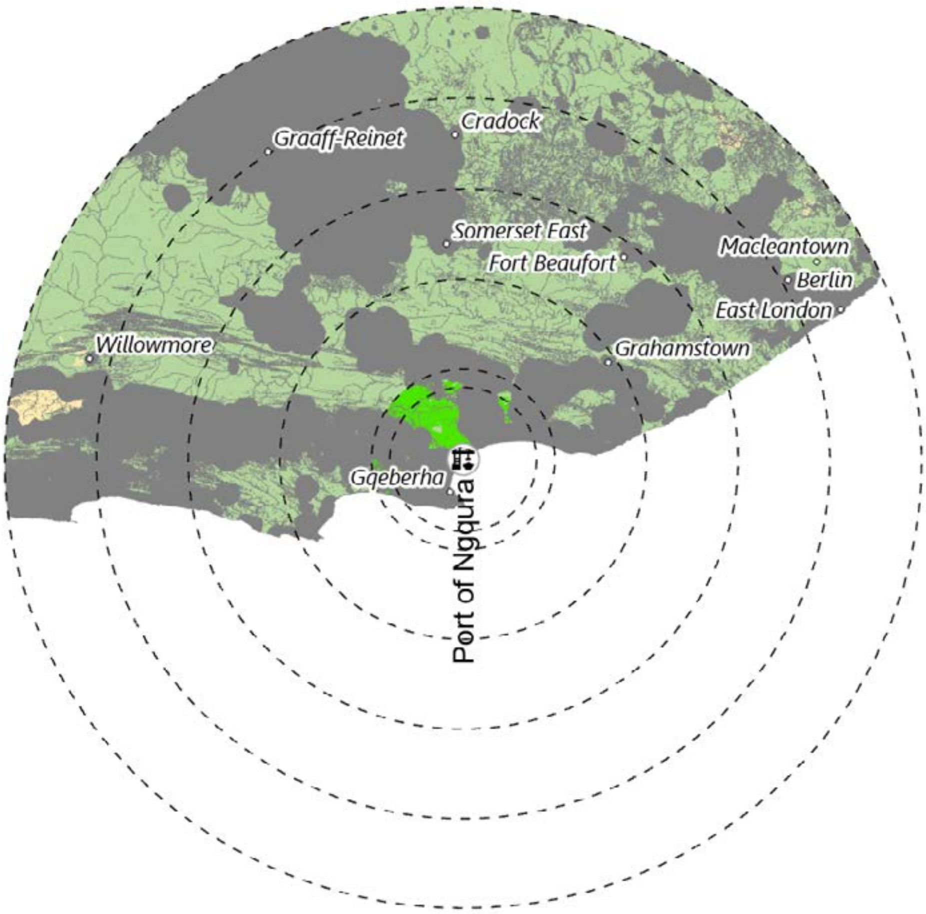
Additionally, notable community programs include:

- Maths and science programme that annually supports learners to complete high school level maths and science,
- Internship programme providing 18-month opportunities for youth to acquire work experience; and
- Disability affirmation programme, aimed at empowering employees with disabilities.

H2.SA developed a green hydrogen potentials atlas to identify broadly suitable regions in South Africa to produce green hydrogen and its derivatives targeting the export market. The atlas considers pull and push factors such as:

- Pull factors:
  - Proximity to export port,
  - Resource availability,
  - Existing infrastructure, and
  - Land use synergies.
- Push factors:
  - Environmental safeguards,
  - Land use conflicts, and
  - Safety.

Based on the atlas, it is possible to get a sense of the relatively most suitable land within 250 km of the selected export ports. Based on the atlas (see Figure 12), we can conclude that Coega region presents widespread suitable land, especially inland of the steep slopes associated with the Cape Fold mountains westward of Gqeberha. Opportunities are driven by good wind resource potential for RE deployment and proximity to the Port of Ngqura. The atlas provides a point of departure for considering environmental and social constraints to avoid and identifies least-risk opportunities within proximity to the Coega SEZ. Investment and development decisions will, however, need to be based on finer-scale investigation, ground truthing and stakeholder engagement.



COEGA		
Land surface within 250 km (ha)	Land surface within 250 km (%)	GH_2/PtX Export Potential
6,033,094	62.6 %	Likely constrained
51,182	0.5 %	Acceptable
3,463,808	35.9 %	Suitable
88,356	0.9 %	Most suitable
9,636,439		

Figure 12: Coega green hydrogen/PtX export potential (CSIR, 2023)

6.1.7 Value proposition

Product offering and potential market demand

Coega IDZ plans to host investments that will export green ammonia and those seeking to produce fertilizer from green ammonia for the agricultural sector in the Eastern Cape. Potential off-takers from nearby industries include (Global Maritime Forum & University College London, 2022):

- The local agricultural industry,
- Ports of Gqeberha and Ngqura (242 kt/y of hydrogen–bunker fuel; port equipment)
- Chief Dawid Stuurman International Airport, and
- Passenger Rail Agency of South Africa.

Incentives

The IDZ's incentives, such as tax reduction and duty-free rebates, will ensure that businesses are set up in a customs-controlled environment to produce inputs in the green hydrogen production value chain. Direct benefits include (Coega, 2023b, 2023c):

1. Simplified processes:

- Business start-up and licence procedures,
- Customs procedures-inspections and customs stops, and
- Stage consignments for imported machinery and equipment.

2. No imported duties on imported raw materials and capital equipment (excluding motor vehicles)

Other incentives the IDZ offers include:

- Training,
- Automotive production and development programme,
- Production incentive programme,
- Aquaculture development and enhancement programme,
- Research and development,
- Export promotion incentives,
- Infrastructure support,
- Reduced municipal costs, and
- Affordable rates for developed and zoned industrial land.

Available Resources

- **Land:** Of the 9,003 ha available at COEGA, 2,384 ha is conservation area (26%), 5,730 ha (63%) is developable land, and 969 ha (11%) is reserved for roads and services. In 2021, the overall percentage of operational developable land was 16.8% (CDC, 2022b). Currently, 20% of the IDZ area is occupied by investors, 30% is unavailable for development, and the remaining 50% is subject to environmental evaluation (Coega MoM, 2023). For the ammonia project, 41 ha has been secured for the hydrogen and production facility (SLR Consulting, 2024). Additionally, land is available for solar and wind generation in the outer region.
- **Water:** Return effluent from Fishwater Flats Wastewater Treatment Works (WWTW) is used as an alternative construction water source since the use of potable water is prohibited (CDC, 2022b). Coega IDZ plans to construct a return effluent scheme for industrial water uses and address the future water demand across the Eastern Cape and Nelson Mandela Bay. This will also include the construction of a pipeline to convey treated effluent or industrial quality water from the Fishwater Flats WWTW to the Coega SEZ (CDC, 2024). This is done mainly to promote sustainability since Nelson Mandela Bay is a drought-stricken area. Additionally, the IDZ has a planned 60 Ml/d desalination project. The EIA and coastal discharge permit have been granted for the project (Coega MoM, 2023).
- **Renewable energy sources:** Coega is looking to reduce reliance on Eskom for power supply, and among other planned activities, seeks to develop a 183 MW wind farm, rooftop PV systems with a total capacity of 12 MW over five buildings and biomass electricity generation projects (Coega, 2023c). South Africa has good potential to establish off-shore wind plants given its extensive coastline and off-shore wind resources (see Figure 9).

  Moreover, a study, ‘Off-shore Wind Resource Assessment Off the South African Coastline’, conducted by Freddie Inamboa and Kumaresan Cunden in 2019, assessed wind speed along the South African coastline and found four potential off-shore sites with suitable resource availability for wind farms. Site two is located about 300 km south of Gqeberha (Inambao & Cunden, 2019).

6.1.8 Customer segments

Aligned with current economic activities, the current targeted customers segments in Coega IDZ include:

- Chemical production,
- Automotive manufactures,
- Energy generation (nuclear, gas, renewable energy, hydrogen),
- Metal manufacturing and beneficiation,
- Aquaculture Farming,
- Agriculture products processors and distributors, and
- Marine Services.

6.1.9 Financial information/ Financial Projections or Revenue Streams

Funding and Revenue Streams

The Department of Trade, Industry and Competition (DTIC) provides funding for capital expenditures (CAPEX) and the provincial treasury for operational expenditures (OPEX). Additionally, Coega currently has SEZ focus and non-SEZ revenue-generating streams. Figure 13 details each revenue stream.

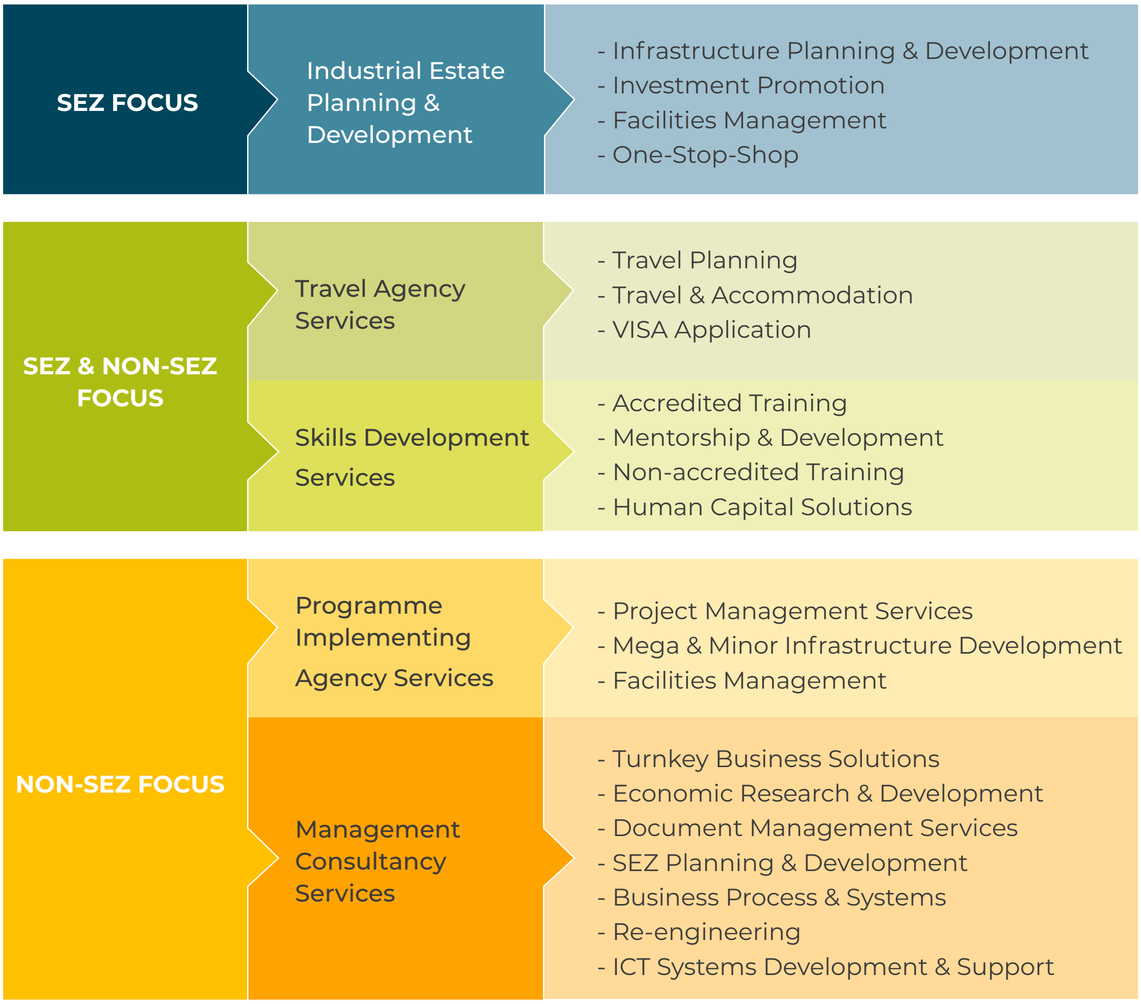


Figure 13: Coega SEZ revenue generating streams (CDC, 2022a)

6.1.10 Gap analysis

The Coega SEZ has sufficient infrastructure for developments in existing zones, however, further investment in enabling green hydrogen infrastructure is required. Enabling infrastructure includes desalination plant and wastewater recycling to ensure that there are water resources to support hydrogen production (Coega, 2023b). To raise the required capital, Coega has established a capital raising unit to explore funding solutions to finance enabling infrastructure (Coega MoM, 2023).

The Coega ammonia project led by Hive Energy will require the expansion and development of multi-use liquid bulk storage facilities, ammonia/hydrogen bunkering and an export hub at Ngqura Port. Additionally, the project will see the addition of 1200 MW of electrolysis, 1445 MW of solar power, 2205 MW of onshore wind and 10 000 MW transmission lines. Construction is set to begin in the second quarter of 2024 (Lancaster, 2021).

6.2 Richards Bay IDZ

6.2.1 Overview

The Richards Bay Industrial Development Zone (RBIDZ) is a 350 ha industrial estate which was designated in 2002 (DTIC, 2012). The IDZ is situated on the north-eastern coast of Kwazulu-Natal (KZN) in the city of uMhlathuze local municipality. The major economic sectors around RBIDZ include:

- Agriculture,
- Commercial farming,
- Manufacturing,
- Mining and
- Tourism.

The RBIDZ is strategically located near the deep-water port of Richard's Bay, which is one of South Africa's premier bulk port, Richard's Bay airport (approximately 12 km away) and several central business districts (City uMhlathuze Municipality, 2023; KZNDoT, n.d.). These include Richards Bay, Empangeni, Heatonville and Buchanana in Ntambanana; with Richards Bay and Empangeni being the most significant economic centres in local and district municipalities (City of uMhlathuze Municipality, 2023).

The deep-water seaport provides opportunities for manufacturing and storage of goods to boost beneficiation, investment, economic growth and, most importantly, the development of skills and employment (DTIC, 2013, 2018).

The IDZ encourages international competitiveness through tax and duty-free incentives to qualifying entities, as well as infrastructure to unlock investment in the IDZ (DTIC, 2013, 2018; RBIDZ, n.d.). Furthermore, serviced land RBIDZ is available for FDI (M&G, 2019). As a major economic node, with amongst the best off-shore wind resource in SA, the RBIDZ has the potential to become an energy hub (DTIC, 2022b; RBIDZ, 2023b). Superior wind speed and consistency for off-shore wind energy present further opportunities for possible cost reduction for green hydrogen production (Grobler et al., 2022). This may result in a net lower cost per unit of energy and require less energy storage and system flexibility services to balance supply and demand (Grobler et al., 2022). As an industrial and trade hub, the RBIDZ has the potential to increase domestic demand for green hydrogen, creating employment, upgrading skills, enabling technology transfer and broadening the region's basket of export products (RBIDZ, 2023d).

6.2.2 Economic activities

The objectives of RBIDZ include attracting local and foreign investment, leveraging advanced international production and technology methods to enhance expertise in global manufacturing, develop linkages between domestic and zoned-based industries and providing world-class infrastructure (KZNEDTEA, 2023; RBIDZ, 2023e). These objectives are pursued while focusing on the following key economic sectors (KZNEDTEA, 2023; RBIDZ, 2019, 2022, 2023e):

- Agro-processing,
- ICT (techno-parks, innovation hubs),
- Renewable Energy (solar, fuel cells, biomass),
- Marine industry, and
- Metals beneficiation ((aluminium, iron ore and titanium).

Agro-processing: Agro-processing activities at the RBIDZ comprise two major categories, including activities such as crop drying, shelling (threshing), cleaning, grading, and packaging, as well as increasing the nutritional or market value of a commodity (KZN Top Business, 2023).

Techno parks: The RBIDZ is looking for investors to establish techno parks in the IDZ. The IDZ has identified these as essential for innovation and enabling the development of new technologies in South Africa.

Metals beneficiation hub: A metals beneficiation hub will offer tenants serviced property located in a secure area with investment and operating incentives, including a customs controlled area (CCA) within a designated SEZ (KZN Top Business, 2023).

Marine industry development and renewable energy: Investment opportunities exist within the marine and renewable energy sectors. The marine industry development activities include ship and rig construction and repair, as well as the construction of support vessels for the off-shore energy industry (RBIDZ, 2020a).

6.2.3 Green hydrogen vision

The IDZ does not have a green hydrogen strategy but intends to develop one in the foreseeable future, given that KwaZulu-Natal plans to position itself as the leading hydrogen ecosystem hub through RBIDZ, with plans to participate in both the domestic and export markets. Figure 14 depicts the envisioned Richards Bay hydrogen hub, which includes potential exports to Japan and South Korea.

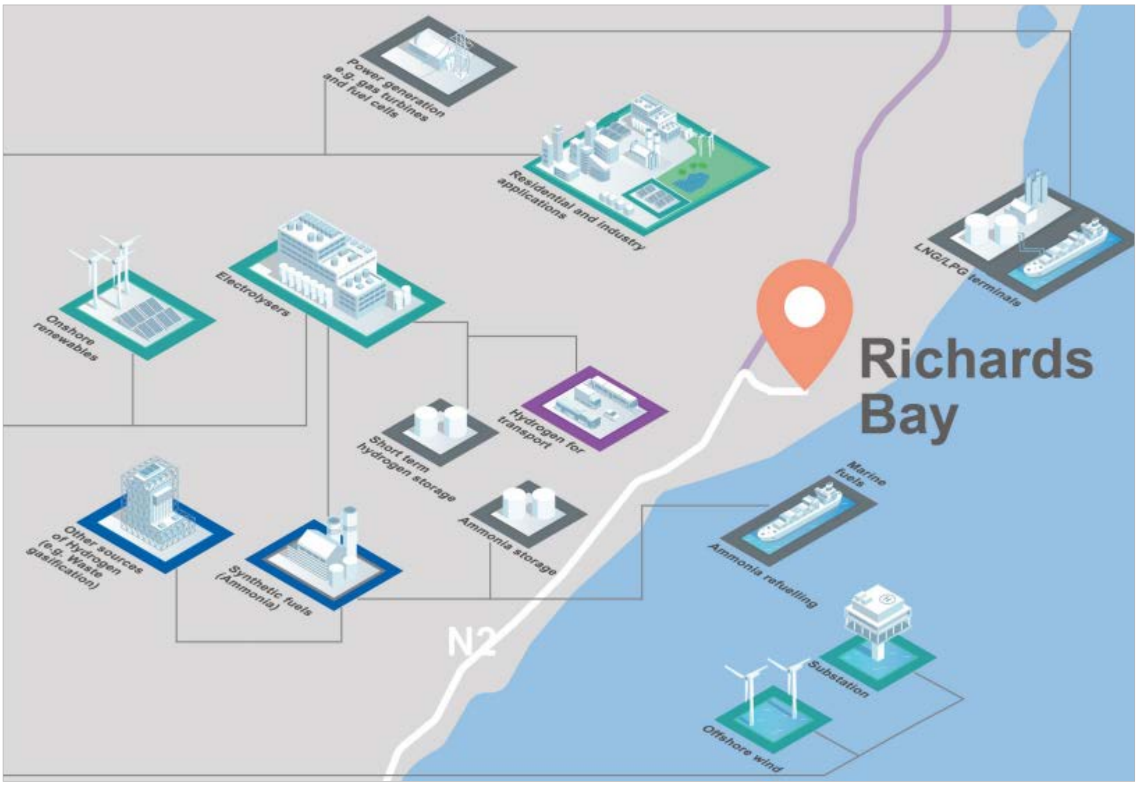


Figure 14: Richards Bay hydrogen hub (eThekwini Municipality, 2022)

In collaboration with South Africa's Department of Science and Innovation (DSI), the South African National Development Institute (SANEDI), fellow hydrogen council steering member ENGIE, and Bambili Energy, Anglo American completed a hydrogen valley feasibility study in October 2021. The feasibility study identifies three hubs – Johannesburg, extending to Rustenburg and Pretoria; Durban, Richards Bay; and Limpopo province, centred around Anglo-American's Mogalakwena mine. The results show that a significant demand hub in Richards Bay, with the potential to reach up to 70 kt hydrogen through heavy-duty trucking, port operations and public busses (Hydrogen Council, 2022). Richards Bay has established mining and fertilizer production companies which can be anchor customers, further driving the adoption of green hydrogen (RBIDZ MoM, 2023) (DFFE, n.d.). Due to the environmental sensitivity of the Richards Bay area, the IDZ, has limited potential for developing onshore renewable energy projects. The IDZ is, however well-positioned to leverage the wind resources off the east coast for the development of off-shore wind projects (see Figure 10).

6.2.4 Technical specifications (available and planned)

There is both existing and planned infrastructure to support activities related to existing tenants, and which can be used to enable the development of a hydrogen industry in the IDZ. This infrastructure includes the following (Nemai Consulting, n.d.):

- Internal roads,
- Sewer infrastructure,
- Railway infrastructure,
- Internal electrical and information and communication technology (ICT) infrastructure,
- Water mains,
- Gas network,
- Stormwater infrastructure; and
- Other service infrastructure.

Other planned infrastructure includes electrical and bulk infrastructure, such as water pipelines and railway lines.

Electrical infrastructure: A new substation with 40 MVA capacity to specifically support the electricity requirements for the investors in Phase 1A (96 ha estate) of the RBIDZ is being pursued. The process for the design of the substation commenced in February 2021 by appointing a service provider tasked to do the designs and supervise the construction of the new substation. The construction of the switching station is underway and is meant to link the substation to the electricity network of the city (RBIDZ, 2022).

Bulk infrastructure: Phase 1F is designated as a zone for accommodating heavy industries and the zone where green hydrogen investments would be hosted. The IDZ has plans to develop a major liquid fuel and gas terminals with the potential for export of hydrogen and ammonia (RBIDZ, 2022). Some of the bulk infrastructure for Phase 1F includes upgrade and expansion of existing water treatment plant, a new bulk portable water pipeline to connect Phase 1F to the Mandlazini reservoirs of the city of uMhlathuse to meet the increased water demand in Phase1F.

6.2.5 Regional opportunities and constraints

The regional opportunities that can support the establishment of a hydrogen industry in the region and specifically the RBIDZ include, among others, existing ports, roads, freight, and railways.

Opportunities

- **Existing ports (Richards Bay and Durban):** Richards Bay and Durban ports are the busiest ports in South Africa, and they support heavy and light manufacturing, agro-processing and mineral beneficiation. Post 2030, marine bunkering using ammonia has the potential to attract bulk carriers, containers, and general cargo into both Durban and Richards Bay ports (DSI et al., 2021). Furthermore, Durban and Richards Bay ports have large storage tank facilities for handling quantities of imported ammonia, butadiene, solvents and olefins, petrochemicals, and fuels as well as exports of alcohols from the local sugar industry (~50,000 tonnes) (KZNDoT, 2023b).

  Richards Bay port: The Richards Bay port handles more than 80 million tonnes of bulk cargo every year, primarily exporting vast quantities of minerals. It has 22 berths with terminals that handle dry-bulk ores, minerals, and breakbulk cargo and occupies 2,157 ha of land area and 1,495 ha of water area (eThekwini Municipality, 2022; Railway Technology, 2009) (Transnet, n.d.-b).

  Notably, the Richards Bay port is the only port that has ammonia terminal facilities and the capacity to handle large quantities of ammonia as well as the infrastructure to store and condition ammonia as required for safe transportation (eThekwini Municipality, 2022). In terms of volume, about 60,000 tonnes of ammonia is handled by the port per year (KZNDoT, 2023b). Furthermore, all the imported ammonia that is used by the fertiliser industry in South Africa passes by the port of Richards Bay (eThekwini Municipality, 2022). Fuel energy requirements for vessels, particularly large and small bulk carriers departing the Richards Bay Port is about 6.68 TWh which can be replaced by green ammonia (Ricardo & EDF, 2021). Figure 15 depicts fuel energy requirements of vessels beyond bulk carriers of differing sizes to include, inter alia, tankers and containers of differing sizes that operate in the Richards Bay port.

  Richards Bay's back-of-port facilities have about two 19,034 cubic metre anhydrous ammonia storage tanks which were designed and built by Thyssenkrupp Uhde (Marimac, 2022).

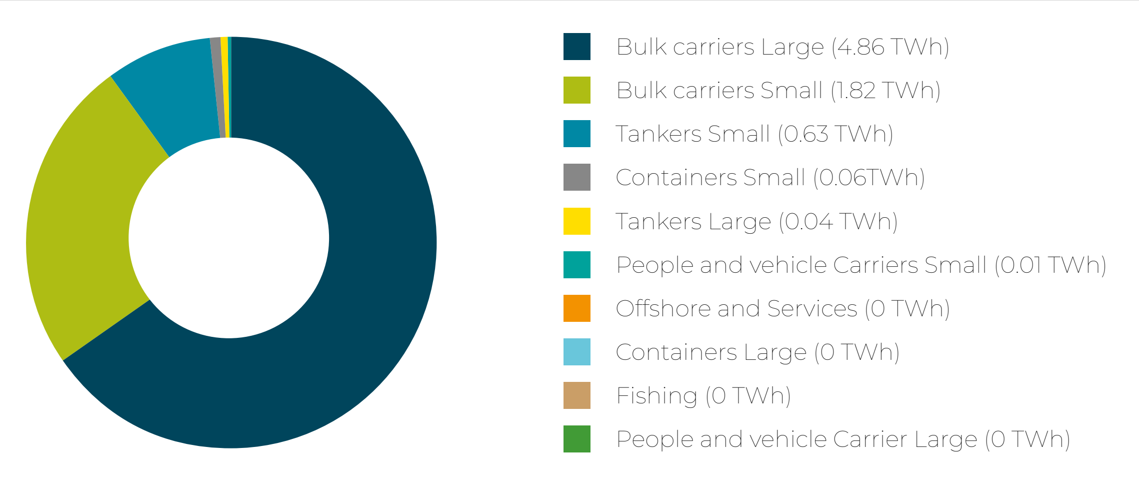


Figure 15: Fuel energy requirement of vessels departing Richards Bay by vessel category (Ricardo & EDF, 2021).

- **Existing railway:** The existing 580 km fully electrified rail line connects Highveld (Mpumalanga), rural KZN and ends at Richards Bay. Minerals, grain, and fuel are transported on this rail line (Railway Technology, 2009). A dedicated railway line connecting the Richards Bay coal terminal port with Mpumalanga province and Gauteng was explicitly designed to handle the majority of South Africa's coal exports (Railway Technology, 2009). However, there are challenges relating to disruptions owing to copper wire theft and locomotive shortages (Odendaal, 2021). Other rail links connect Richards Bay with Durban in the south and Swaziland and Mpumalanga in the north.
- **Road freight**: It is a corridor route from Richards Bay to Mpumalanga and is important for timber, coal, and other commodities. The N2 corridor links KZN to the Eastern Cape and the southern regions of South Africa (KZNDoT, 2023a). In addition, it provides multi-access road and rail systems to major routes in the region (e.g., the Gateway to Southern Africa).
- **Existing gas infrastructure:** There is an existing gas pipeline that connects Secunda, Richards Bay and eThekwini (M&G, 2019; RBIDZ, 2023a). Converting natural gas pipelines to carry a blend of natural gas and hydrogen (up to about 15-20% hydrogen) may require only modest modifications to the pipeline. If the hydrogen in the existing pipeline network (MSP and extension and TGPN) is above 15-20%, new pipelines will need to be laid.

- **Electricity grid infrastructure (EGI) corridor (eastern):** The RBIDZ is near the eastern EGI corridor. This will lead to significant benefits for electricity generators, including renewable energy project development, by providing an expedited EA process (Laurie et al., 2019).

- **Planned projects:** RBIDZ has attracted investments worth ZAR 7 billion from various projects, such as chemical manufacturing (Elegant Afro Line), edible oils manufacturing (Wilmar SA), and Nyanza Light Metal, which is investing about ZAR 4.5 billion in the production of titanium dioxide pigment (eThekwini Municipality, 2022).

  The IDZ has been identified as the site for a 3,000 MW gas-to-power project, which has already obtained environmental authorisation. To mitigate the negative environmental impact associated with the project in the form of carbon emissions, advanced technologies and innovations to capture carbon to allow for clean energy are being considered (RBIDZ, 2023a). For example, the Zululand Basin in KwaZulu-Natal forms a potential onshore target for carbon capture and storage (CCS) in South Africa (Chabangu et al., 2014). Additionally, the Zululand basin is being investigated as a possible site for pilot carbon storage project driven by the CCS flagship programme (DFFE, n.d.).

  There are plans to develop renewable energy projects, particularly off-shore wind energy on the coast of Richards Bay. Richards Bay which has the highest unallocated seabed and has been identified as the preferred site for the development of the Gagasi 800 MW off-shore floating wind farm to be located about 5 km off the coastline (Myeni, 2022).

- **Existing industries:** Richards Bay has well-established fertilizer production companies such as Foskor and mining companies such as Rio Tinto which could expand the scope of local adoption of green hydrogen (DFFE, n.d.). Much of the surrounding area is occupied by industrial operations (eThekwini Municipality, 2022). Other fertiliser and chemicals manufacturing companies with operations in Richards Bay, that could expand the scope of local production of green hydrogen include (Dun & Bradstreet, 2023):

  - Ekor (Pty) Ltd,
  - Kynoch Fertilizer,
  - LAP Chemicals (Pty) Ltd,
  - Phila and Nkanyi Chemicals (Pty) Ltd,
  - KZN Seeds and Fertilisers (Pty) Ltd,
  - Ichem Africa Chemical Solutions (Pty) Ltd, and
  - ZG Chemicals (Pty) Ltd.

The constraints which may possibly hinder and delay the development of green hydrogen activities in the IDZ are outlined below:

Constraints

- **Lengthy environmental approval process:** Environmental approvals are lengthy and can take about two years before the construction can start (RBIDZ MoM, 2023) (RBIDZ, 2020a, 2022). This subjects the RBIDZ investments to a lengthier approval timeline which is partly because the RBIDZ hosts heavy industry.
- **Skills available:** The RBIDZ is investing in skills development to drive socio-economic development in KZN. The IDZ provides bursaries directed to scarce skills such as engineering, manufacturing, financial management, information technology and mining, as well as onboarding interns and leadership candidates to participate within the RBIDZ structure (RBIDZ, 2020b, 2022). The IDZ is also considering establishing a skills development hub to service the needs of investors working with MERSETA (RBIDZ MoM, 2023).

6.2.6 Social-environmental considerations

The RBIDZ is subject to relevant national, provincial and local environmental legislation and, through a strategic partnership with the city of uMhlathuze, has a wealth of environmental information on local environmental management frameworks and programmes, climate change strategies, air quality zones, and coastal management. This positions RBIDZ to be able to provide robust assistance to investors and operators in terms of permitting, approvals and compliance. Additionally, the RBIDZ prides itself on its various social initiatives, including employee, community, and enterprise development programmes. RBIDZ is ISO 9001 and ISO 14001 certified.

The IDZ implements several environmental and social programmes aimed at conserving and enhancing the health of ecosystems and people within the IDZ and beyond (see Figure 16).

Employment, training and development

- Study bursary programme for employees.
- Internship programme for young professionals.

Local community initiatives

- Study bursary programme for disadvantaged students from surrounding communities.
- Corporate Social Investment Initiatives, including development of emerging rural farmers.

Enterprise development programmes

- Small, Medium and Micro Enterprise capacity building in project management, health and safety, quality management, financial management, and information technology.

Waste management

- E-waste recycling programme for recycling electronic and electric waste.

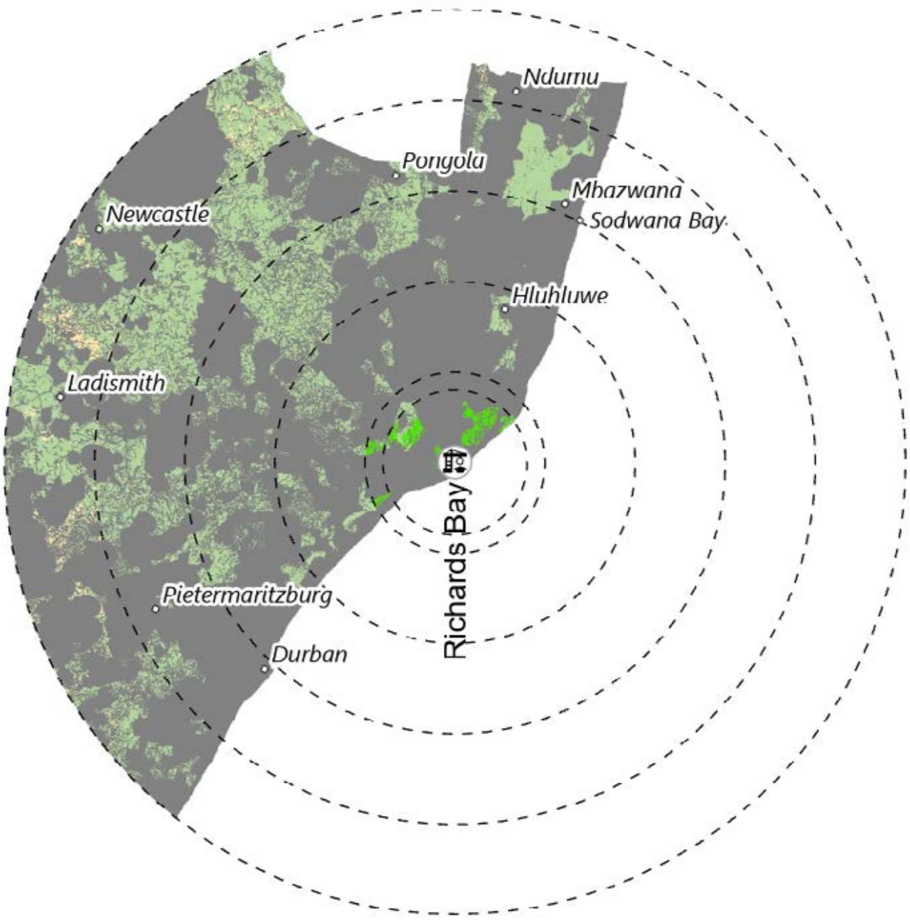
Safety, Health and Environment support

- Safety, Health and Environment Guidelines are in place to assist investors and operators better manage their environmental impact. Assistance is provided with regards to:
  - Waste and effluent Management.
  - Resource (Water and Energy) Conservation.
  - Biodiversity and Land Management.
  - Air Quality Management.
  - Aesthetics and Noise Management.
  - Environmental Compliance.
- Strategic Land Evaluation provides an accurate assessment of the environmental constraints associated with each development area. This supports informed and streamlined decision-making with regards to the placement of investors within the IDZ.

Figure 16: BIDZ's main social-environmental sustainability initiatives (RBIDZ, 2022)

According to the H2.SA green hydrogen potentials atlas, the Richards Bay region is relatively constrained, primarily due to population density, scattered villages and agricultural activities (7). Decentralised and distributed renewable deployment, synergistic land uses e.g., agrivoltaics and rooftop solar, or off-shore wind energy development, which is reportedly already being considered off the Richards Bay coast[2], can be considered to address potential onshore land constraints. The atlas provides a point of departure for consideration of environmental and social constraints to avoid and identify least-risk opportunities within proximity to the RBIDZ to explore. As outlined in section 6.1.6, investment and development decisions must be based on finer-scale investigation, ground truthing and stakeholder engagement.

2 https://www.pressreader.com/south-africa/zululand-observer-monday/20221031/281569474671331



RICHARDS BAY		
Land surface within 250 km (ha)	Land surface within 250 km (%)	GH_2/PtX Export Potential
6,391,263	79.0 %	Likely constrained
69,394	0.9 %	Acceptable
1,590,724	19.7 %	Suitable
37,021	0.5 %	Most suitable
8,088,402		

Figure 17: RBIDZ green hydrogen/PtX export potential (CSIR, 2023)

6.2.7 Value proposition

Competitive advantages.

The RBIDZ boasts unique competitive advantages such as (RBIDZ, 2023e).

- Access to the eastern markets,
- Proximity to natural and minerals and beneficiation of resources,
- Well-established sea routes,
- Good rail and road connectivity into Africa,
- Well-established metals, paper, pulp and wood sectors, and
- Possibility to anchor local hydrogen uptake through ammonia production.

Other competitive advantages include incentives, one-stop-shop approvals, a customs-controlled area, a bulk port, a deep-water port with a link to rail, an infrastructure and supplier network, an industrial estate, and connectivity (to Johannesburg and the rest of Africa) (RBIDZ MoM, 2023).

Available resources.

- **Water supply:** South Africa is a water-scarce country, as are many of its regions, including Richards Bay. Given that the region is water-constrained, two water sources have been 1) desalinated seawater and 2) recycled wastewater. There is an existing 10 Ml/d Richards Bay desalination plant (DWS, 2017). The use of the wastewater recycle stream comes with additional co-benefits (eThekwini Municipality, 2022).
- **Land:** The availability of land is limited in the region posing a risk for realising industrialisation prospects. For example, limited tracts of land are rapidly being committed, limiting how much land is available for future investments (RBIDZ, 2020a). In part, this shortage is caused by delayed processes to conclude land acquisitions. However, efforts are made to secure additional land acquisitions such as identified land in the KwaMbonambi area (RBIDZ, 2020a).

  Additionally, about 350 ha industrial land has been set aside for investment. That includes 130 ha designated for accommodating heavy industry investment and 200 ha earmarked for the development of RE projects in Nsezi Yard Expansion Area. Moreover, there is 172,000 ha of land that can be developed (RBIDZ MoM, 2023). The land used to belong to Transnet and has been handed over to Mandlazini community recently. Moreover, the RBIDZ is also looking to secure privately owned land (RBIDZ, 2022).
- **Renewable energy sources:** The limited availability of land in the region will hinder the development of onshore wind and solar PV plants. A study conducted by Rae & Erfort (2020) has however identified Richards Bay as a potential location for off-shore wind energy development. The study further reveals that the region has suitability factors of up to 98% within proximity to the coastline. Additionally, the off-shore

wind energy development pixels are in a shallow low depth range of 40-60 m which is suitable for deployment of cheaper fixed-bottom foundations of off-shore wind energy (Rae & Erfort, 2020).

6.2.8 Customer segment

The RBIDZ targets the following customers (RBIDZ, 2023c, 2023f):

- Metal beneficiation,
- Chemical production,
- Agro-processing,
- Energy generation and storage,
- Logistics,
- ICT,
- Repair and maintenance of ships and drilling rigs, and
- Provision of bunkering and maritime services.

6.2.9 Financial information/ financial projections or revenue streams

The RBIDZ's CAPEX is funded by the DTIC, while the OPEX is funded by the provincial economic development department. Currently, all the infrastructure funding is sourced from the DTIC; however, in the future, the RBIDZ plans to set aside funds and stop relying on DTIC. The main source of income is rental from land and top structures as well as management fees.

6.2.10 Gap analysis

The development of hydrogen economy in Richards Bay will require the following infrastructure and technologies (eThekwini Municipality, 2022):

- Electrolysis of water powered by renewable electricity,
- Reformation of natural gas with carbon capture and storage,
- Reformation of synthetic methane derived from renewable syngas and
- Syngas processing and upgrade to produce further hydrogen to remove carbon monoxide (CO) and carbon dioxide (CO_2), and
- Renewable electricity, particularly off-shore wind energy generation, given the competitive resource potential in the region. Sites have been identified for 100 MW onshore, 1.5 GW off-shore wind, and 4.33 GW solar PV in Richards Bay (eThekwini Municipality, 2022).

6.3 Saldanha Bay IDZ

6.3.1 Overview

Freeport Saldanha was designated in 2013, is located within the Saldanha Bay municipal area in the Western Cape. The IDZ is 110 km from Cape Town International Airport and there is a small light aircraft airport at Saldanha Bay. The municipality has a coastline of 238 km and is the largest economy within the West Coast District Municipality. The nearby towns include Saldanha, Paternoster, Jacobsbaai, Langebaan (SBM, 2023b). Saldanha Bay is well known for its harbour, steel mill and established fishing industry (SBM, 2022a).

Freeport Saldanha is the first sector-specific SEZ in South Africa to be located within a port in the Southern Hemisphere. The SEZ currently has 356 ha of land and focuses primarily on the energy and maritime sectors, with active projects in oil, gas (upstream, midstream, and downstream), marine repair, fabrication, logistics and related services. Other active sectors near Freeport Saldanha include mining, steel, aquaculture, fishing, agriculture and tourism (SBIDZ, 2023c). Figure 18 shows the project outlook for Saldanha Port area with projects at different stages of development.

Figure 18: Project outlook for Saldanha port area (SBIDZ, 2023c)

6.3.2 Economic Activities

Freeport Saldanha focus sectors include marine sector, energy, maintenance and repair services, fabrication services, communal services, supply and other services, exploration and maintenance and support services as outlined in Table 1 below:

Table 1: Freeport Saldanha focus sectors (SBIDZ, 2023c, 2023d)

Activity	Description
Marine sector	• Marine services hub • Boat building & repair • Vessel decommissioning • Off-shore supply base
Energy sector	• Bulk fuels storage • Manufacturing hub • Services hub • Integrated logistics facility
Maintenance and repairs services	• Maintenance, repair, upgrade and conversion of rigs and other vessels, parts and structures – Inspection, certification
Fabrication services	• Structures, subsea manifolds • Spare parts
Communal services	• Property development • Customs clearance • Marketing and administrative functions • Security, medical, food and retail • Utilities, waste management, transport • Road and quay access
Supply and other services	• Bonded warehousing / storage • Scheduling and forecasting • Logistics and transport – sourcing and forwarding (air, ship, rail and road) • Lifting, stacking, moving • Pipe coating and upsetting • Tugging / piloting • Project and engineering services

Activity	Description
Exploration and maintenance	• Drilling companies: Office space, warehousing, logistical facilities and/or support services. • Petroleum companies: Office and warehousing space for an operational base close to active fields. • Oilfield service companies: 24-hour operational nodes along the coast, in the form of office spaces and warehousing bases. In sites such as off-shore supply bases [OSSBs] and/or quaysides for supply and re-fuelling purposes
Support services	• Knowledge workers (such as consultants), shipping agents, insurance agents, possibly banking/finance, legal, ICT, fuel bunkering, petrol fuel stations, private security, food and retail, hospitality, waste disposal, medical, diving, and a diverse set of trainers and inspectors

6.3.3 Green hydrogen vision

Freeport Saldanha plans to establish a green hydrogen hub as illustrated in Figure 19. Green hydrogen opportunities at Saldanha include green iron & steel, shipping fuels, mobility, exports., logistics gateway (handling of e.g., wind turbine blades) and a manufacturing hub (SBIDZ MoM, 2023).

Figure 19: Planned green hydrogen hub (SBIDZ, 2023c)

In July 2023, Sasol signed a Memorandum of Understanding (MOU) with Freeport Saldanha to develop a green hydrogen hub (SBM, 2022c). Steel producer ArcelorMittal South Africa (AMSA) is set to be the local offtake to produce green hydrogen directly reduced iron (DRI). The International Maritime Organisation decarbonisation targets will also drive a market for green bunker fuels, and Saldanha has been identified as a green bunker port. The South Africa-EU green iron ore corridor consortium, which comprises of Anglo American, steel producer Tata Steel, CMB, VUKA Marine, Freeport Saldanha and ENGIE will also require green bunkers (Parker, 2023). The corridor is at inception stage, but the partners have committed to developing the maritime green corridor.

Additionally, Freeport Saldanha is considering developing a green hydrogen master plan. Elements to be considered in the master plan include renewable generation zones, land ownership, environmental considerations, risk and safety for major hazard installations, existing infrastructure, new infrastructure urban planning and precinct development.

6.3.4 Technical specification (available and planned)

To support the operations of the Freeport Saldanha the following infrastructure is available (DEMACON Market Studies, 2009):

- Water supply and existing desalination plant owned by Transnet Port Terminal (TPT),
- Wastewater systems,
- Waste disposal facilities,
- Electricity,
- Fencing,
- Road access,
- 35 m quayside owned by TNPA,
- Quay equipment such as cranes, tugs, forklifts,
- Bulk electricity supply,
- Rail,
- Multipurpose terminal, and
- General maintenance quayside.

For dry docking facilities, Freeport Saldanha is conducting a feasibility study with TNPA on port infrastructure that could accommodate dry docking utilising a ship lift.

6.3.5 Regional opportunities and constraints

6.3.5.1 Opportunities

- **Land:** The west coast district has 11.5 km² and 21km² of feasible land, respectively for wind and solar (SBIDZ, 2023c). The land costs in the region are lower than those near Cape Town where the Greentech manufacturing zone, Atlantis SEZ, is located.
- **Water:** Sea Harvest has a desalination plant for its own use which has a capacity of 1.15 Ml/d. Freeport Saldanha has received environmental approval for the development of a 25 Ml/d desalination plant at Danger Bay.
- **Renewable resource potential:** The Western Cape has good wind resources with 22% of existing onshore wind projects being located in the province (DMRE, 2024). The average annual wind speed in the region is 8.33 m/s at 100 m above the ground which is only slightly lower when compared to that of the Eastern Cape (8.68 m/s) (World Bank, Wind DTU, et al., 2023). For solar resources, the direct normal irradiance ranges between 4.47-8.05 kWh/m² which is high although not as high as the Northern Cape and has resulted in the province hosting 11% of the country's solar PV plants (IPP Office, 2023; World Bank, ESMAP, et al., 2023). Additionally, Freeport Saldanha is close to Overberg (290 km away) & Kombersberg (360km) REDZs and central and western corridors which offer an advantage to incentivise the deployment of renewable energy projects in the region as previously mentioned (DTIC, 2022b).
- **SEZ and port, rail and road infrastructure:** Freeport Saldanha is located within a port. The deep-water port (23 maximum draft) covers the sea surface with 6 berths ranging up to 318.5 metres (Transnet, n.d.-a). The rail and road infrastructure offers a competitive advantage in serving domestic and global green hydrogen demand. Freeport Saldanha is supported by a dedicated rail line which connects to Sishen & Kolomela mines in the Northern Cape, and the Saldanha SEZ (SBIDZ, 2023a). Additionally, the N7, R27, N1 and N2 national routes are part of the regions' proclaimed roads (Krie et al., 2017; WCDM, n.d.).
- **Access to skilled workforce:** Freeport Saldanha offers three development programmes (Lakabane, 2021):
    - Skills development – To facilitate the development of local skills in the maritime and energy sector within the Saldanha Bay municipality area to be able to respond to investor skills demand (Lakabane, 2021). Figure 20 shows the skills demand at Freeport Saldanha.

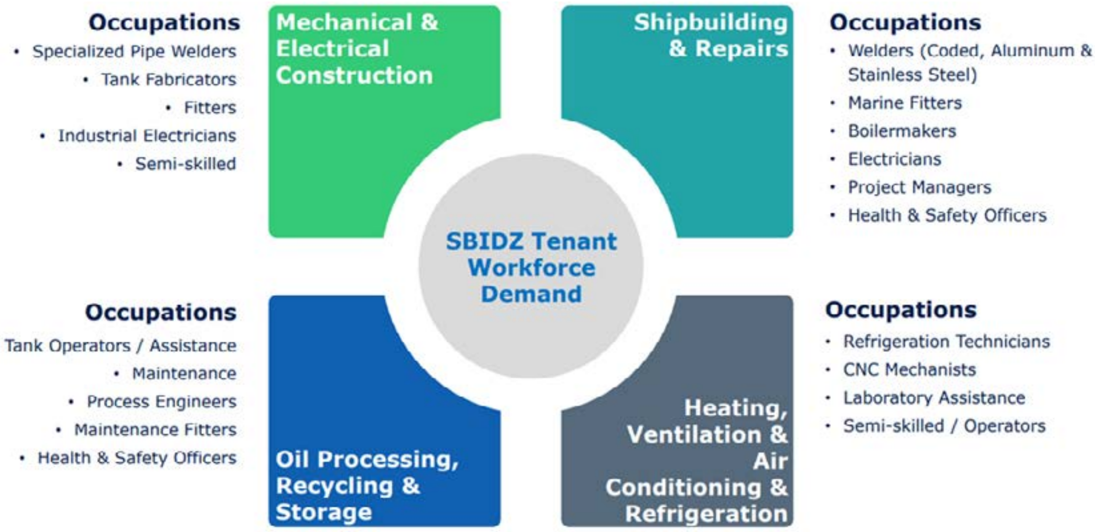


Figure 20: Freeport Saldanha skills demand (Lakabane, 2021)

- Enterprise development – To build necessary skills capabilities for small, medium, and micro enterprises (SMMEs) in the marine and energy sectors for them to participate in current and future zone-related projects
- Contractor development – To capacitate local contractors and suppliers to effectively respond to infrastructure project needs

  Furthermore in 2022, the Chemical Industries Education and Training Authority (CHIETA) opened a SMART Skills Centre in Saldanha Bay to develop digital skills required in the future. The programme was developed in partnership with CHIETA, Freeport Saldanha, the National Electronic Media Institute of South Africa (NEMISA), and the Media, Information and Communication Technologies Sector Education and Training Authority (MICT SETA) (SA News, 2022). The centre's services will include training courses aimed at job seekers, business start-ups, and SMMEs that wish to grow their operations (DHET, 2022).

  Moreover, the Western Cape is home to two of three of hydrogen South Africa's centres of competency (i.e., HYSA catalysis at University of Cape Town and HYSA system at University of the Western Cape). Additionally, the University of Stellenbosch offers specialised hydrogen related courses.

- **Existing industries:** AMSA, South Africa's largest steel producer closed its Saldanha steel plant in 2020 due to high electricity cost port tariffs and rail regulated factor costs, the loss of beneficial iron ore pricing, and reduced access to developmentally priced domestic coal, which eroded savings made from improved production efficiencies and reduced fixed costs (AMSA, 2020). There are however plans to revive the plant to produce green steel using hydrogen (IOL, 2022). Subject to regulatory and funding arrangements being made and affordable renewable energy and rail transport being secured, AMSA project that Saldanha could produce 600,000 tonnes of steel per year by as early as 2023. At 104,000 tonnes per year, AMSA projects that Saldanha Works could account for South Africa's largest single private-sector off-taker of green hydrogen, catalysing the development of a green hydrogen industry (ArcelorMittal, 2023).

- **Electricity supply:** The Western Cape aims to reduce reliance on Eskom and mitigate the impacts of load-shedding through its energy resilience programme. The targets for reduced reliance on Eskom are as follows:
    - Reduce off-take between 500MW – 750MW by 2025,
    - Reduce off-take between 750MW – 1,800MW by 2027, and
    - Reduce off-take between 1,800MW – 5,700MW by 2035.

In January 2023, the Western Cape established an Energy Council whose purpose is to identify and implement solutions to mitigate the impacts of load-shedding as well as ensure the implementation of the province's energy strategy (WCG, 2023b).

Constraints

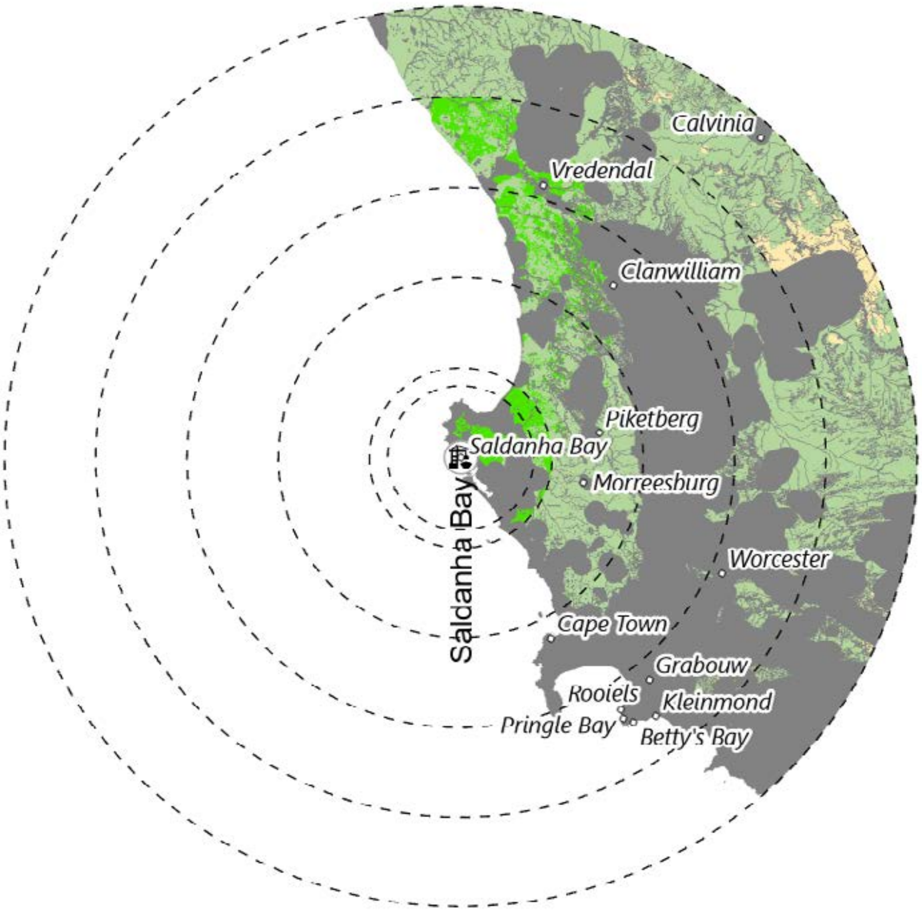
- **Water:** Saldanha Bay is water constrained. As a result, this hinders the development of large-scale water-intensive energy projects. However, Freeport Saldanha encourages water-intensive industries to use treated effluent water/groundwater. This also offers an opportunity to attract additional industries and for the region to meet sustainable development goals (SDGs) (SBIDZ, 2020).
- **Land:** Suitable land for project development depends on environmental status and zoning (SBIDZ, MoM).
- **Electricity:** The current energy crisis and the predictability of future energy costs remain challenges. Like the case of the COEGA IDZ, the Eskom GCCA report indicates that the grid is constrained in areas where renewable energy projects have largely been developed in South Africa. This includes the Eastern Cape, Western Cape, and Northern Cape (Eskom, 2022).

6.3.6 Social-environmental considerations

Freeport Saldanha is committed to the overarching policy and planning context at national, provincial and local levels, ranging from the NEMA to the Western Cape Spatial Development Framework (WCG, 2014) and the Saldanha Bay Infrastructure Development Plan (SBM, 2022b). Despite being a relatively newly established IDZ, Freeport Saldanha has made significant strides insofar as corporate social responsibility, development programmes and building in-house capabilities to support environmental and other permitting processes (Figure 21).

Figure 21: Freeport Saldanha's main social-environmental sustainability initiatives and ambitions (SBIDZ, 2022; Conservation South Africa, 2022)

According to the H2.SA green hydrogen potentials atlas, the Saldanha Bay region is constrained by agriculture, protected areas, densely populated areas and steep slopes of the Hottentots Holland, Wellington and Hex River mountain ranges between Cape Town and Clanwilliam (see Figure 22). Opportunities in the region are largely driven by good RE resources and decreasing land use constraints and conflicts moving northwards up the coast and further inland. The atlas provides a point of departure for consideration of environmental and social constraints to avoid and identify least-risk opportunities within proximity to the Freeport Saldanha to explore. As outlined in section 6.1.6, investment and development decisions must be based on finer scale investigation, ground truthing and stakeholder engagement.



SALDANHA BAY		
Land surface within 250 km (ha)	Land surface within 250 km (%)	GH_2/PtX Export Potential
5,027,431	64.2 %	Likely constrained
117,202	1.5 %	Acceptable
2,380,297	30.4 %	Suitable
301,622	3.9 %	Most suitable
7,826,553		

Figure 22: Freeport Saldanha green hydrogen/PtX export potential (CSIR, 2023)

6.3.7 Market potential/ Value proposition

Product offerings and possible market demand

Table 2 below shows the potential domestic off-takers for green hydrogen produced at Freeport Saldanha for PtX products.

Table 2: Freeport Saldanha green hydrogen potential off-takers and demand (Global Maritime Forum & University College London, 2022; T. Roos et al., 2022)

Off-taker	Hydrogen demand
Transnet – bunker fuel	504 kt/y
Airports Company of South Africa – airport ground vehicles	0.96 kt/y
Passenger Rail Agency of South Africa – Cape Town Metrorail locomotive	6.6-11.0 kt/y
City of Cape Town – MyCiti buses	1.2 kt/y
ArcelorMittal – iron ore	104 kt/y

Competitive advantages

- IDZ located inside a port,
- One of six SEZs that have a full bouquet of SEZ incentives (i.e., Customs Controlled Area (CCA) status), which, among others, include reduced corporate tax incentives and exemption for import-export duties (which would help bring down the cost of hydrogen),
- Ease of doing business one-stop-shop located in the IDZ, and
- Easy access to logistics by sea, land, rail, and air access.

Available resources

- **Land: I**DZ has 356 ha of land, of which 200 ha are currently leased (100 ha allocated for investors that need to close out certain conditions). The IDZ therefore needs to expand but there are limitations on the ability to secure new land: 1) land is privately owned and 2) IDZ cannot afford to purchase new land. Private sector players are however able to purchase land and conclude back-to-back leasing agreements with the IDZ on the land (SBIDZ MoM, 2023).
- **Water:** AMSA and TNPA own desalination plants for their own use, the municipality has a licence for a desalination plant which could potentially be scaled to provide water, not only for residents but also for industry in Saldanha. Additionally, AMSA's prior greywater allocation could be made available for the development of green hydrogen projects (SBIDZ MoM, 2023). A desalination plant is housed in the Saldanha

Bay for Sea Harvest operations as well, it produces 1.15 Ml/day of potable water. Additionally, the Municipality has an EA for a 25 Ml desalination plant in Danger Bay.

- **Renewable energy:** Projects under consideration are in the pre-feasibility stage, Boston Consulting Group estimates there is 11.5 km² and 21 km² available for the development of wind and solar projects (SBIDZ MoM, 2023), respectively. This translates to a rough approximation of ~23MW of wind and ~1GW of solar. As aforementioned, South Africa has good potential to establish off-shore wind plants given its extensive coastline and off-shore wind resources see Figure 10. The 'Off-shore Wind Resource Assessment Off the South African Coastline', conducted by Freddie Inamboa and Kumaresan Cunden in 2019, included a site 570 km northwest of Saldanha Bay (Inambao & Cunden, 2019).

6.3.8 Customer segments

Aligned with current economic activities, Freeport Saldanha targets the following customers:

- Energy/heating,
- Emergency maritime response services,
- Maritime defence and surveillance,
- Fishing,
- Navigation,
- Logistics,
- Maritime transport,
- Carbon and renewable energy production,
- Off-shore and onshore field operations,
- Construction/Building,
- Chemical production,
- Ship/vessel building & repair,
- Manufacturing, and
- Business support services.

6.3.9 Financial information/ financial projections or revenue streams

The DTIC (national government) funds the IDZ's CAPEX while DEDAT (provincial government) funds the OPEX. Additionally, the IDZ generates revenue mainly from leasing land. Figure 23 below shows the funding model for the IDZ which includes funding for specific projects and other revenue such as administrative/management fees and interest (SBIDZ, 2022).

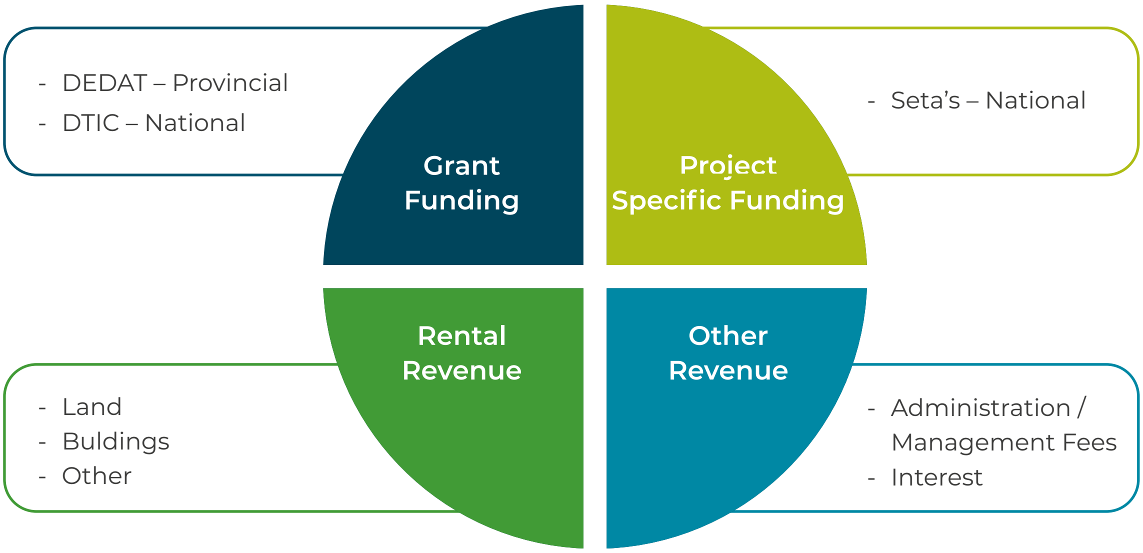


Figure 23: Funding model (SBIDZ, 2022)

6.3.10 Gap analysis

Infrastructure: As with the other SEZs/IDZs enabling infrastructure investment is required to accommodate green hydrogen production. This includes pipelines, servitudes, ports, road, rail, the development of desalination plants, hydrogen production and storage facilities. Ammonia production will require production plant, storage, and bunkering facilities (World Bank, 2024). Additionally, it should be noted that significant investment is required for upgrading the port infrastructure, and the transmission and distribution infrastructure since the substation (i.e., 400 MVA Aurora substation via a 132 kV line to the Blouwater substation) that feeds the Saldanha Bay area is already constrained on transmission capacity and requires further upgrades (SBIDZ, 2022; SBM, 2023a). The following port developments are envisioned in the short to long term: 1) Increase the footprints of the liquid bulk storage, energy and LNG; 2) additional berth facilities or liquid bulk; 3) marine services jetty; 4) floating dry dock; 5) Berth 205, potential maritime engineering, and other bulk cargo (IDC, 2024; Transnet, 2022b).

TNPA will invest 16.1 billion in infrastructure as part of its capital investment plan at the ports of Cape Town, Saldanha Bay and Mossel Bay. Of the total investment, 8.4 billion has been allocated to Saldanha Bay (Venter, 2022). Additionally, the Western Cape government has allocated ZAR 14.7 million to the Department of Infrastructure to further drive municipal Independent Power Producer (IPP) procurement, which will include the project preparation facility, the grid infrastructure development work, and exploring gas power (WCG, 2023a) The development of the Atlanthia green hydrogen project will lead to the deployment of solar and wind plants, and possibility of battery storage (BESS) technology, and a 40 MW electrolyser (VUKA, 2023). The development of the Saldanha green hydrogen project will lead to the deployment of 2.5 GW of renewable energy projects (Dosko, 2024).

Land: The green hydrogen vision in the IDZ envisages that the development value chain will require approximately 70 000 ha of land for renewable energy projects and 400 ha for green hydrogen production (SBIDZ, 2023b).

6.4 Boegoebaai SEZ

6.4.1 Overview

Boegoebaai is in the Richtersveld Local Municipality (LM) within the Namakwa District Municipality of the Northern Cape. It is situated ~60 km north of Port Nolloth and 20 km south of the border between Namibia and Souh Africa and has been identified as the primary site for the establishment of a new Boegoebaai SEZ to drive the development of green hydrogen mainly for export (Transnet, 2022b) (see Figure 24). It is a well-positioned site that lies a short distance between the coastline and relatively deep water. Furthermore, compared to other existing ports, the Boegoebaai location is uniquely positioned for being near rich mining and agricultural sectors.

Figure 24: Boegoebaai location map (DTLS, 2020; Global Africa Network, 2023c)

6.4.2 Economic activities

Once established, the Boegoebaai SEZ plans to host economic activities related to manufacturing, engineering services, and petrochemicals, among others as reflected in Figure 25.

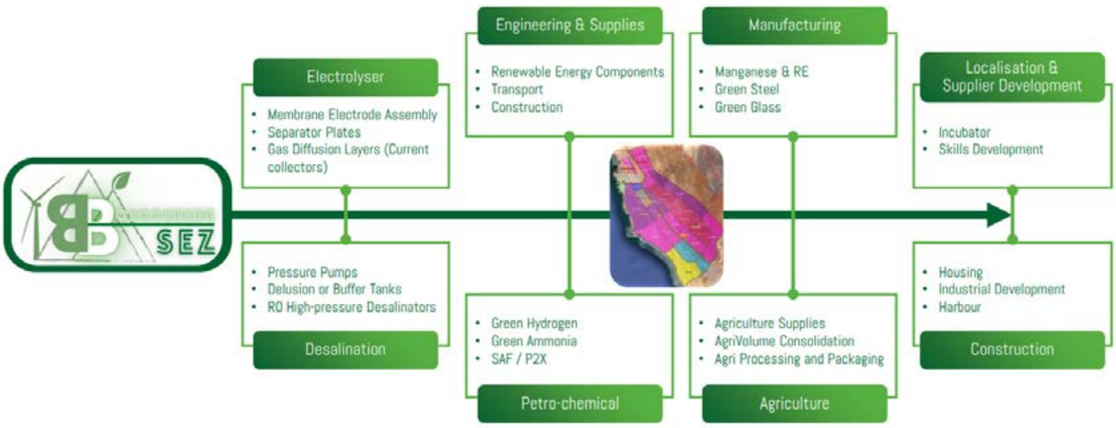


Figure 25: The economic activities of Boegoebaai SEZ (NCEDA, 2023a)

6.4.3 Green hydrogen vision

The Boegoebaai green hydrogen SEZ will be adjacent to the planned Boegoebaai port and is considered one of the first green hydrogen lighthouse projects to be developed in South Africa (NC, 2021). The SEZ aims to support 40 GW of electrolyser capacity by 2050 (Global Africa Network, 2023a).This plan complements the Northern Cape Green Hydrogen Strategy which was launched in 2021 at COP26 (Global Africa Network, 2023a). Additionally, Sasol is exploring the feasibility of establishing the Boegoebaai SEZ project as a green hydrogen export hub, positioning itself as an anchor investor (Sasol, 2023). Figure 26 gives an illustration of the envisioned phasing layout of the Boegoebaai SEZ.

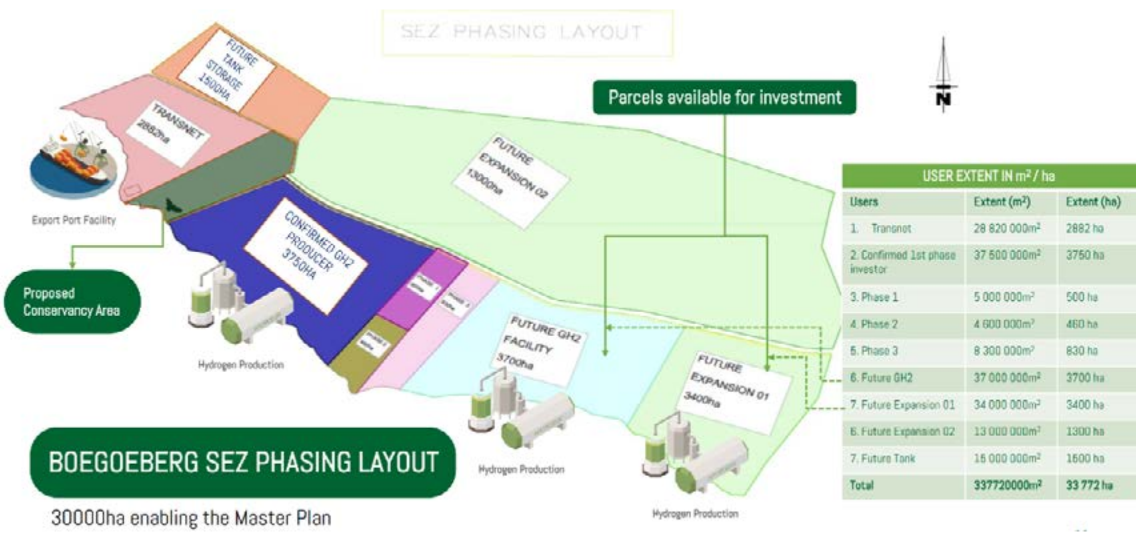


Figure 26: Boegoebaai SEZ phasing layout (NCEDA, 2023a)

Additionally, there are clear targets pertaining to green hydrogen and renewable energy production, and their associated markets and demands from 2023 - 2040 and beyond. These targets are illustrated in Figure 27. The aim is to (1) progressively scale up the green hydrogen operations to serve multiple export off-takers and the local market by 2040 as well as ultimately benefit the Southern African market, and (2) scale up renewable energy capacity to facilitate green hydrogen production (NCEDA, 2023c).

Figure 27: Northern Cape green hydrogen ambition and roadmap anchored on Boegoebaai SEZ (NCEDA, 2023c).

6.4.4 Technical specifications (available and planned)

There are plans to partner with the private sector for the development of a green hydrogen pipeline system to connect projects across the province to the SEZ and state-owned freight and logistics company, Transnet for the deployment of dedicated rail infrastructure to link green hydrogen producers to the SEZ, as well as other ports in the country by 2030 (Barradas, 2023a). TNPA reported that three consortiums, Boegoebaai Port and Rail Consortium, Boegoebaai Development Consortium and Project Elephant Consort, were selected to make firm proposals to build ZAR 50 billion Boegoebaai port and associated rail links to, among others, ship commodities, including hydrogen and its derivatives from northwest South Africa. Some of the identified groups' participants include Vopak, which operates 78 terminals in 23 countries and Port of Rotterdam, Europe's biggest harbour and energy import gateway. The port is expected to occupy 2, 882 ha and sit alongside a 1,500 ha tank storage area. The rail network would stretch ~800 km inland. The port is expected to begin operating in March 2030 and the rail links may be complete by May 2036 (Bloomberg, 2023).

The identified planned and available Infrastructure relevant to supporting the SEZ's activities includes ports, rails, and several plants and facilities, which are detailed and explored on the next page.

Ports and rail infrastructure: Transnet is forging ahead with several developments, including a new deep-water port and rail network to serve the proposed new Boegoebaai hydrogen production hub and mines in the Northern Cape (Global Africa Network, 2023a; Yono, 2021). The port will include the following infrastructure (Global Africa Network, 2023a; NCEDA, 2023d):

- Dry bulk terminal for exports
- Liquid bulk terminal to handle various bulk liquid products
- Multi-purpose container terminal

Deep-water port development comprises two berths, (1) dry bulk export berth and (2) break bulk berth, supported by a 550 km railway line, bulk services and associated social infrastructure. Regarding the project status, business case and feasibility studies reports have been completed and conditional approval from the National Treasury (Treasury Approval 1 – TA1) has been obtained. TA2 entailing form of request for qualification process has been undertaken (Global Africa Network, 2021c). Furthermore, the project is estimated to cost ZAR 13.8 billion with an internal rate of return of 13.3% (NCEDA, 2023d).

Existing road and rail infrastructure: The Trans-Oranje corridor links up with the southern Port of Lüderitz (in Namibia) and its entire length of tarred road network is supported by rail. Its road and rail network are perfectly positioned to service the two-way trade between Angola, Namibia, South Africa, Europe, the Americas and the Far East (WBCG, 2005). The Northern Cape roads include N7 and N14, which provide access to Namibia and Botswana.

SEZ infrastructure: The proposed SEZ is expected to feature the following infrastructure (Barradas, 2023a):

- Electrolyser park
- Desalination plant
- Green ammonia production plant
- Storage facility for green hydrogen and ammonia
- Solar, wind and battery park
- Supplier park for common components
- Gigafactory, comprising an advanced manufacturing site to ramp up the production of electrolysers

The construction of ~10 GW capacity of electrolyser is expected by 2025/26, and ~240 000 ha is allocated for the development of renewable energy generation infrastructure. A hydrogen production plant is already established, and the expanded development is expected to include ~60 000 ha adjacent to the existing plant.

6.4.5 Regional opportunities and constraints

Opportunities

SEZ/IDZ: Below are identified SEZs and industrial parks proposed in the Northern Cape province that are close to the proposed Boegoebaai SEZ.

- Namakwa SEZ: DTIC designated the Namakwa SEZ in May 2024. The value proposition of Namakwa SEZ is based on the existence of the Gamsberg zinc mine and the proposed building of a smelter by Vedanta Zinc International which would be the anchor tenants of the SEZ. Targeted activities include mineral beneficiation and green energy generation, construction, transport, agriculture, petrochemical, engineering supplies (Global Africa Network, 2023b).
- De Aar rail logistics hub: Targeted activities include logistics functions. The hub feasibility studies for the hub are complete and the analysis included a container terminal, vehicle parking terminal and warehouse (Global Africa Network, 2023a) (NCEDA & NCDEDAT, 2021).
- Kathu industrial park (KIP): The KIP targets economic sectors requiring serviced industrial space. However, the major portion of the initial tenant makeup primarily serves the established mining sector, by virtue of the KIP's central proximity to the Postmasburg-Hotazel iron-ore/ manganese belt. The KIP is also well-positioned to serve the emerging REIPPPP sector in the region (Global Africa Network, 2023a). The project has been submitted to Infrastructure South Africa to register as a catalytic project. It is located on the R380 and is easily accessible from the N14 and the Kathu airport.
- Upington industrial park: Upington Industrial Park forms part of the Northern Cape Industrial Corridor and is near Upington International Airport. Targeted activities include renewable energy (e.g., components manufacturing), aviation (e.g., maintenance, repair and overhaul facility and storage for aircraft), automotive (e.g., vehicle testing), agro-processing and logistics (Global Africa Network, 2023a; NCEDA & NCDEDAT, 2021).
- Metals industrial cluster: The project is anchored around steel manufacturing but makes allowance for other related industries to be hosted in the cluster. Targeted sectors include metals manufacturing, agriculture, mining, and construction. Project status: Project feasibility and business case completed. It is now in the establishment phase and located along the N14, approximately southeast of Kuruman (Global Africa Network, 2023b; NCEDA & NCDEDAT, 2021).
- Prieska power reserve: It is a catalytic project that focuses on producing green hydrogen, and ammonia using renewable energy sources including 180 MWp solar (fixed-tilt and single-axis tracking), 130 MWp of wind and 110 MWh of battery storage (Global Africa Network, 2023a). The facility will include 140 MW electrolyser and 300 mtpd ammonia synthesizer. About 77,000 tonnes of green ammonia/year and 12,900 tonnes of green hydrogen/year in the beginning of 2025 and expected to escalate to 500,000 by 2030 (Mahlako, 2022; Prieska Power Reserve, 2021).

In addition to the Boegoebaai green hydrogen project and the Prieska power reserve, both of which are registered as Strategic Infrastructure Projects (SIPs), two additional hydrogen-related projects have been registered with the ISA in the Northern Province: the Ubuntu Green Energy Hydrogen Project and the Upilanga Solar and Green Hydrogen Park. Additionally, the Enertrag Postmasburg ammonia project is pending SIP registration (DPWI, 2022b).

REDZ and EGI corridor: Four of the 11 REDZs are located in the Northern Cape, with Springbok being the closest to the planned Boegoebaai SEZ (DFFE, 2018; Global Africa Network, 2021b). The majority (62%) of the solar photovoltaic and onshore wind (35%) energy projects in South Africa are in the Northern Cape and the renewable energy sector is becoming a significant economic driver for the region. REDZs seek to encourage localisation through the development of manufacturing hubs that can make components for the sector (Global Africa Network, 2021b).

The planned Boegoebaai SEZ is near the northern EGI corridor, while the western EGI corridor is partially located within the northern province. The expanded western EGI corridor is predominantly located in the Northern Cape province, near the planned Boegoebaai SEZ. The key towns within the corridor, from north to south, are Alexander Bay, Port Nolloth, Springbok, and Hondeklipbaai. This will lead to significant benefits for electricity generators, including renewable project development by providing an expedited EA process via the adoption of a streamlined EA process (Laurie et al., 2019).

Existing industries: the major existing industries in the Northern Cape which can be potential anchor customers for the green hydrogen-products produced at Boegoebaai include agriculture, mining (iron, manganese) and manufacturing (cement and steel) (DTIC, 2022b).

Constraints

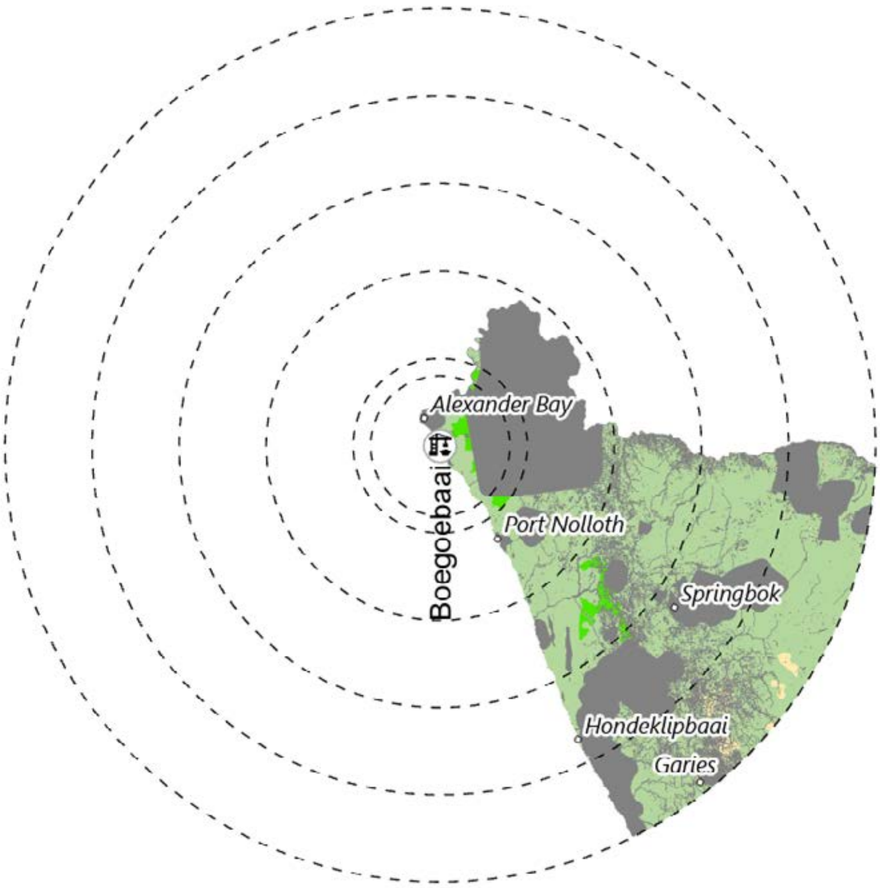
Constrained grid capacity: Eskom's GCCA report also identifies the Northern Cape as an area with severe grid constraints. Therefore, there will need to be a prioritisation of expanding the grid in these constrained areas (Eskom, 2022). Other challenges faced by the Northern Cape province include limited logistics and industrial infrastructure (DTIC, 2022b).

Skills availability: Retention of key skill sets has been identified as a challenge for the province. However, skills development and training initiatives are being put in place, and the most recent interventions include the Northern Cape province signing of an MOA with the Manufacturing, Engineering and Related Services Sector Education and Training Authority (Hoo, 2023). Additionally, there is a planned collaboration between CHEITA and NCEDA, which seeks to ensure a well-coordinated and shared response towards skills planning for the green hydrogen economy (Hydrogen Africa, 2023). The province of Northern Cape is only home to one university the Sol Plaatje University which does not offer an engineering programme, but natural and applied science are among its programmes.

6.4.6 Social – environmental considerations

The Boegoebaai SEZ is still in early development planning phases and will be subject to various investigations and assessments to obtain the relevant approvals and permits. The proposed greenfield development in a remote and rural region of South Africa is poised to be implemented in a manner that is socially and environmentally responsible.

According to the H2.SA green hydrogen potentials atlas, the Boegoebaai region presents some opportunities, and are especially favourable from an RE resource perspective. There are numerous large protected areas in the region, and enabling infrastructure is sparse (see Figure 28). However, abundant RE resource potential and limited agricultural land use (mainly due to the region's aridity) present opportunities. The atlas provides a point of departure for consideration of environmental and social constraints to avoid and identify least-risk opportunities within the Boegoebaai region to explore. As outlined in section 6.1.6, investment and development decisions must be based on finer scale investigation, ground truthing and stakeholder engagement.



BOEGOEBAAI		
Land surface within 250 km (ha)	Land surface within 250 km (%)	GH_2/PtX Export Potential
2,005,538	50.7 %	Likely constrained
30,868	0.8 %	Acceptable
1,868,815	47.2 %	Suitable
50,729	1.3 %	Most suitable
3,955,950		

Figure 28: Boegoebaai green hydrogen/PtX export potential (CSIR, 2023)

6.4.7 Value proposition

Competitive advantages.

The Boegoebaai SEZ will boast unique advantages, including, amongst others:

- Access to the Americas and European market,
- Option to upscale freely for future production,
- Incentivised renewable energy production, and
- Possibility to anchor local hydrogen uptake through the mining industry (DTIC, 2022b).

There is also a potential R13 billion investments into iron ore/manganese export port infrastructure (DTIC, 2022b).

Available resources

Other enabling factors include available resources, mainly renewable energy resource potential, land availability and water supply.

- **Land availability:** Boegoebaai has large tracts of land (M. Creamer, 2022). About 98% of the Northern Cape land is considered flat and suitable for renewable energy development while ~57% of the land is available for solar and wind energy (NCEDA, 2023b)
- **Renewable energy potential**: Renewable energy potential includes solar and wind energy with average capacity factors of 26% and 37%, respectively. Additionally, about 11,400 GW capacity and 846 GW capacity of solar and wind energy can be developed in the province (NCEDA, 2023b). Sasol plans to deploy ~10GW of renewable energy capacity (Northern Cape & NCEDA, 2023).
- **Water supply:** Desalination plants will be built to support the green hydrogen economy in the Northern Cape. Any excess desalinated water can be used to address water security issues and provide a diversified water mix within the region. With 300 km of shoreline, the province also provides convenient access to an ocean water source (Northern Cape & NCEDA, 2023).
- **Products:** All these enabling factors complement the ability of the SEZ to carry out its intended activities and be able to offer green hydrogen and its derivatives for both domestic use and exports. Upon successful implementation, the Boegebaai SEZ is expected to produce 4 kt of green hydrogen per year, which will also unlock opportunities to create 4,000 jobs (Yono, 2021). It has the potential to produce up to 400 kt of green hydrogen per year, which will require renewable energy of 9 GW or about 20% of South Africa's current installed energy capacity (BusinessTech, 2022).

6.4.8 Customer segments

Regarding the targeted customer segments, local agriculture and mining sectors are targeted to convert their energy demands to green hydrogen and renewable energy while establishing downstream beneficiation that will tap into green hydrogen. Furthermore, local transport and mobility sector is also among the sectors targeted to decarbonise by using green hydrogen (NCEDA & NCDEDAT, 2023). Anglo American is one of the biggest investors in the Northern Cape and is running a project to power its trucks with green hydrogen. Its plans involve turning its entire truck fleet to run on hydrogen at all its mines including the Norther Cape province (Global Africa Network, 2023a).

6.4.9 Gap analysis

Investment in infrastructure is required particularly in the grid, roads, rail, ports, and pipelines, among other things, to ensure the successful establishment of the hydrogen industry. Green hydrogen-related infrastructure that will be required include (NCEDA, 2023b):

- Water desalination plant,
- Electrolysis plant,
- Synthesis plant, and
- Storage and renewable energy facilities, including renewable energy components.

CHAPTER 7

Potential Green Hydrogen Competitors

7 POTENTIAL GREEN HYDROGEN COMPETITORS

According to the Hydrogen Council, over 30 countries are developing roadmaps or strategies to set out their intentions to use hydrogen for the decarbonisation of applications where it is not feasible to use renewable electricity directly. Most countries, like South Africa, are targeting green hydrogen production using solar and wind energy for either domestic and/or export markets. In this section of the report a few countries' hydrogen activities have been profiled to highlight the developments in other countries and potential competition for South Africa's green hydrogen aspirations. The countries include Chile, Namibia, Morocco, Egypt, China, the United States of America (USA), the United Arab Emirates (UAE) and Australia.

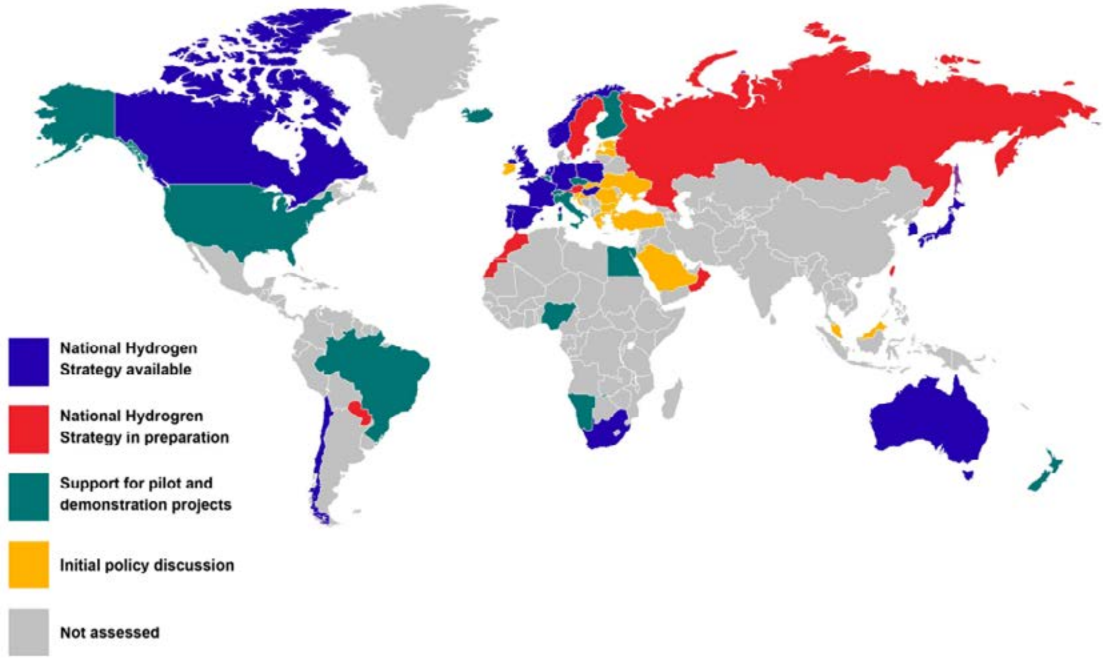


Figure 29: Global hydrogen activity (eThekwini Municipality, 2022)

7.1 Chile

7.1.1 Overview

Chile uses grey hydrogen in the refining, food, glass, and power generation industries. Approximately 58,500 tonnes of hydrogen is produced annually and 98% is used by refineries and the rest by food and glass manufactures (CMS, 2021). Additionally, the mining sector uses imported grey ammonia to produce ammonium nitrate explosives (Martin, 2023). Although the country contributes only 0.3% to global emissions, it has committed to transition to a low carbon economy (Ministry of Energy, 2020).

To showcase its efforts, Chile is exploring the opportunity of developing a green hydrogen industry to take advantage of its renewable resource potential. To make this a reality, in 2020, the Chilean government published its National Green Hydrogen Strategy (Ministry of Energy, 2020). The strategy outlines Chile's goal to become the most cost-effective producer of green hydrogen by 2030 and exporter of green hydrogen and its derivates in the long term. According to the strategy, to reach the goal, Chile aims to produce 5GW of electrolysis by 2025 and 25 GW by 2030 (McKinsey, 2020; Ministry of Energy, 2020). The deployment of green hydrogen will be in six applications to develop a local supply chain and experience. Applications include oil refineries, ammonia, mining haul trucks, heavy-duty trucks, long-range buses and blending into gas grids (Cortés Leiss et al., 2023). Three of the six applications (i.e., mining haul trucks, long-range buses, and heavy-duty trucks) are directly associated with the mining industry which is a significant contributor to the country's economy (Chavez-Angel et al., 2023). Therefore, green hydrogen is an opportunity to decarbonise local mining and transportation sectors.

According to the strategy, to develop the green hydrogen industry and create an enabling environment, Chile has identified 4 actions which are described in Figure 30 below (Ministry of Energy, 2020).

Promotion of domestic and exports markets	• Launch of a funding round of up to 50 MUSD to support green hydrogen projects • Establishment of a public-private roundtable, to discuss the path towards a carbon price and taxes that better reflect the externalities of fossil fuels used in Chile. • Chile will deploy a green hydrogen diplomacy to position itself internationally as a source of clean fuels and energy carriers
Standards, safety and piloting	• Bridging of regulatory and standards gaps throughout the hydrogen value chain to ensure safety and give certainty to investors. • Establishment of a task force to accompany developers in permitting and piloting processes for green hydrogen projects and derivatives. • Review of natural gas regulation and infrastructure to promote the introduction of green hydrogen quotas
Social and local development	• Creation of early and transparent participatory mechanisms between communities and projects. • Exploration of green hydrogen uses to replace or complement fossil fuel-based generation in isolated electric systems. • Assessment of opportunities and challenges offered by green hydrogen to territorial plans, policies, and distribution.
Capacity building and Innovation	• Industry, academia, and technical centers will work together to identify gaps and prepare national capabilities to supply a new, burgeoning industry. • An R&D roadmap to solve local implementation challenges will be constructed by the public and private sectors. • A work group with public companies will be created to accelerate the adoption of green hydrogen in their activities and in their supply chain.

Figure 30: Chile National Green Hydrogen Strategy Action Plan (Ministry of Energy, 2020)

To showcase the country's efforts in developing the green hydrogen industry, in 2023, the Chilean Government and the European Union launched "Team Europe Project for the Development of Renewable Hydrogen in Chile", a technical assistance program that will strengthen the conditions for the promotion of the hydrogen economy in Chile. The conditions include enabling environment, capacity building and knowledge transfer, technology development, generation of impact assessments on infrastructure and sustainability, as well as the development of projects and business cooperation and financing. The project will be financed by the EU and German Federal Ministry of Economics and Climate Protection, each contributing EUR 4 million (EEAS, 2023).

Additionally, the Chilean government announced the creation of a USD 1 billion fund, financed by the Inter-American Development Bank (USD 400 million), the World Bank (USD 150 million); the German Development Bank KfW (USD 100 million); and the European Investment Bank with (USD 109.67 million), among others. This financing program is set to begin in the second half of 2024. The fund will assist in promoting the development of green hydrogen projects as well as mitigate the financial risks and reduce costs associated with the development of these projects (Dentonnes, 2023; EEAS, 2023).

7.1.2 Renewable energy potential

Chile has vast potential in solar and wind resources. The country has one of the world's best radiations and its solar generation is more competitive in comparison to fossil fuel electricity generation. The solar resource potential is in northern regions close to large consumption centres, gas grids, and logistical hubs, such as ports and distribution centres. The north of Chile has a solar potential of 1,260 GW for solar PV and 550 GW for concentrated solar power. Monofacial solar PV plants have the potential to achieve a 35% capacity factor. The country's wind resources are located in the south (Team Europe Initiative, n.d.) and have a capacity factor exceeding 60% which can be achieved for 120-meter-high wind turbines which is equivalent to off-shore performance in other countries (Ministry of Energy, 2020). The capacity factors of wind and solar in comparison to the other countries are shown in Figure 31.

The installed capacity for wind and solar in the region is estimated to be approximately 1,800 GW. The levelised cost of electricity (LCOE) for this installed capacity is estimated to be less than USD 35/MWh. This LCOE is low in comparison to the 2019 global weighted average LCOE of USD 53/MWh (wind onshore), USD 115/MWh (wind off-shore), and USD 68/MWh (solar). The global installed capacity in the same period was 622 GW and 580 GW, respectively for wind and solar (Cortés Leiss, 2022).

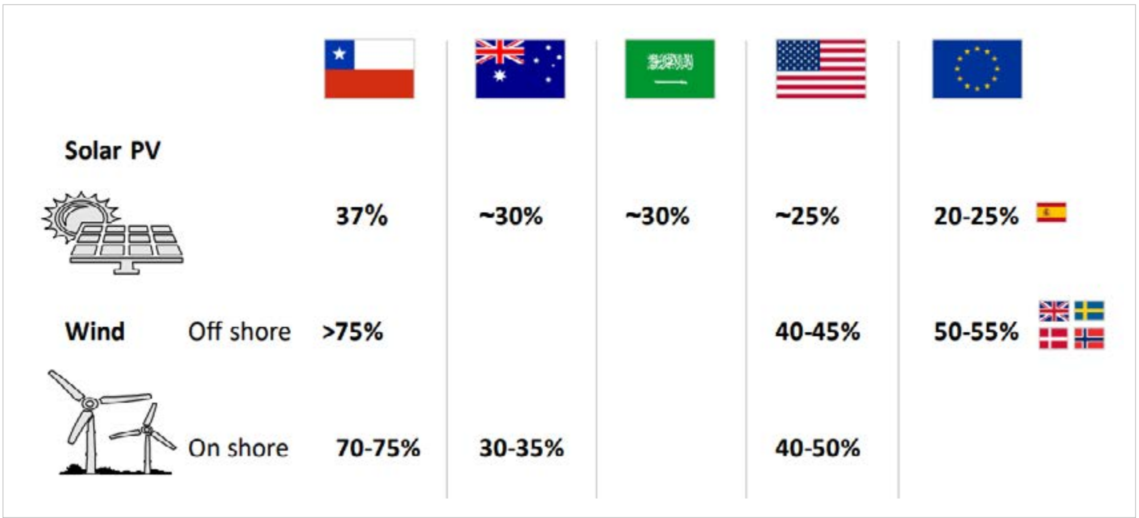


Figure 31: Capacity factors per country (Ministry of Energy, 2021)

7.1.3 Green hydrogen production and infrastructure

The Chilean government aims to produce approximately 13% of the world's green hydrogen demand potentially using 126 GW of wind energy (Bartlett, 2022). Domestic demand is estimated to account for 3 Mt of total hydrogen demand by 2050, with most demand coming from the transport sector (McKinsey, 2020). By 2030 the country envisions producing the cheapest green hydrogen at approximately USD 1.50 kg (Villagrasa, 2022).

However, there is a lack of existing transport and storage infrastructure for the development of a green hydrogen value chain (Deakin, 2022) Additionally, Chile is not near major hydrogen export markets such as the United States, Europe and China and therefore requires the development of new pipelines or the adaptation of existing pipelines which will require substantial investment.

Moreover, this would require the establishment of two potential hydrogen hubs (i.e., Antofagasta and Magallanes regions). Antofagasta has a solar potential of 1,400 GW and the Magallanes region has an onshore wind potential of approximately 130 GW. The two regions should be selected based on existing infrastructure (e.g., ports, transmission grid), proximity to domestic demand, synergies with existing industries (e.g., mining and ammonia) (Cortés Leiss et al., 2023), local capacities (e.g. availability of skilled workers), hazard risks and the local development of hydrogen projects, among others (Altmann et al., 2022). Export-scale hydrogen projects are planned for both regions (BNamericas, 2023).

7.1.4 Exports

The domestic market application in oil refineries, mining trucks, and heavy trucks will enable the country to compete in the international export market. Chile aims to export green hydrogen, green ammonia and e-fuel exports. The targeted countries for these exports are Europe, China, Japan/Korea, the USA, and Latin America. Figure 32 shows the estimated market size and period for Chilean exports (Ministry of Energy, 2020).

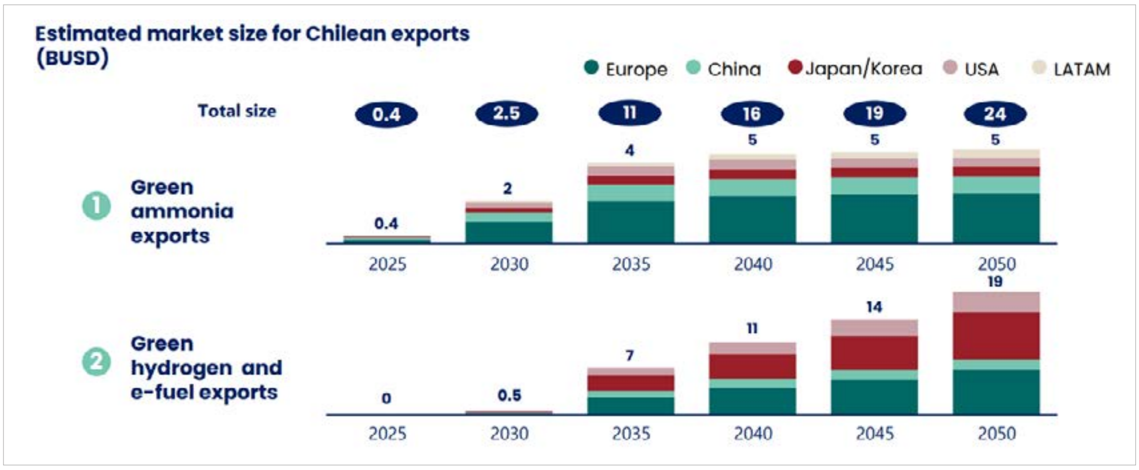


Figure 32: Estimated market size for Chilean exports (Ministry of Energy, 2020)

This opportunity will unveil in 3 distinct waves:

1. **Short term:** Green hydrogen will be used to supply the domestic market, produce green ammonia and replace grey hydrogen used in oil refineries.
2. **Medium term:** Opportunity for green hydrogen and green ammonia exports.
3. **Long-term:** Scale-up of green hydrogen production due to increased export markets. Furthermore, the decarbonisation of the aviation and shipping sector in domestic and international markets through the use of green hydrogen fuels.

Table 3: Chile planned projects (Cortés Leiss et al., 2023; SGE, 2022)

Project Name	Description	Estimated commissioning date
Atacama Hydrogen Hub Project	Large-scale electrolysis facility with export potential and hydrogen fuel cell-powered freight train	2027
HyEx Project	Green ammonia production in the north of Chile for domestic and international consumption, replacing ENAEX ammonia imports	2025
Green Steel Project	Green hydrogen blending into CAP's blast furnaces to reduce consumption of coke and eventually replace it entirely with steel production.	2025
HIF Project	Industrial-scale plant in Magallanes which produces synthetic climate-neutral fuels for export.	2022
Quintero Bay H_2 Hub Project	Production of green hydrogen in the central zone of Chile, close to potential off-takers.	2025
HNH ENERGY Project	Large-scale green ammonia production in Magallanes for export.	2027

7.2 Namibia

7.2.1 Overview

Namibia is a net energy importer. This implies that the country imports all fossil fuels for electricity generation mainly from South Africa, Zimbabwe and Zambia (GIZ, 2022; OEC, 2021). Additionally, Namibia mostly generates its electricity from hydropower (AFREC, 2020). Green hydrogen is an opportunity for the country to decarbonise, diversify its energy mix, develop new industries such as domestic steel manufacturing and zinc processing, stimulate economic growth and position itself as an export hub (Atlantic Council, 2021; NIPDB, 2022).

In 2022, Namibia published its Green Hydrogen and Derivatives Strategy which outlines the country's vision to produce green hydrogen by leveraging its renewable energy resources potential. Namibia aims to become a net exporter of green hydrogen and meet the 10 million tonnes of global demand by 2030 (MME, 2022). To establish the hydrogen industry, Namibia plans to develop:

- **Skill development and labour strategy:** Map out the resources and skills needed, identify how to close gaps and develop programmes.
- **Purpose regulatory and institutional framework:** Introduction of regulations and policies to create an enabling environment.
- **Modern delivery support system:** Set up the structures and processes required to create a transparent, streamlined, and user-friendly process for all stakeholders in prospective hydrogen projects through the assistance of the Implementation Authority Office.
- **Shared infrastructure:** Establish a common use infrastructure for the first large-scale hydrogen projects to enable integration of hydrogen clusters and lower costs.

To raise the required funding to develop the hydrogen industry, in 2023, the Namibian government announced the conclusion of agreements for the establishment and management of SDG Namibia One, a blended financing infrastructure fund which is going to be used to raise funds for investors to develop hydrogen projects in the country. Invest International is set to provide EUR 40 million in grant funding while the European Investment Bank has signed a letter of intent with Namibia to raise EUR 500 million of which a portion of it will go to the SDG Namibia One (Creamer, 2023; EIF, 2023).

7.2.2 Renewable energy potential

The low-cost favourable wind and solar resources will enable Namibia to produce hydrogen and become a green hydrogen exporter. By taking advantage of these resources, the country could achieve a levelised cost of hydrogen of USD 1.2-1.3/kg for production by 2030 which exceeds that of Morocco and Saudi Arabia at USD 1.7/kg. Furthermore, wind resources in the south and north coast have wind capacity factors of approximately 56% -58%, exceeding that of potential exporters such as Australia and South Africa which average at less than 40%. For solar, the capacity factors are approximately 33%-35%. (MME, 2022).The cost of producing hydrogen from renewable energy sources remains high in comparison to fossil fuels sources, and therefore require incentives and government interventions (Detlof von Oertzen, 2021).

7.2.3 Green hydrogen production and infrastructure

Namibia aims to produce 5-8% of (~10-15 million tonnes per year) of global green hydrogen production volume by 2050. By 2030, green hydrogen and ammonia could be produced at the cost of USD 1.5 /kg hydrogen (MME, 2022). The estimated domestic demand for hydrogen and its derivatives could reach 95 kt of hydrogen equivalent by 2040 (MME, 2022).

As outlined in its strategy, the country plans to set up three hydrogen valleys (see Figure 33) which will produce ammonia, synthetic fuels and HBI in the southern region (Kharas) the central region (including Walvis Bay port and the capital Windhoek) and the northern region (Kunene). The southern region and northern region have good renewable resources (MME, 2022). The southern region further has the port, Luderitz. These enable the development of a large hydrogen infrastructure. The central region is closer to the export infrastructure (i.e., Walvis Bay Port), has access to domestic biogenic carbon sources and has the required labour force. Namibia plans to further invest in infrastructure and is considering upgrading the Walvis Bay port and establishing a SEZ (MME, 2022).

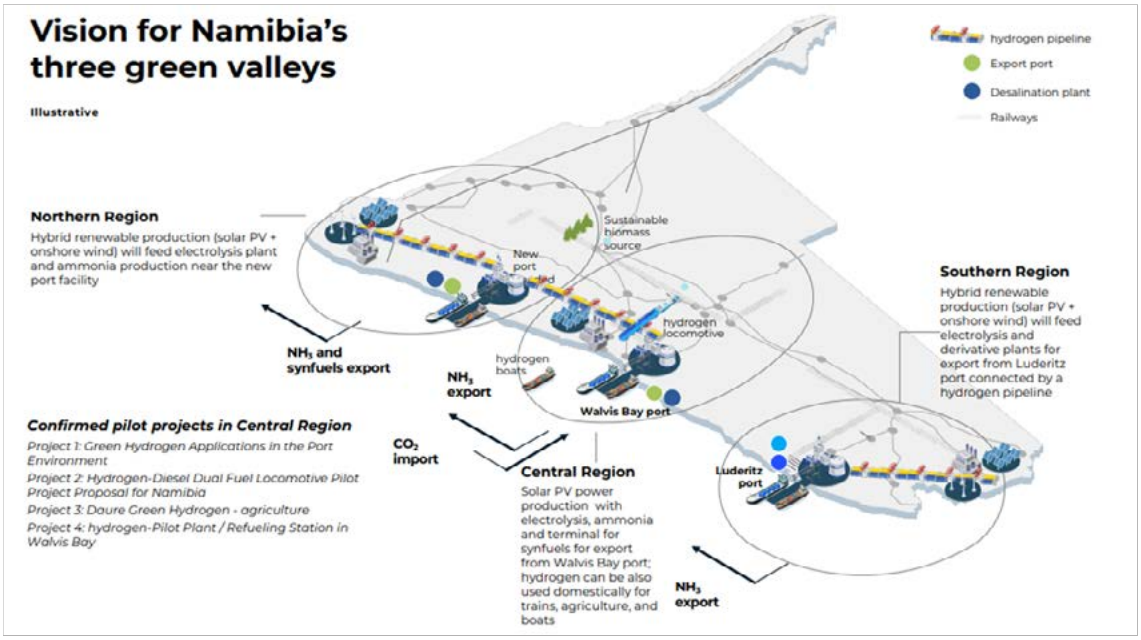


Figure 33: Namibia's planned three green valleys (MME, 2022)

However, it should be noted that Namibia has several challenges to develop the green hydrogen market such as infrastructure and water which are described below:

Infrastructure: Currently, Namibia does not have the production, distribution and transport infrastructure required for green hydrogen development. Another challenge is that Namibia is not close to hydrogen consuming industrial markets such as Europe. Therefore, this requires investment in hydrogen enabling infrastructure such as seawater desalination plants, pipelines, storage, liquefaction, harbour and shipping facilities (Robin Sherbourne, 2022). Furthermore, its electricity transmission infrastructure and the Lüderitz harbour's freight handling capacities for exports is limited.

Water: Namibia is a water scarce country with a water scarcity risk classification of extreme. This implies that the current water quantities cannot meet green hydrogen production water requirements (Detlof von Oertzen, 2021).

Other challenges include (list not exhaustive) (M. de Roos, 2022):

- Lack of practical and technical expertise
- Uncertainty of demand
- Limited subsidies available
- Limited financial resources
- Little expertise within universities

7.2.4 Exports

Namibia is set to focus on exporting green hydrogen derivatives including ammonia, methanol, synthetic kerosene and hot- briquetted iron to Europe, Japan, South Korea and China (MME, 2022). To date, Namibia has concluded bilateral agreements with Germany, The Netherlands and Belgium (CDH, 2022).

Namibia will explore the potential to export ammonia in the short-medium term and biogenic CO_2 synthetic fuels (i.e., methanol, synthetic kerosene) in the long-term. Demand for hydrogen for the production of ammonia, methanol and synthetic kerosene as clean fuels is estimated to reach 110 Mt (MME, 2022).

Table 4: Namibia planned projects (Africa Energy Portal, 2022; T. Creamer, 2021)

Project Name	Description	Estimated Commissioning date
Cleanergy	Construction of a pilot plant for green hydrogen and green ammonia production plant for applications such as heavy-duty transport, including trucks, locomotives, mining equipment and ships.	2023
Hyphen	Construction of a two GW of renewable-electricity generation capacity, and electrolyser capacity to produce green hydrogen for conversion into green ammonia. The plant will be able to produce 300,000 tonnes per year of green hydrogen and green ammonia for export into regional and global markets from 2026 onwards.	2026
Renewstable Swakopmund Project	Facility including 85 MW solar PV plant, hydrogen fuel cells, battery storage, desalination and hydrogen plant.	2024

7.3 Morocco

7.3.1 Overview

Morocco's energy sector is highly reliant on imports. Imports account for 90% of the country's primary energy consumption. Imported fossil fuels including refined oil, gas, and coal (ITA, 2022b). Furthermore, the country imports approximately 2 million tonnes of ammonia from the chemical and industrial sectors (GGGI, 2021). Therefore, to reduce dependence on imports and ensure energy security, the Moroccan government seeks to leverage its renewable energy potential to produce green hydrogen. Green hydrogen is an opportunity to decarbonise the country's economy, strengthen energy security, and replace imports of ammonia with local production (GGGI, 2021). In 2021, Morocco published the National Roadmap for Green Hydrogen. The roadmap sets outs Morocco's plan to create an economic and industrial sector around green molecules (i.e., hydrogen, ammonia and methanol) and identifies the following eight actions for the development of green hydrogen: Cost reduction; research & innovation; local content; industrial cluster; domestic markets; storage; exports; financing. Further description of each action is shown in Figure 34 below (Ministry of Energy Transition and Sustainable Development, 2021).

Furthermore, to develop the green hydrogen economy approximately USD 60 million investment has been planned for green ammonia and green hydrogen projects (Zawya Projects, 2023).

7.3.2 Renewable energy potential

Morocco has good wind and solar resources. The country's average solar irradiation exceeds 5 KWh/m² while the average annual wind speed for off-shore and onshore wind fields exceeds 10 m/s (Res4Africa et al., 2022). The total installed capacity for solar and wind currently amounts to 831 MW and 1,466 MW respectively (ITA, 2022b). By 2030, the country envisions that 52% (i.e.,7,300 MW) of total installed capacity will come from renewable energy sources. To meet the 2030 target, the country aims to add approximately 10 GW of RE capacities consisting of 4,560 MW of solar, 4,200 MW of wind, and 1,330 MW of hydropower capacity (IEA, 2019).

7.3.3 Green hydrogen production and infrastructure

Morocco aims to produce 4% of global hydrogen demand. The estimated cost of production is estimated between USD 0.7/kg and USD 1.4/kg in 2050 (Anouar, 2022). To produce, Morocco has extensive experience in the development of large-scale energy projects and infrastructure. The existence of large-scale energy projects and infrastructure such as ports, high-speed line trains, mining, ammonia production plants make the development of the green hydrogen market feasible (Res4Africa et al., 2022). The country's maritime transport infrastructure is also an enabler for green hydrogen exports and storage. The country has 34 ports, including 13 which are open to foreign trade (Res4Africa et al., 2022).

Figure 34: Morocco National Green Hydrogen Strategy Action Plan (PwC, 2022)

The Maghreb – Europe natural gas pipeline and the planned Morocco-Nigeria gas pipeline which is set to connect Nigerian gas resources to West African countries and Morocco to serve Europe offer a competitive advantage (Res4Africa et al., 2022). Additionally, the seafront is an advantageous geographical location and is at the crossroads of major international communication axes between Europe, Africa, and the Middle East, and good port connectivity (Res4Africa et al., 2022).

However, it should be noted that the country has the following challenges to develop the green hydrogen market (Res4Africa et al., 2022):

- **Infrastructure:** Morocco does not have transport and storage infrastructure to accommodate green hydrogen but plans to leverage its gas and port infrastructure to export green hydrogen and its products to Europe.
- **Water supply:** Morocco has a lack of water required for green hydrogen production and therefore desalination is the only viable alternative.

7.3.4 Exports

From 2025, the country aims to produce approximately 10,000 tonnes of hydrogen annually for domestic use and export markets in Europe. As outlined in the roadmap, the development of the green hydrogen market will unfold in three phases as illustrated in Figure 35 (GIZ, 2021):

- Short term: To use green hydrogen to produce green ammonia for local use and export green hydrogen derivatives including ammonia and liquid fuels to targeted countries.
- Medium-term: Local use of green hydrogen derivatives in the electricity sector.
- Long-term: Local use of green hydrogen in industry, heat production, the residential sector, urban mobility and air transport.

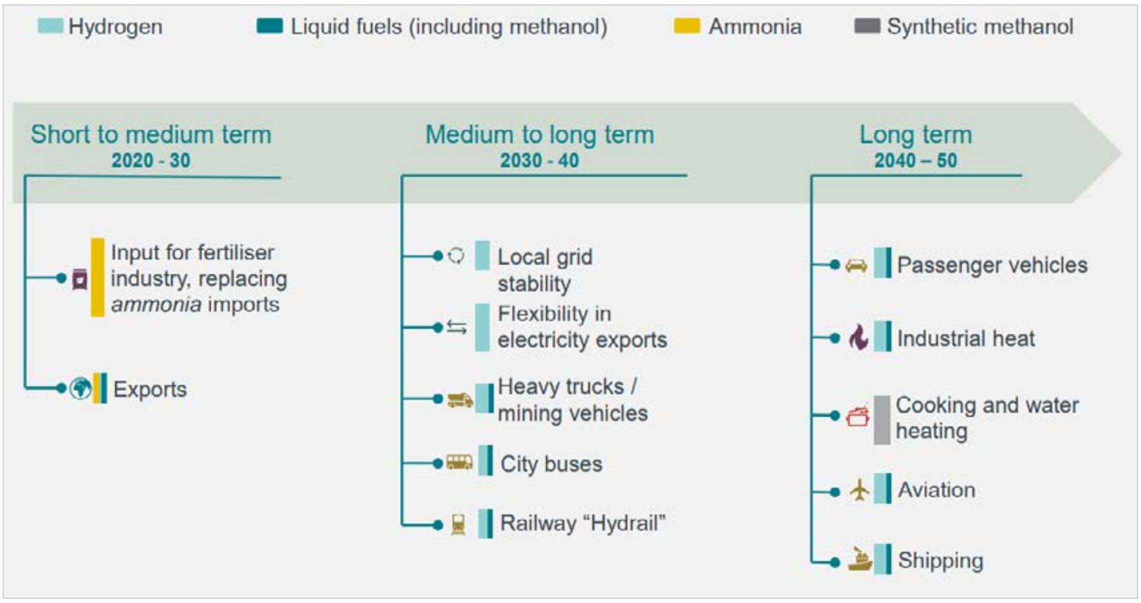


Figure 35: Hydrogen opportunities/ applications (GIZ, 2021)

Table 5: Morocco planned projects

Project name	Description	Commissioning date
Power to X	Construction of 100 MW renewable energy plant to produce green hydrogen via electrolysis.	2025
Hevo Ammonia Maroc project	Producing green ammonia and green hydrogen.	2026

7.4 Egypt

7.4.1 Overview

Egypt is considered one of the largest industrial economies in the Middle East. The country has a large grey hydrogen production estimated to be ~1.8 million tonnes/year and is domestically consumed across sectors including fertiliser, petrochemicals, refineries, and steel. It is accountable for ~20 million tonnes of CO_2/year (Barnard, 2022; Habib & Ouki, 2021). The grey hydrogen is locally produced from natural gas (using the steam methane reforming process) without abatement of the CO_2 resulting from the production process. Noting that a sustained production and consumption of grey hydrogen could become a major challenge for exports of manufactured products in the long term, the Egyptian government is planning to develop a low-carbon hydrogen alternative (Habib & Ouki, 2021). The plan is to replace the large domestic production of grey hydrogen with low-carbon hydrogen, and it is estimated that ~110,585 GWh of renewable electricity will be required to replace the current production of grey hydrogen with green hydrogen in Egypt.

Currently, the Egyptian state does not have any existing strategies related to hydrogen other than those that are currently being revised, updated and under-development. Such strategies include the National Green Hydrogen Strategy and the Integrated Sustainable Energy Strategy (ISES). The National Green Hydrogen Strategy which is being developed in cooperation with the European Bank for Reconstruction and Development (EBRD) is expected to feature important targets like positioning Egypt as a regional and global energy centre specifically in the production, consumption, and distribution of green hydrogen (GH_2 Organisation, 2023c). Furthermore, the National Green Hydrogen Strategy is envisioned to lay a foundation for a green hydrogen contribution of between USD 10 and USD 18 billion of gross domestic product (GDP) and 100,000 jobs by 2025 (Kamel, 2022). The Integrated Sustainable Energy Strategy is being revised and updated to determine the extent of the possibility of increasing renewable energy including green hydrogen in the energy mix of the country (GH_2 Organisation, 2023c; OBG, 2022).

7.4.2 Renewable energy potential

The current share of renewable energy capacity (excluding hydroelectricity) is ~4% of the total installed power capacity of ~58 GW in Egypt (Habib & Ouki, 2021). Egypt is working on ramping up the supply of electricity generated from renewable energy sources to 20% and 42% by 2022 and 2035, respectively. Solar PV is expected to account for a larger share of 21.3% followed by wind energy at 14%, concentrating solar power at 5.5% and hydropower at 1.98% (ITA, 2022a). The East and West Nile of Egypt have been identified through Wind and Solar Atlas as having the potential to produce 31,150 MW and 52,300 MW of wind energy and solar energy, respectively (ITA, 2022a). The onshore wind farms have a capacity factor of 40.6 - 55% on average (Collins, 2019; EWEA, n.d.). While the average capacity factor for solar PV is 30.09% (EL-Shimy, 2009). Additionally, the minimum value of the PV power plant capacity factor is 27.6% at Safaga, and the maximum value is 33.7% at Wahat Kharga. The average values of energy production and capacity factor all over the sites are found to be 26.35 GWh/year and 30.09%, respectively (EL-Shimy, 2009).

7.4.3 Green hydrogen production and infrastructure

Egypt boasts a long-term potential competitive advantage in producing green hydrogen and ammonia. This is due to the high potential of renewable energy sources, robust transmission network, and unique geographical location, among others (GH_2 Organisation, 2023c; Kamel, 2022). green hydrogen production cost targets of USD 2.7/kg and USD 1.7/kg are expected by 2025 and 2050, respectively (Ahram Online, 2023).

However, a dedicated infrastructure in the form of pipelines, and renewable energy supplies is lacking and needs to be developed. Part of the existing natural gas pipeline can be repurposed for transporting green hydrogen, but an extensive assessment will need to be carried out to assess the required modifications. However, the existing gas pipeline might not be available in potentially desired regions (Habib & Ouki, 2021). Dedicated renewable energy supplies required to power electrolysis are lacking and renewable energy targets of the Egyptian state are mainly set to reduce the carbon emissions produced by fossil fuel-based thermal power plants and expand the clean electrification of the economy. This triggers a need for the development of a huge renewable energy capacity dedicated to green hydrogen production to replace the existing production and consumption of grey hydrogen. That comes with challenges such as:

- Significant levels of investment will be required to scale up electrolyser capacity to the levels of gigawatts required to support green hydrogen (Habib & Ouki, 2021).
- Water supply will be required as an important input for green hydrogen. The country is water-constrained and receives minimal rainfall in a year. Additionally, the water supply of the country is expected to become more constrained in the coming years as a result of climate change, among others (Habib & Ouki, 2021).

The Egyptian state is considering the provision of incentive packages and facilities necessary to support green hydrogen production. The intention is to attract more investments in the sector and activate the signed agreements and MOUs related to green hydrogen (Daily News Egypt, 2023). Other developments relate to the prioritisation and promotion of SEZs, seawater desalination and sovereign wealth fund to support the development of green hydrogen (Matalucci, 2022).

Green ammonia is likely to play a critical role in the decarbonisation of industrial sectors. Egypt is the seventh largest producer of ammonia in the world and the industrial processes that currently use ammonia and can switch to green ammonia include the manufacturing of plastics, textiles, and dyes, with fertiliser being the main consuming industry of ammonia (HSF, 2022). The country has existing storage, transportation and import infrastructure which can be leveraged and used for green ammonia (Heinemann et al., 2022; HSF, 2022). Additionally, the Egyptian state plans to increase its green investments from 40% to 50% of total public investments by 2024/25 (Matalucci, 2022).

7.4.4 Export potential

Egypt aims to become one of the largest exporters and global regional centre for green hydrogen by 2030 (Dosko, 2022; GH_2 Organisation, 2023c). Egypt plans to secure 5% and 8% of the global hydrogen market by 2030 and 2040, respectively. This is planned to be achieved by establishing an international export centre for hydrogen and its derivatives. The country also notes that localising the hydrogen industry will help to decarbonise the industrial sectors and ultimately bring about job creation and improve GDP (Dosko, 2022; GH_2 Organisation, 2023c). Other benefits include the opportunity to create and use local skills in hydrogen businesses and value chains, improved energy security and reduced dependence on oil imports (Habib & Ouki, 2021). Additionally, by 2040, the country is expected to supply ~50% of green hydrogen demand in Europe. This is after the European Union adopted an ambitious plan to import ~10 million tonnes of green hydrogen and locally produce 10 million tonnes of green hydrogen all by 2030 (Dosko, 2022; GH_2 Organisation, 2023c).

7.4.5 Planned projects

Table 6 below summarises the planned hydrogen-related projects for Egypt.

Table 6: Egypt planned projects

Project Name	Description and estimated production	Commissioning date
Egypt Green Hydrogen S.A.E Company (green hydrogen production facility in the Suez Canal Economic Zone) (EBRD, 2022). Egypt Green Hydrogen owners include Scatec ASA, Fertiglobe PLC, Orascom Construction PLC, and the Sovereign Fund of Egypt's Infrastructure and Utilities Fund.	The project involves the construction of a 100 MW electrolyser facility, related facilities, and civil works. An estimated production of green hydrogen is 15,000 tonnes/year. This is equivalent to more than 130,000 tonnes/year of CO_2 (EBRD, 2022; Smith, 2023). Green hydrogen is planned to be used to replace some of the grey hydrogen for Fertiglobe's subsidiary and as an input for green ammonia production (EBRD, 2022). The project is funded by a loan from the EBRD (EWS, 2023; Scatec, 2022).	2022 -2025 (Commission in phases) (Fertiglobe, 2022)
Globeleq and the government of Egypt large scale green hydrogen facility in the Suez Canal Economic Zone.	The project joint development of a large-scale hydrogen facility. About 3.6 GW of electrolysers powered by ~9 GW of combined solar and wind energy is targeted and the project will be developed in three phases. The first phase targets 100,000 tonnes/year of green ammonia with green hydrogen as an input. This is mainly targeted for exports to Europe and Asia for utilisation in fertilisers (Globeleq, 2022).	2026-2027 (Expected operation)
ReNew Power and El Sewedy Electric green hydrogen	There is a signed agreement for USD 8 billion project that will produce 220 kilotonnes of green hydrogen and 1.1 million tonnes of ammonia a year (Enterprise, 2022).	2026 (Commissioning date)
2026 (Commissioning date)	There is signed agreement for a $3 billion facility to produce about 350 kilotons of green ammonia for ships (Enterprise, 2022; HSF, 2022)	2026 (Expected operation)
Al Nowais subsidiary AMEA Power green hydrogen plant	An agreement has been reached for the construction of an ammonia plant (500 MW), which is expected to deliver 390 kilotonnes of ammonia/year (Enterprise, 2022).	2025 (Expected operation).

7.5 China

7.5.1 Overview

China is the largest producer of hydrogen globally, accounting for about one-third of the global hydrogen output (Brown & Grünberg, 2022; Gong et al., 2023). Its production volume reached ~33 million tonnes in 2020 (Gong et al., 2023). Grey hydrogen is mainly produced from coal (~60%) and gas (~20%) sources accounting for a larger fraction (Brown & Grünberg, 2022). Major use cases and consumers of hydrogen in China include ammonia production, methanol production and refinery processes predominantly chemical and metallurgy industries. They account for 32%, 27% and 25%, respectively (ARC Group, 2022). The use of hydrogen in heavy-duty and commercial fuel cell vehicles is a well-established unconventional application in China apart from the traditional use and the country is the third largest fuel cell electric vehicles market (Brown & Grünberg, 2022; Nakano, 2022).

The existing incentive packages include the new energy vehicles credit system meant for the manufacturers of fuel cell vehicles and subsidies mainly granted by local governments on the construction and operation of hydrogen refuelling stations (Gong et al., 2023; Gong & Quitzow, 2022). Other support mechanisms for hydrogen development include local industrial funds, preferential tax treatment and discounted electricity prices (Gong & Quitzow, 2022). However, major support in terms of incentives and other mechanisms relating to hydrogen lies mainly in the transport sector especially fuel cell vehicles. It is therefore argued that the priority should also be given to other sectors like hard-to-abate sectors (Gong & Quitzow, 2022).

National Development and Reform Commission, in 2022, published Medium- and Long-Term Plan for Hydrogen Energy Industry Development (2021–2035). The policy document lays out the long-term vision for China's hydrogen economy and aims to increase the share of green hydrogen in the final energy consumption by 2035 (Miller-Wang, 2023). It highlights the importance of hydrogen and the need to expand its application beyond transport to a wide range of sectors including the hard-to-abate sectors, such as steel, transport, and chemical industries as well as developing safety standards (Habib & Ouki, 2021; Institut Montaigne, 2023; Zhou et al., 2022).

7.5.2 Renewable energy capacity

China is endowed with abundant solar, wind and hydropower resources and is increasingly expected to unlock renewable-based electricity generation to support green hydrogen production. About 30% of total power generation in China was accounted for by renewable-based electricity in 2021. There is an expectation for that to increase to ~33% by 2025 (Gong et al., 2023). Furthermore, there are plans to increase the current capacity of solar and wind generation from ~600 GW to 1200 GW by 2020 and 2030, respectively (ARC Group, 2022). The average capacity factor for new onshore wind is 35% while that of the off-shore wind is 37% (IRENA, 2022). The solar PV capacity factor is 20.1% (GEM, 2023).

7.5.3 Green hydrogen production and infrastructure

China intends to achieve its peak carbon emissions and carbon neutrality by 2030 and 2060, respectively. Accelerating the development and deployment of green hydrogen to mainly replace fossil fuel-based hydrogen will be crucial (Brown & Grünberg, 2022). Currently, renewable-based hydrogen only accounts for a small fraction of ~1%. However, the country is increasingly accelerating the production and consumption of renewable-based hydrogen (Alexander, 2022; Gong et al., 2023; Nakano, 2022). The country is also providing incentives to grow related industries.

The Chinese government has set targets for renewable-based hydrogen including:

- Production price targets of USD 4/kg and USD 2.4/kg by 2025 and 2030, respectively (GH_2 Organisation, 2023b),
- Production of 100,000 to 200,000 tonnes of renewable-based hydrogen annually by 2025 –(Kaya Partners, 2023; Nakano, 2022),
- A fleet of 50,000 hydrogen-based fuel vehicles which is estimated to reduce the country's carbon emissions by one to two million tonnes annually by 2025 (Nakano, 2022).

China accounts for a third of global electrolyser manufacturing capacity and is expected to become more competitive as its production scales up (Brown & Grünberg, 2022). Its global share of patents in green hydrogen specifically water electrolysis had risen to about two-thirds by 2019 (Brown & Grünberg, 2022). It is a major producer of alkaline electrolysers, and the cost is estimated to be as low as ~USD 300/kW which is significantly below the estimated cost of ~USD 750-1,200/kW in Europe and North America (IEA, 2022a). In the country, the electrolyser capacity is growing rapidly and is expected to increase further in the coming years with an electrolyser capacity of 38 GW forecasted by 2030 (Hydrogen Central, 2023; Ryze Hydrogen, 2023).

However, limited access to key materials for water electrolysers such as catalysts, proton exchange membranes (PEM) and carbon papers is a major challenge for the country. Currently, these key materials are largely imported (Ren et al., 2020). Other challenges include hydrogen supply and demand mismatch, high production costs, limited infrastructure, codes, standards, and regulations.

- **Hydrogen supply and demand mismatch:** The production of green hydrogen is highly concentrated in the west, north and northeast sites of China whereas hydrogen-consuming sites such as economic centres of China are clustered along the coastal provinces in the east and southeast (Tu & Wang, 2020). This propels relocation of end-users to the production sites which will also bring economic benefits to less developed projects or the development of long-distance power transmission networks (or green hydrogen grid infrastructure) to help link the existing hydrogen consumers with green hydrogen production sites (Tu & Wang, 2020).
- **Green hydrogen production costs:** The production cost of green hydrogen per kg in China is two to five folds higher than the coal-based hydrogen/kg (Tu & Wang, 2020).
- **Limited hydrogen infrastructure.** Hydrogen infrastructure is still in the early stages of development and only about 100 km of dedicated pipeline infrastructure has been built in China. Transportation by truck is the most used method although is considered the most expensive and less efficient means of transportation than pipelines. This limited infrastructure hinders the development of green hydrogen. Therefore, a major expansion of the existing infrastructure is required but it is costly. Such infrastructure includes the development of hydrogen production, large storage facilities, pipelines, refuelling stations, and port terminals which must be prioritised (Li et al., 2022; WEF, 2023).
- **Hydrogen standards, and regulations:** Hydrogen codes, standards and regulations which ensure and prove quality and safety compliance of hydrogen have not been completed. The development and completion of standards and regulations would be beneficial for the long-term development of the hydrogen economy in China (Ren et al., 2020).

7.5.4 Export potential

China may become a leading exporter of green ammonia starting as early as 2024. This can be supported by the country's technological prominence, the large land mass available for developing renewable energy and its reputation for constructing projects quickly (Kakish & Owen, 2023). Investment is being allocated into port infrastructures to support a potential expansion of ammonia exports (Kakish & Owen, 2023). There is currently a plant under construction targeting to produce ~ 20,000 tonnes/year of green ammonia with plans to increase to 300,000 tonnes/year. It is located in Mongolia and will be powered by wind energy with the exportation of green ammonia being expected by late 2024 (Kakish & Owen, 2023). The Inner Mongolia region has increasingly become the focus for hydrogen and ammonia facilities run on renewable energy over recent months.

7.5.5 Planned projects

Currently, China has about 120 green hydrogen projects at different stages of development (Brown & Grünberg, 2022). This includes several gigawatt-scale projects. These projects are primarily located in inland regions such as Inner Mongolia, Ningxia, and Xinjiang where renewable energy potential is abundant (Brown & Grünberg, 2022). Both state-owned enterprises (SOEs) and private companies have shown interest in tapping into the market. About one-third of SOEs have plans to expand their operations in the hydrogen industry value chain whether production, storage, refuelling stations or related businesses. On the other hand, private companies in the renewable energy industry plan to integrate green hydrogen into their business plans (Brown & Grünberg, 2022). Some examples of the projects are summarised in Table 7 below. The majority of these projects are demonstration projects and some of them were expected to be commissioned in 2021 and 2022. It is unknown if they have been commissioned.

Table 7: China planned green hydrogen projects (Tu & Wang, 2020)

Project Name	Description and estimated production.	Commissioning date
Yanqing Renewable Energy Hydrogen Production Project	~980 tonnes/year of hydrogen production output is expected. A combination of renewable energy sources like wind, solar and hydropower will be used.	Unknown
Yumen Oilfield 160MW Renewables Hydrogen Production.	~7,000 tonnes/year of hydrogen production output is expected. The renewable energy source to be used is solar energy.	2024
Zhangjiakou Green Hydrogen Energy Integration project	Produces ~2,800 tonnes/year of hydrogen production. The renewable energy source used is wind energy.	2022
HCIG Guyuan Wind Power Hydrogen Production	Produces ~1,700 tonnes/year of hydrogen production output is expected. The renewable energy source used is wind energy.	2021
HCIG Wind to Hydrogen Project (Chongli)	Produces ~313 tonnes/year of hydrogen output. The renewable energy source used is wind energy.	2022

Project Name	Description and estimated production.	Commissioning date
Zhongzhi Tiangong Wind and Solar Power Generation and Utilisation (Hydrogen Production).	~8,000 tonnes/year of hydrogen production output is expected. The renewable energy source to be used is both solar and wind energy.	Unknown
Jilin Changling Longfenghu 200MW Hydrogen Production project	~5,393 tonnes/year of hydrogen production output is expected. The renewable energy source to be used is wind energy.	2023
Baicheng City Wind Power to Integrated Hydrogen Production	~3,883 tonnes/year of hydrogen production output is expected. The renewable energy source to be used is both solar and wind energy.	2026
Ningdong Renewable Hydrogen and Carbon Reduction Demonstration Zone Project	Refuelling services for 150 hydrogen fuel cell heavy trucks per day, with a refuelling scale of 3,000 kg/day.	2023
Sinopec Xinjiang Kuche Green Hydrogen Project	Produces ~20,000 tonnes/year of hydrogen output. The renewable energy source used is solar energy.	2023

7.6 United States of America

7.6.1 Overview

The USA is the second-largest producer and consumer of hydrogen accounting for 11% of production globally (Zhang & Hieminga, 2022). Currently, the USA produces approximately 10 million metric tonnes/year of hydrogen compared to the global output of ~90 million metric tonnes/year (U.S. DoE, 2023b). The hydrogen production generates ~100 million metric tonnes/year of GHG emissions, particularly CO_2-equivalent (U.S. DoE, 2023b). The primary demand for hydrogen is petroleum refining, and ammonia and methanol which collectively account for a large fraction of 55% and 35%, respectively (see Figure 36) (U.S. DoE, 2023d). Apart from traditional applications, other end-use applications include fuel cell-based vehicles, buses and forklifts as well as hydrogen fuelling stations and fuel cells for stationary and backup power (U.S. DoE, 2023b).

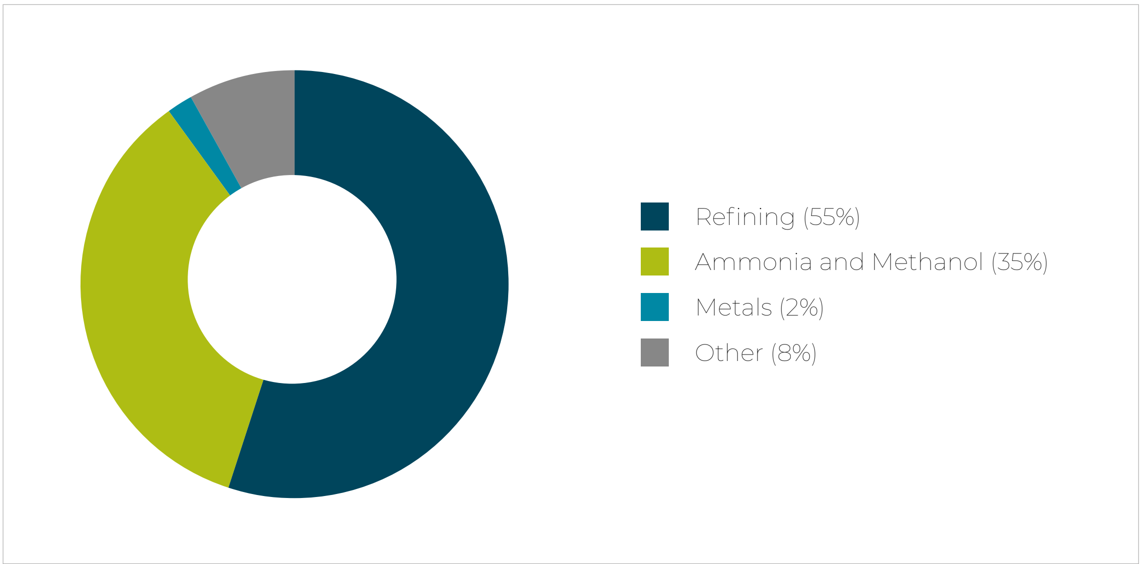


Figure 36: Hydrogen Consumption by end-use in the U.S., 2021(U.S. DoE, 2023b)

In November 2021, the Bipartisan Infrastructure Bill (also known as the Infrastructure Investment and Jobs Act) was passed and included USD 9.5 billion in support for hydrogen with USD 8 billion dedicated to establishing regional hubs (GH_2 Organisation, 2023a). Furthermore, in June 2023, the U.S. National Clean Hydrogen Strategy and Roadmap was passed to serve as a national framework for facilitating large-scale production, processing, delivery, storage, and use of clean hydrogen to help meet bold decarbonisation goals across virtually all sectors of the economy (U.S. DoE, 2023b). The strategy identifies actions and milestones with:

- 2022-2025 milestones targets include catalysing RD&I in electrolysis, thermal conversion, scalable production from renewables, nuclear, and fossil and waste with CCS.
- 2026-2029 milestones targets include deploying gigawatt-scale electrolysers and developing domestic supply chains, among others (U.S. DoE, 2023c).

The Inflation Reduction Act (IRA) proposes incentives for hydrogen including a production tax credit which intends to boost the U.S. market for clean hydrogen (U.S. DoE, 2023b). The law also made provision for a USD 3 tax credit/kg of hydrogen for green hydrogen producers in their first ten years of operation (Hanafusa, 2022; U.S. DoE, 2023b).

7.6.2 Renewable energy capacity

The USA is endowed with enormous potential for renewable energy sources. Every region of the country has access to multiple renewable energy sources such as solar, wind and geothermal (U.S. DoE, 2022). Only 0.2% of the total available renewable energy potential has been explored in 2020 leaving a large untapped technical potential to convert renewable resources into electricity (U.S. DoE, 2022). It is estimated that about 463,400 TWh of renewable energy technical potential is available to the U.S. annually and this is equivalent to more than 100 times the electricity consumed (4,000 TWh) in 2020 (U.S. DoE, 2022). Renewable energy sources generate ~20% of the total electricity in the USA and it continues to grow. Both Solar and wind were expected to add 46% and 17% respectively of the utility-scale generating capacity to the power grid of the USA in 2022 (EIA, 2023; U.S. DoE, 2023f). The capacity factors for solar energy and onshore wind energy in the USA are 17-27% and 24-56%, respectively (Bolinger et al., 2022; CSS, 2022). The capacity factors for solar energy vary across regions and are in part driven by solar resource quality, differing use of technology like trackers (Bolinger et al., 2022).

7.6.3 Green hydrogen production and infrastructure

The U.S. government (i.e., Department of Energy, DOE) has identified green hydrogen as a key technology to decarbonise several sectors such as ammonia, steel, energy storage and heavy-duty transport. Additionally, hydrogen development will be prioritised in cases where other high-efficiency and low-cost options such as electrification are less likely to occur (U.S. DoE, 2023b). Green hydrogen is crucial in achieving the U.S. government's goal of a 100% clean electrical grid and net zero carbon emissions by 2035 and 2050, respectively (GH_2 Organisation, 2023a). According to the Roadmap to a U.S. Hydrogen Economy Report, hydrogen can help achieve 14% of U.S. final energy demand by 2050. This is equivalent to ~2,468 TWh/year (FCHEA, 2022).

The government of the USA (i.e., DOE) plans to achieve the following targets in relation to clean hydrogen:

- Establish regional clean hydrogen hubs to serve as a network of hydrogen producers, consumers, and local connective infrastructure to accelerate the use of hydrogen as a clean energy carrier that can deliver and store large amounts of hydrogen. An amount of USD 7 billion has been allocated to establish six to ten regional clean hydrogen hubs across the U.S. – (U.S. DoE, 2023e).
- Achieving a production price of USD 1/kg of clean hydrogen within a decade (by 2031) – (U.S. DoE, 2023d). This will be enabled by tax incentives and on-going research, development and demonstration of hydrogen projects (U.S. DoE, 2023a).
- Production of 10 Mt/year, 20 Mt/year and 50 Mt/year of clean hydrogen by 2030, 2040 and 2050 respectively (Environmental Finance, 2022).

7.6.4 Export potential

The potential for exporting clean hydrogen or hydrogen carriers has been identified as among the long-term opportunities targeted by the USA. For example, the U.S. National Clean Energy Strategy and Roadmap is committed to developing market structures and regulatory guidance to enable clean hydrogen export as one of the actions to support clean hydrogen use and broader market adoption (U.S. DoE, 2023b). This is expected to take place between 2030 and 2035. Some of the capabilities positioning the U.S. as the potential exporter of clean hydrogen include hydrogen hubs and ports in coastal states. Japan is regarded as a possible export destination for U.S. clean hydrogen. Also, the Port of Rotterdam and Corpus Christi signed a MOU to collectively develop new technologies such as hydrogen, among others (Environmental Finance, 2022). This will facilitate the trade of the fuel in the future which is significant for U.S. green hydrogen producers targeting early EU off-take. These producers are uniquely well-suited to deliver green fuel more quickly and cheaply than other early suppliers (Environmental Finance, 2022). Moreover, the U.S.' hydrogen production tax credit will effectively reduce the cost of exported green hydrogen-derived commodities (Janzow et al., 2023).

7.6.5 Planned projects

There is a high concentration of planned projects along the Gult Coast and about 65% of the planned capacity is concentrated in coastal Texas and Louisiana (N. Jones, 2023). Some of the identified projects are listed in the Table 8 below.

Table 8: Green hydrogen project in the USA (Airswift, 2023)

Project Name	Description and estimated production	Commissioning date
St. Gabriel Green Hydrogen Plant	The project is located in Louisiana and is expected to produce ~15 tonnes/day of green hydrogen, by 2023 to supply the fuel cell market. By 2025, ~500 tonnes/day of liquid green hydrogen is expected and by 2028, ~1,000 tonnes/day of liquid green hydrogen is expected.	2023
Sauk Valley Green Hydrogen Plant	The plant will have a capacity of 52 tonnes/year and will be able to store 400kg of hydrogen on-site. The facility will be equipped with Ohmiu's PEM electrolyser, which produces 6kg of hydrogen/hour.	2023
Kingsland Green Hydrogen Plant	The plant will produce 15 tonnes/day of hydrogen, which will be liquefied and stored before being loaded for transport.	2023
Casa Grande Green Hydrogen Plant	The plant will be owned and operated by Air Products, producing 10 metric tonnes/day of green hydrogen. Its product will be sold to the hydrogen for mobility market in California and other locations.	2023
Donaldsonville Green Hydrogen Project	The plant will have a 20 MW alkaline water electrolysis plant to produce green hydrogen. It will be integrated into existing ammonia synthesis loops and produce 20,000 tonnes of green ammonia per year.	2023
Hy Stor Energy Green Hydrogen	The project will produce 110,000 metric tonnes of green hydrogen and store ~70,000 metric tonnes of green hydrogen in its underground salt caverns by 2025 (GH_2 Organisation, 2023a).	2025
Rocket Fuel for SpaceX	A Texas start-up Green Hydrogen International, intends to establish a 60 GW renewable hydrogen project powered by wind and solar energy with an on-site salt cavern for H_2 storage. It is expected to produce more than ~2.5 million tonnes/year of green hydrogen (Collins, 2022; GH_2 Organisation, 2023a)	2026

7.7 United Arab Emirates (UAE)

7.7.1 Overview

The UAE produces a significant portion of its energy from natural gas and oil. It is also touted as the major exporter of oil and gas (IEA, 2022b). As countries and industries transition towards a low-carbon world to mitigate climate change, the country has also committed to achieve net zero emissions by 2050 and hydrogen is expected to play a key role. However, in the short-term natural gas is still expected to play a significant role in supporting the production of grey hydrogen as well as blue hydrogen supported by carbon capture technology. For example, ADNOC intends to increase its carbon capture capacity fivefold from 800,000 tonnes to five million tonnes by 2030 which will make the Abu Dhani region one of the low-cost and largest producers of blue hydrogen (Abu Dhabi Media Office, 2022).

The UAE is well-positioned to be a leader in low-carbon hydrogen with natural competitive advantages in both blue and green hydrogen. Additionally, UAE is one of the countries globally with the lowest costs for green hydrogen and with available land for solar photovoltaic (UAE MOEI, 2021). In response to the opportunities that come with the development of the hydrogen economy, the UAE published both the UAE Hydrogen Leadership Roadmap and UAE National Hydrogen Strategy. The UAE Hydrogen Leadership roadmap seeks to position UAE as a global leader in low-carbon hydrogen and home to a robust and vibrant low-carbon hydrogen ecosystem. It focuses on three core objectives including (IEA, 2023; UAE MOEI, 2021):

- Unlocking new sources of value creation through exports of low-carbon hydrogen, derivatives, and products to crucial importing regions,
- Fostering new hydrogen derivative opportunities through low-carbon steel, sustainable kerosene as well as other priority industries and
- Contributing to the UAE’s 2050 net zero commitments.

Likewise, the UAE National Hydrogen Strategy aims to support low-carbon local industries, contribute to achieving climate neutrality and enhance the UAE’s position as one of the largest producers of hydrogen by 2031. This will be achieved through the development of supply chains, the establishment of hydrogen hubs and a dedicated national research and development centre for hydrogen technologies (UAE Government, 2023a; UAE MOEI, 2023).

Both the strategy and the roadmap seek to position the UAE as among the largest producers of low-carbon hydrogen.

7.7.2 Renewable energy potential

The UAE is the fastest growing market for renewables and renewable energy consumption accounted for 19.77% of the total final energy consumption in 2020 in the UAE (UAE MOEI & UAE MOCCAE, 2021; World Bank, 2023). The UAE plans to generate most of its electricity from renewable energy and targets a 44% share of renewables by 2050 which is a significant increase from 2020 levels at 7% (MEPC, n.d.; MOEC, 2023). The renewables portfolio will include solar energy as the primary energy as well as wind, waste to energy and geothermal which also have the potential (IRENA et al., 2015). Solar energy has a capacity factor of 5%-35% on average (Apostoleris et al., 2021). The UAE has three of the world's largest solar plants and is rapidly developing more as solar energy is available at 1.35 cents/kWh. For example, the Abu Dhabi region committed more than USD 20 billion to renewable energy programs through Masdar. This has expanded the renewable energy portfolio of the UAE by 400% in the last 10 years.

The updated UAE Energy Strategy 2050 which was launched in 2017 aims to triple the contribution and share of renewable energy to 14 GW by 2030 (Dahan, 2023; Garicia, 2022). This brings about an investment of between dirham (AED) 150 and AED 200 billion by 2030. The updated strategy seeks to promote the deployment of renewable and encourage investments in the country's renewable energy and clean energy sector (UAE Government, 2023b).

UAE in partnership with leading international universities has established two graduate-level research universities dedicated to clean energy as well as research, and development (R&D) facilities and commercialisation of products and services. The projects are designed to create a supply of technical expertise in the market and manage funding for R&D and commercialisation efforts with a heavy focus on renewable energy (IEA, 2021).

7.7.3 Green hydrogen production and infrastructure

The UAE targets hydrogen production of 1.4 million tonnes per year by 2031 with green hydrogen accounting for a significant proportion of 1 million tonnes per year and blue hydrogen accounting for the remaining 0.4 million tonnes per year (UAE MOEI, 2023). Additionally, 7.5 million tonnes per year and 15 million tonnes per year of hydrogen production are targeted by 2040 and 2050, respectively (Martin & Parkes, 2023). The UAE is also targeting to establish a hydrogen research and development (R&D) centre and two hydrogen hubs by 2031 as well as a globally recognised innovation centre and five hydrogen hubs (oases) by 2050 to support the hydrogen production targets (UAE Government, 2023b). The following enablers have been identified by the UAE and are being put in place to support the low carbon hydrogen activities (CCLW, 2021; IEA, 2023):

- Clear regulatory framework backed by policies, incentives, standards, and certifications. The UAE has completed drafting the technical regulations for hydrogen fuel cell vehicles (K&L Gates, 2023).
- Best-in-class technology through value-add partnerships and the vibrant and robust UAE domestic research and development structure,
- Access to existing and new government-to-government relationships to accelerate the growth of a domestic ecosystem,
- Readily available land and infrastructure resources to support domestic production, and
- Green financing within the UAE and in international capital markets.
- Other existing enablers include various existing infrastructure and technical expertise such as:
- Large scale hydrogen and ammonia production facilities and large scale carbon capture and storage capacities which the ADNOC, national oil company owns and continues to advance (World Energy Council, 2022).
- Recycled water infrastructure: Recycled water is expected to be increasingly utilised, and government is increasingly investing in the infrastructure. For example, about 60% of treated wastewater was re-used in Abu Dhabi and the new pipe network was expected to help achieve 100% re-utilisation of treated wastewater in 2014 (IEA, 2017).

7.7.4 Exports

The UAE targets 25% market share of low-carbon hydrogen by 2030 in the key export markets, including Japan, South Korea, Germany, India, and Europe (IEA, 2023). The port of Fujairah, one of the world's largest bunkering hubs, can serve as a strategic location for large-scale hydrogen-based exports. Partnerships between ADNOC, Mubadala and ADQ as well as potential collaboration with well-established U.S. corporations is being considered to support the development of end use properties for clean hydrogen to create demand and contribute to UAE's export of hydrogen. In January 2021, the UAE launched the Abu Dhabi Alliance which will advance low carbon green and blue hydrogen in emerging international markets. Additionally, the UAE has signed a deal with the Port of Amsterdam, SkyNRG, Evos Amsterdam and Zenith Energy Terminals which will see green hydrogen produced in Abu Dhabi and then exported to The Netherlands via the Port of Amsterdam. This will help countries strive to reach net-zero targets, especially in sectors that are hard-to-decarbonise such as iron, steel, chemicals, aviation and shipping (Hebden, 2023).

7.7.5 Planned projects

Table 9 below summarises the planned hydrogen-related projects.

Table 9: Planned projects UAE

Project Name.	Description and estimated production.	Expected commissioning date.
State-owned DEWA's pilot green hydrogen project	The pilot plant is expected to produce hydrogen using renewable solar energy, store it, and use it for re-electrification, transportation, and other industrial uses. The US$14 million project is a PPP project between DEWA, Expo 2020 Dubai, and Germany's Siemens (K&L Gates, 2023)	The project was expected to be commissioned in 2020. It is unknown if it has been commissioned.
Masdar green hydrogen pilot project	Produce hydrogen fuel for use in local vehicles, such as buses, in Masdar City and to develop aviation fuel for use by Etihad and Lufthansa. There also will be research into the use of fuel in the maritime and shipping industry (K&L Gates, 2023).	The plant design is expected to be ready by the end of 2021, with construction taking an additional two years. The commissioning date is unknown.
USD 1 billion green hydrogen and green ammonia project (in Abu Dhabi's Khalifa Industrial Zone Abu Dhabi)	The project, which is planned to be developed in two phases, will be powered by 800 MW of solar power and produce 200,000 tonnes of green ammonia from 40,000 tonnes of green hydrogen (Energy & Utilities, 2022; Power Technology, 2022).	Technical and financial feasibility studies have been completed (2022) with unknown commissioning date.
Germany's Uniper SE and Masdar green hydrogen project	Build a plant that will run on almost 1.3 GW of solar power and is expected to produce hydrogen from 2026.	2026

7.8 Australia

7.8.1 Overview

Australia's annual grey hydrogen production is approximately 650 kt and is mostly used in industrial processes including ammonia (~65%) and crude oil refining (~35%) (DCCEW, 2023). Since Australia is a signatory to the Paris agreement and has committed to reduce 26%-28% of GHG emissions by 2030, the country has identified low-carbon hydrogen (i.e., blue and green hydrogen) as one of the pathways to assist in reaching the targets. Australia has the vision is to develop a *"clean, innovative, safe and competitive hydrogen industry that benefits all Australians and is a major global player by 2030"*. To become a major global player, the country aims to be among the top three exporters of hydrogen to Asian markets. Additionally, clean hydrogen is an opportunity for the country to decarbonise industrial processes (i.e., ammonia) and reduce imported fuels especially for the transport sector. Further potential uses of Australian hydrogen will include heat and grid electricity (COAG Energy Council, 2019).

To develop the green hydrogen economy, in 2019, the Council of Australian Governments (COAG) Energy Council Working Group published the Australian Hydrogen Strategy which outlines the country's potential, opportunities, the journey to hydrogen, enabling industry growth, building benefits, tracking progress and even an outlook beyond 2030. It further identifies 57 actions that will assist in achieving the vision. The actions consider hydrogen in relation to exports, transport, industrial use, gas networks, electricity systems, and cross-cutting issues such as safety, skills, and environmental impacts. Actions are themed as follows (COAG Energy Council, 2019):

- **Developing supply and demand:** Pilots, trials and demonstration projects will drive technological development, develop industry expertise, promote international collaboration, enable business model innovation, and prove hydrogen supply chains at scale.
- **Responsive regulation:** Review and reform underpinning regulatory and legal frameworks, to develop consistent approaches for:
  - efficient supply chains and markets
  - a supportive investment environment
  - robust training requirements and safety standards
- **International engagement:** Strategic and coordinated international outreach, focused on key markets, to harmonise standards and encourage trade.
- **Innovation, research and development:** Provide targeted support for research and development activities, with a focus on international collaboration and Australian priorities.
- **Skills and workforce:** Improve workforce skills and establish training regimes.
- **Community confidence:** Work with industry to earn the community's trust and build confidence in hydrogen.

Additionally, it should be noted that in 2023, Australia published the National Hydrogen Infrastructure Assessment which identifies existing infrastructure and gaps, and investment priorities.

To promote the development of green hydrogen economy, the Australian Government announced the establishment of Hydrogen Headstart, an AUD 2 billion revenue support program to support large scale renewable hydrogen in the 2023-24 federal budget (ARENA, 2023b). Hydrogen Headstart will provide support for investment in green hydrogen production and the reduction of costs. Additionally, the program will support the development of two to three flagship projects which could potentially deliver 1 GW of electrolyser capacity. To date, AUD 4.2 million has been allocated to support the development of the program (ARENA, 2023a).

7.8.2 Renewable energy potential

Australia has good wind, solar and hydro resources. Southern and western coastlines have one of the best wind resources. While Tasmania, Victoria and New South Wales have most of the hydroelectric resources. Figure 37 below shows the areas suitable for renewable energy production. These areas take approximately 3% (~262,000 square kilometres) of Australia's total land area which exceeds that of the European Union nation (DISER, 2021). According to Rystad Energy, in August 2022, the capacity factors for Australia were 21%-18% and 46%-51% respectively for solar and wind.

According to Commonwealth Scientific and Industrial Research Organisation (CSIRO), to meet future green hydrogen demand of 15 GW to 17.5 GW for wind and solar would be required (PWC, 2020). The cost of renewable energy production is estimated to be AUD 7/kg. However, due to improved efficiencies and as renewable energy costs continue to decline, CSIRO estimates that costs could decline to AUD 2.29-2.79/kg by 2025 (Kornhaas et al., 2021).

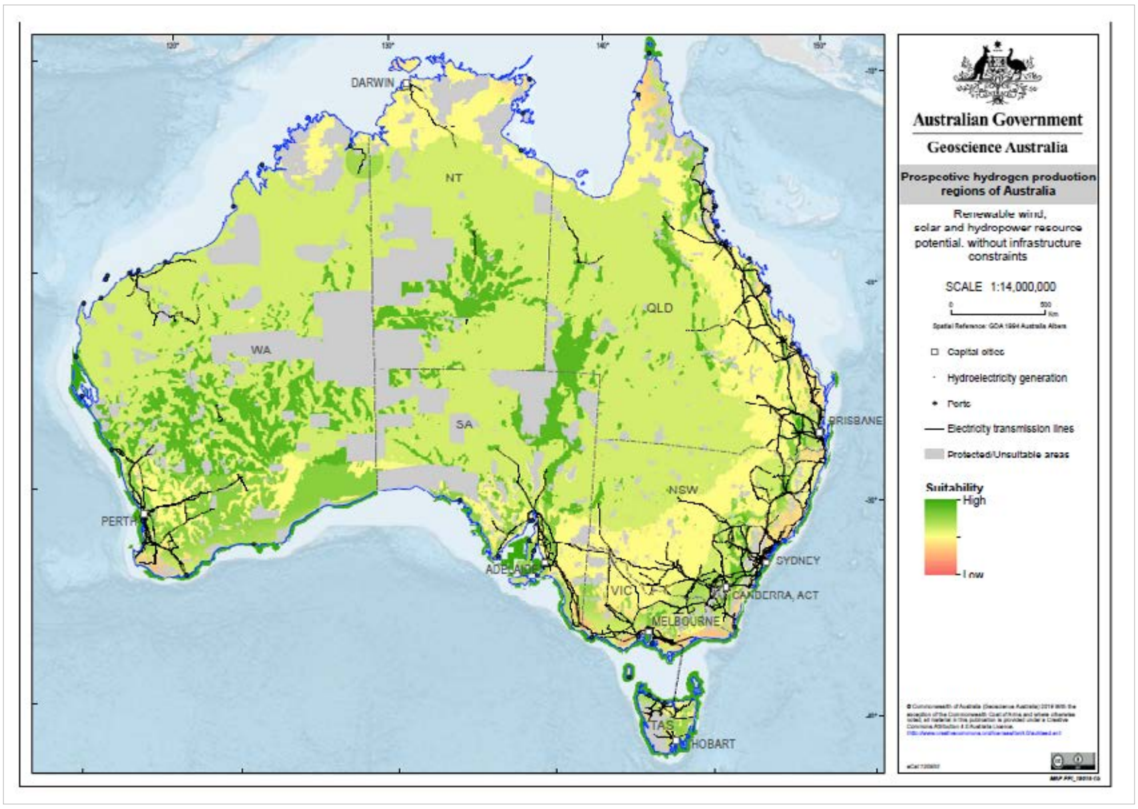


Figure 37: Renewable hydrogen potential (COAG Energy Council, 2019)

7.8.3 Green hydrogen production and infrastructure

According to the strategy, Australia has a target to produce hydrogen below AUD 2/kg by 2030 for use in trucks, cars, fertilizer plants, and refineries (COAG Energy Council, 2019; Kar et al., 2022). In terms of infrastructure, Australia has extensive experience in building industries for exports, notably renewable energy sector and LNG. The country is one of the largest exporters of LNG globally and leader in renewable energy deployment (COAG Energy Council, 2019).

The existing supply chains for hazardous chemicals and liquid natural gas, natural gas transmission pipelines, ports, shipping, road and rail networks for the domestic transport of goods make the development of a clean hydrogen supply chain feasible (DCCEW, 2023).

Moreover, to support further demand growth, Australia aims to create hydrogen hubs. The creation of hubs will minimise the cost of infrastructure, promote efficiencies from economies of scale, stimulate innovation, increase workforce skills development and promote synergies from sector coupling (COAG Energy Council, 2019). The hubs will be selected based on:

- Access to demand
- Land availability and ownership
- Port potential (including current capacity, shipping distance and scalability)
- Grid connectivity
- Road and rail infrastructure access
- Access to existing gas transmission pipeline easements
- Water access
- Economic, social and environmental factors (such as workforce access, weather, safety and other factors)
- Stakeholder and community interest and acceptance
- Proximity to prospective hydrogen production regions
- Potential for hydrogen storage
- Electricity pricing

However, it should be noted that the following challenges exist to develop a green hydrogen value chain:

- **Hydrogen costs:** The cost of producing clean hydrogen is estimated to be between AUD 2.30 - AUD 5/kg and AUD 2 – AUD 4/kg, respectively for 2025 and 2030. To reduce the cost to AUD 2 target, Australia will have to increase its clean energy capacity and develop & deploy electrolysers (DISER, 2021).
- **Lack of infrastructure:** Australia has a lack of infrastructure to accommodate green hydrogen production. Additionally, for the transportation sector there is lack of adequate production capacities, rudimentary supply chain, and insufficient refuelling facilities (Kar et al., 2022). However, the country has plans to build large-scale export industry infrastructure including powerlines, pipelines, storage tanks, refuelling stations, ports, roads and railway lines from 2025 (COAG Energy Council, 2019).
- **Technological maturity:** The development of hydrogen market and associate technology in Australia is still in infancy therefore this makes large-scale hydrogen transportation expensive (Kar et al., 2022)
- **Low market readiness:** There is low technology readiness and willingness from potential hydrogen industry consumers (Kar et al., 2022).

7.8.4 Exports

In 2022, Australia became the first country to export liquefied hydrogen to Japan. According to Australian Renewable Energy Agency the demand for green hydrogen exports could be over 3 million tonnes each year by 2040 (Austrade, 2023). The target countries for exports include Japan, Korea, China and Europe. To date, Australia has several agreements with other countries including Germany, Japan and South Korea to develop green hydrogen supply chain (Austrade, 2023). According to PwC, Australia has the opportunity to export over 500 kt of hydrogen to East Asia by 2030 (PWC, 2020).

7.8.5 Planned projects

Australia has over 100 hydrogen projects planned which can be found on Geoscience Australia's website (Australian hydrogen projects dataset) (DISER, 2021). For the purpose of this study only five were selected based on production method (i.e., electrolyser), and electrolyser capacity from 10 MW and earliest commissioning date (see Table 10).

Table 10: Operational and planned projects Australia

Projects	Description	Commissioning date
Hydrogen Energy Supply Chain (HESC) Pilot Project	Tests the liquefied hydrogen supply chain from Australia to Japan.	2022 (DCCEEW, 2022)
Illawarra Hydrogen Technology Hu	The project will be developed in stages, with Phase 1 involving the installation of a 10 MW electrolyser with a hydrogen production capacity of 4 tonnes per day. The produced hydrogen will be used for mobility, including buses and trucks, as well as supplying existing hydrogen customers in the region. Up to five hydrogen refuelling stations are planned in this phase, along with 30 hydrogen fuel cell buses and ten trucks. The project aims to have hydrogen production and refuelling infrastructure in place by 2025.	2025

Projects	Description	Commissioning date
H_2-HubTM Gladstone	This project involves the establishment of large-scale green hydrogen and ammonia production for export to North Asia. The hub will be powered by 100% renewable energy (i.e., solar and wind) and build in stages to integrate an up to 3 GW electrolysis plant. The hub is projected to produce up to 5,000 tonnes per day of ammonia.	2025
Early Production System	This project involves developing a 10 MW solar farm, a hydrogen plant which will have a 10 MW electrolyser with hydrogen production capacity estimated to be 4.4 tonnes/day. Hydrogen production offtake is focussed on the heavy transport sector, targeting back-to-base logistics operators and local governments with in-depot refuelling.	2024
H_2Perth	This project involves the establishment of a large-scale hydrogen and ammonia production facility at a site in southern Perth. The project would initially target 300 tonnes per day of hydrogen production, which can be converted into 600,000 tonnes per year of ammonia or 110,000 tonnes per year of liquid hydrogen. Hydrogen and ammonia would be produced using 250 MW electrolysis, and 40 terajoules per day of natural gas reforming, with 100% of carbon emissions abated or offset.	Construction in 2024, subject to the Final Investment Decision (FID)
Yuri Renewable Hydrogen Ammonia Project	Project involves deploying a 10 MW electrolyser powered by 18 MW of solar PV and supported by an 8 MW battery energy storage system, to generate renewable hydrogen to produce renewable ammonia at Yara Pilbara Fertilisers' neighbouring liquid ammonia plant in Karratha, Western Australia.	2027 (ARENA, 2023c)

7.9 Implications and opportunities for a South African green hydrogen economy

	Chile[3]	Namibia[4]	Morocco	Egypt[5]	Australia[6,7,8]	China[9,10]	USA[11]	UAE[12,13,14]	South Africa
GH_2 roadmap/strategy									
Funding schemes									
Envisaged 2050 share of global market	13 %	5-8 %	4 %	5-8 %	40 %	-	-	25 %	4 %
Estimated cost	2030: USD1.4/kg[15] 2050: USD1 – 1.14/kg	2030: USD1.2-1.3/kg 2050: USD0.8-0.9/kg	2030: 3.93USD 2050: USD0.7-USD1.4/kg	2030: USD2.7/kg by 2025 2050: USD1.7/kg	2030: USD2/kg 2050: 0.75 – 1.30/kg	2030: USD2.2/kg 2050: USD0.9 – 1.25/kg	2030: USD2/kg 2050: 0.9/kg – 1.25/kg	2030: USD4.51/kg 2050: 0.8 – 1.25/kg	2030: USD2.94-USD3.24/kg 2050: USD1.18-USD1.47/kg
Project pipeline	Planned: 5 Development: 0 Operational: 1	Planned: 3 Development: 1 Operational: 0	Planned: 2 Development: 0 Operational: 0	Planned: 5 Development: 0 Operational: 0	Planned: 5 Development: 0 Operational: 1	Planned: 10 Development: 0 Operational: 6	Planned: 7 Development: 0 Operational: 3	Planned: 4 Development: 0 Operational: 0	Planned: 3 Development: 0 Operational: 1
Land									
Water									
Renewable Energy									
Infrastructure									
Skills									
Initial market priority	Domestic	Export		Export	Export/ Domestic	Domestic	Domestic	Exports	Export
Potential market	Eastern market	Western market	Western Market	Western and Eastern Markets	Eastern and Western markets	N/A	N/A	Western and Eastern Markets	Western and Eastern Markets
Special Economic Zones	√	√	√	√	√	√	√	√	√

3 https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2022/Jul/IRENA_Global_hydrogen_trade_part_1_2022_.pdf
4 https://gh2.org/countries/namibia#:~:text=Capacity%20and%20price&text=McKinsey%20estimates%20that%20Namibia%20could,US%241.5%2Fkg%20by%202030.
5 https://english.ahram.org.eg/News/507526.aspx
6 https://www.rechargenews.com/energy-transition/green-hydrogen-now-cheaper-than-blue-in-middle-east-but-still-way-more-expensive-in-europe/2-1-1173423
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14 https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2022/Jul/IRENA_Global_hydrogen_trade_part_1_2022_.pdf
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CHAPTER 8

Conclusion

8. Conclusion

Hydrogen is emerging as a crucial player in the global energy transition landscape, offering a cleaner and more versatile energy carrier that can be used to decarbonise various industries, i.e., the hard-to-abate sectors. South Africa has ambitions of becoming a major producer and exporter of green hydrogen, capturing a 4 percent global market share by 2050.

One of the strategic approaches many countries with export ambitions are adopting is to produce hydrogen near a port for export due to, among others, access to global markets, existing infrastructure, and ease of export. For this study, four SEZs (Coega, Richards Bay Industrial Development Zone, Freeport Saldanha, and Boegoebaai) are profiled as initial preferred locations for green hydrogen development for exports and domestic consumption in South Africa. The selection of these four SEZs emanated from an analysis of the SEZs and their applicability in the green hydrogen economy. The purpose of the Investment Profiles is to highlight the synergistic effect between the SEZs for the export of South African green hydrogen and hydrogen related products.

Currently, all four SEZs have green hydrogen ambitions but have no operational projects, firm off-take agreements and their green hydrogen strategies are at different stages of development, Boegoebaai being the most advanced. There are however numerous discussions underway for the development of various projects that have been gazetted as SIPs in the National Hydrogen Programme, including Hive at Coega, Boegoebaai and numerous projects at Saldanha. The projects having SIP status will enable for development of projects to be fast tracked with reduced approval timelines, for environmental approvals reduced from 107 days to 57 days. Each SEZ is developing a strategy that focusses on their individual priorities/focus areas, however, by combining efforts to access international green hydrogen markets, the SEZs can together identify and target export opportunities, establish trade agreements and promote South African green hydrogen on a global scale.

Key observations include that the three existing SEZs are well positioned to export green hydrogen given existing infrastructure (air, ports, rail, and road). Richards Bay is the only port that has facilities to handle ammonia. Moreover, Saldanha and Richards Bay are both deep sea water ports and can provide efficient export of PtX products. Once established, Boegoebaai will also be a deep-water port.

Significant infrastructure upgrades and the development of new infrastructure will be required to accommodate green hydrogen investments, including the establishment of a new port at Boegoebaai. All four SEZs however have good quality renewable energy resources (solar and onshore wind) with RBIDZ and Freeport Saldanha having good off-shore wind resource with the first off-shore wind project currently under development off the coast of Richard's Bay. The facilities may need to be located inland where renewable energy resource is better and fewer land use constraints and environmental sensitivities exist. Coega, Freeport Saldanha and Boegoebaai are further located close to REDZ which are located inland and will enable the fast tracking of renewable energy projects located close to these SEZs. The SEZs have identified different potential sources of water, which in the main, include desalination plants and the use of grey water. Land availability is a concern at the three existing ports. Each SEZ has however identified remedial actions which include securing additional land that is earmarked for the development of energy projects (RBIDZ), entering back-to-back leases with customers (Freeport Saldanha) and Coega (securing additional land and establishing satellite sites).

All the SEZs currently have no green hydrogen skills programmes in place, however, Coega and Freeport Saldanha to a smaller extent, have established training centres that are used to service the needs of existing customers. Establishing a robust green hydrogen ecosystem, including training centres and work development programs can benefit all zones. Sharing best practices in skills development and promoting a skilled labour force for the hydrogen industry can enhance overall competitiveness.

Internationally, some of the biggest competitors for green hydrogen and PtX products export to markets such as Japan and Australia. South Africa however has better capacity factors than Australia for wind and solar PV. It would, in addition to this, be prudent for Japan and other countries to diversify their supply options and therefore, Australia and South Africa along with other potential suppliers can be included as multiple supplier options of green hydrogen and PtX products. South Africa is also competing against other African countries such as Morocco, Namibia and Egypt which have wind and solar PV resources that are comparable to South Africa's resources. South Africa however has the most developed renewable energy sector, and industrial processes as well as being a leader in science and innovation, including being a global leader in Fischer-Tropsch-Technology.

Given the pace at which the global green hydrogen market is evolving, successfully capturing a four percent global market share by 2050 will require a concerted effort from the South African government. Collaboration among these SEZs for green hydrogen exports holds significant promise, however, it also requires effective coordination, strategic planning, and strong governance to address potential challenges and ensure the successful implementation of a synergistic approach. Moreover, the growth of the global green hydrogen market and evolving technology trends should be closely monitored to adapt to changing dynamics.

CHAPTER 9

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