Shipping's Energy Transition:

Strategic Opportunities in South Africa

By Global Maritime Forum
& University College London

For the P4G Getting to Zero Coalition Partnership

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About the Getting to Zero Coalition

The Getting to Zero (GtZ) Coalition, a partnership between the Global Maritime Forum and World Economic Forum, is a community of ambitious stakeholders from across the maritime, energy, infrastructure and financial sectors, and supported by key governments, IGOs and other stakeholders, who are committed to the decarbonization of shipping.

The ambition of the Getting to Zero Coalition is to have commercially viable ZEVs operating along deep-sea trade routes by 2030, supported by the necessary infrastructure for scalable net zero-carbon energy sources including production, distribution, storage, and bunkering.

About Partnering for Green Growth and the Global Goals 2030

The Partnering for Green Growth and the Global Goals 2030 (P4G) is a global delivery mechanism pioneering green partnerships to build sustainable and resilient economies. The P4G mobilizes a global ecosystem of 12 partner countries and 5 organizational partners to unlock opportunities for 66 partnerships working in five SDG areas: food and agriculture, water, energy, cities and circular economy.

About the Global Maritime Forum

The Global Maritime Forum (GMF) is an international not-for-profit organization dedicated to shaping the future of global seaborne trade to increase sustainable long-term economic development and human wellbeing.

About Friends of Ocean Action

Friends of Ocean Action is a unique group of over 55 global leaders from business, international organizations, civil society, science and academia who are fast-tracking scalable solutions to the most pressing challenges facing the ocean. It is hosted by the World Economic Forum in collaboration with the World Resources Institute.

About the World Economic Forum

The World Economic Forum (WEF) is the International Organization for Public-Private Cooperation. The Forum engages the foremost political, business, cultural and other leaders of society to shape global, regional and industry agendas. It was established in 1971 as a not-for-profit foundation and is headquartered in Geneva, Switzerland. It is independent, impartial and not tied to any special interests.

About Environmental Defense Fund

Environmental Defense Fund Europe is an affiliate of Environmental Defense Fund (EDF), a leading international non-profit organisation that creates transformative solutions to the most serious environmental problems. Since 1967, EDF has used science, economics, law and innovative private-sector partnerships to bring a new voice for practical solutions.

About University College London

University College London (UCL) Energy Institute Shipping Group aims to accelerate the shipping transition to an equitable, globally sustainable energy system through world-class shipping research, education and policy support. The group specialises in multi-disciplinary research anchored in data analytics and advanced modelling of the maritime sector.

About International Association of Ports and Harbours

The International Association of Ports and Harbours (IAPH) was formed in 1955 and over the last sixty years has grown into a global alliance representing over 180 members ports and 140 port-related businesses in 90 countries. The principal aim of IAPH revolves around the promotion of the interests of Ports worldwide, building strong member relationships and sharing best practices among our members.

About UMAS

UMAS delivers consultancy services and undertakes research for a wide range of clients in the public and private sectors using models of the shipping system, shipping big data, and qualitative and social science analysis of the policy and commercial structure of the shipping system. UMAS's work is underpinned by state-of-the-art data supported by rigorous models and research practices, which makes UMAS world-leading on three key areas; using big data to understand drivers of shipping emissions, using models to explore shipping's transition to a zero emissions future and providing interpretation to key decision makers.

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Acknowledgments

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Disclaimer

This report is from the P4G - Getting to Zero Coalition Partnership project, a project between the Global Maritime Forum, the Friends of Ocean Action, the World Economic Forum, University College of London, Environmental Defense Fund, and the International Association of Ports and Harbours. The views expressed are those of the authors alone and do not represent the opinions or views of the partners involved.

Foreword

Office of the Presidency

The Office of the Presidency welcomes the release of this report as an important contribution to South Africa's journey towards a green hydrogen-based economy. Decarbonizing South African industry is essential to meeting the major challenges the nation is facing, enabling a just transition to new cleaner forms of energy, and sustainably future-proofing the wider economy for decades to come.

The maritime industry can be an important player in this transition, as a large potential offtaker and carrier of these fuels and moreover a bridge to other land-based sectors and geographies with increasing demands for alternative fuels.

It is our hope that South African stakeholders can leverage the opportunities outlined in this report, reducing emissions whilst also taking advantage of South Africa's unique position to benefit from the wider industrial transition to zero emission fuels globally.

Because of the multi-sectoral nature of the green hydrogen potential in South Africa, the Presidency will play a convening and coordinating role to enable the aggregation of all expertise and interests across various government departments.

More work and collaboration will be needed to achieve this and ultimately ensure that international maritime decarbonization can truly drive and contribute towards our wider national ambitions.

Mr. Mondli Gungubele
Minister in the Presidency
Republic of South Africa

Foreword

South Africa is well positioned to benefit from international maritime decarbonization due to its large renewable capacity and unique location sitting at the gateway between the Atlantic and Indian Oceans. Tapping into this global energy transition holds the potential to accelerate the transition to cleaner forms of energy across the economy, creating several opportunities for the country.

In supporting national efforts towards greening and future proofing the economy, South Africa could seek to also leverage the opportunities surrounding maritime decarbonization to achieve wider national ambitions. This includes promoting national and international collaborations in research and development, advancing climate action, moving to a just transition through decarbonizing industry, developing a strong national renewable energy market, tapping into markets and increasing export potential, regional development, job creation, energy and water security, and local air quality.

To realize this, there is a need for South Africa to support the development of policy levers, capable of facilitating and effectively contributing to decarbonizing the maritime sector. This would require more clearly defining national objectives to ensure that benefits are realized, unlocking potential value chains, as well as supporting and advancing international policies capable of accelerating the just transition to zero emission fuels globally.

As local stakeholders and members of the National Committee, we welcome the findings outlined in this report and call on relevant actors to engage further around realizing these opportunities for South Africa.

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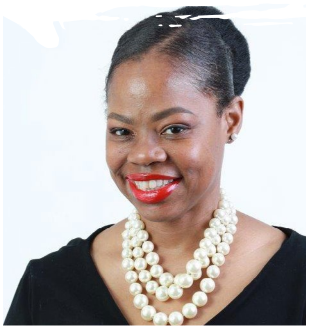

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Executive Summary

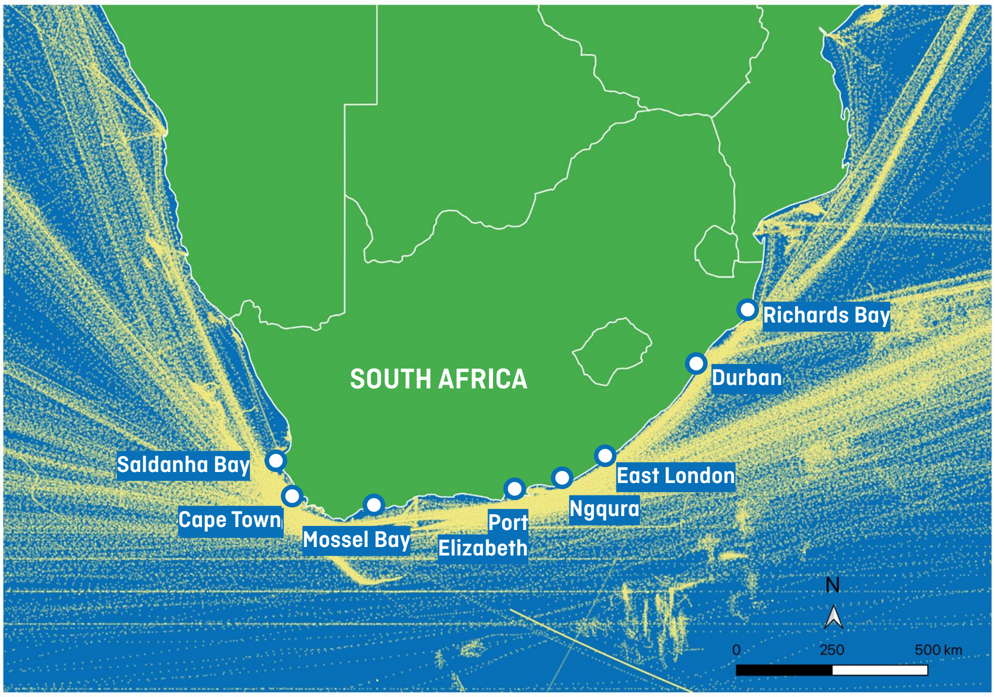
South Africa – a potential leader in shipping's energy transition, supporting decarbonization of the maritime value chain through the production and export of green fuels.

Situated along busy international shipping routes, South Africa has the highest volumes of maritime traffic in Africa outside of the Mediterranean region. The country has one of the best-connected port systems on the continent that supports the trade of valuable commodities, including the country's large reserves of platinum group metals. As such, imports and exports constitute over a third of the country's gross domestic product (GDP). From a political, social, and economic standpoint, South Africa relies on its ocean economy to facilitate trade and provide employment across several industries.

However, as the world's 16th largest contributor to greenhouse gas (GHG) emissions, South Africa also has an acute need to tackle its emissions. This is particularly true given its high vulnerability to climate change, with droughts and extreme weather events disproportionately impacting the country. Maritime activities in South African waters contribute towards these emissions and, depending on the approach taken, calculations show domestic shipping emissions to be heavily underestimated.

New estimates show that South Africa's domestic maritime emissions are underestimated by at least 87%.

Figure 1: Maritime activity round South Africa's coastal waters (2018).



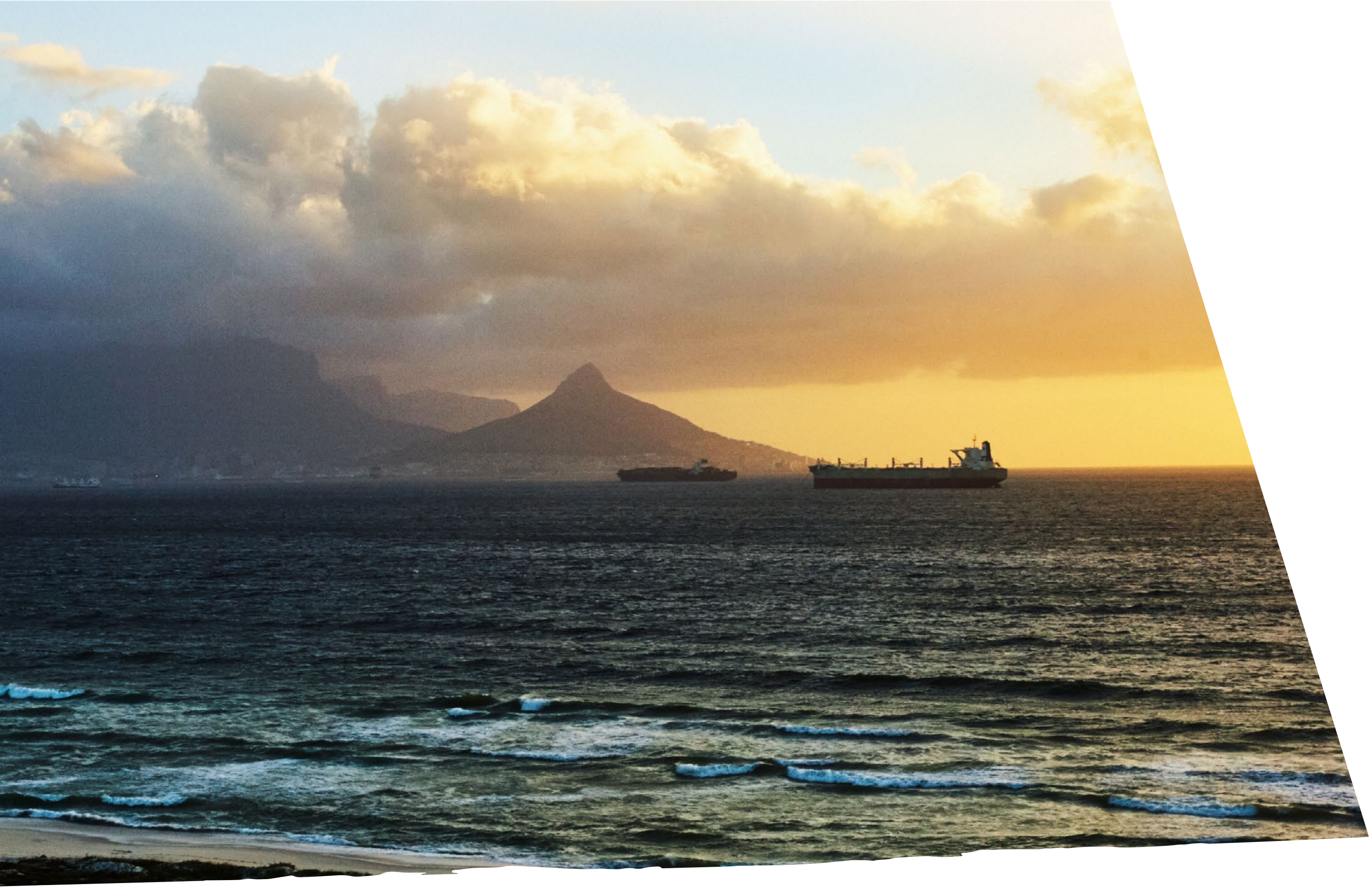
As the maritime industry moves ahead in its decarbonization agenda, the need for green fuels and associated technologies are increasing in urgency and relevance. In particular, scalable zero emission fuels (SZEF) such as green hydrogen and green ammonia are considered the most promising fuels for the industry's transition. These fuels will require substantial amounts of renewable energy for their production, storage, and distribution.

Fortunately, South Africa benefits from large untapped renewable energy sources in the form of solar and wind. As a priority, the country has stated in its Integrated Resource Plan the need for affordable, reliable, and sustainable energy as part of the nation's energy transition road map. Taking advantage of these resources could see the country producing up to 1,578.3 – 5,698.3 Terawatt hours per year (TWh/y) of renewable energy by 2030. This represents more than enough energy to meet domestic electricity demand, decarbonize local industries as well as contributing to the decarbonization of domestic and international shipping. Assuming 5% of the global fleet transitions to SZEF by 2030, then the green energy demand for vessels in South Africa would represent about 3.8 TWh/y, which conservative calculations shows is only 0.2% of South Africa's total renewable potential.

Strategic Business Opportunities

With its strong maritime connections and large renewable potential, South Africa finds itself in a unique position to benefit the global energy transition and maritime decarbonization. Development of SZEF infrastructure to serve South Africa's shipping sector could attract investment up to R175 billion Rand ($11.1 billion USD) in onshore infrastructure by 2030.

By capitalizing on its renewable potential and its established trade relations, South Africa could become a leading zero-carbon marine fuel producer, fulfilling its climate and energy commitments whilst simultaneously addressing its sustainable development goals. Being part of the transition for shipping would allow South Africa to engage in, for example, green fuel production, exports, and bunkering; supporting a just and equitable job transition; creating green hubs and green ports; as well as allowing for green corridors along key shipping routes. After extensive consultation with key South African stakeholders, three key opportunities for South Africa were identified to be Saldanha Bay Industrial Development Zone, the proposed port of Boegoebaai, and the Hydrogen Valley project.

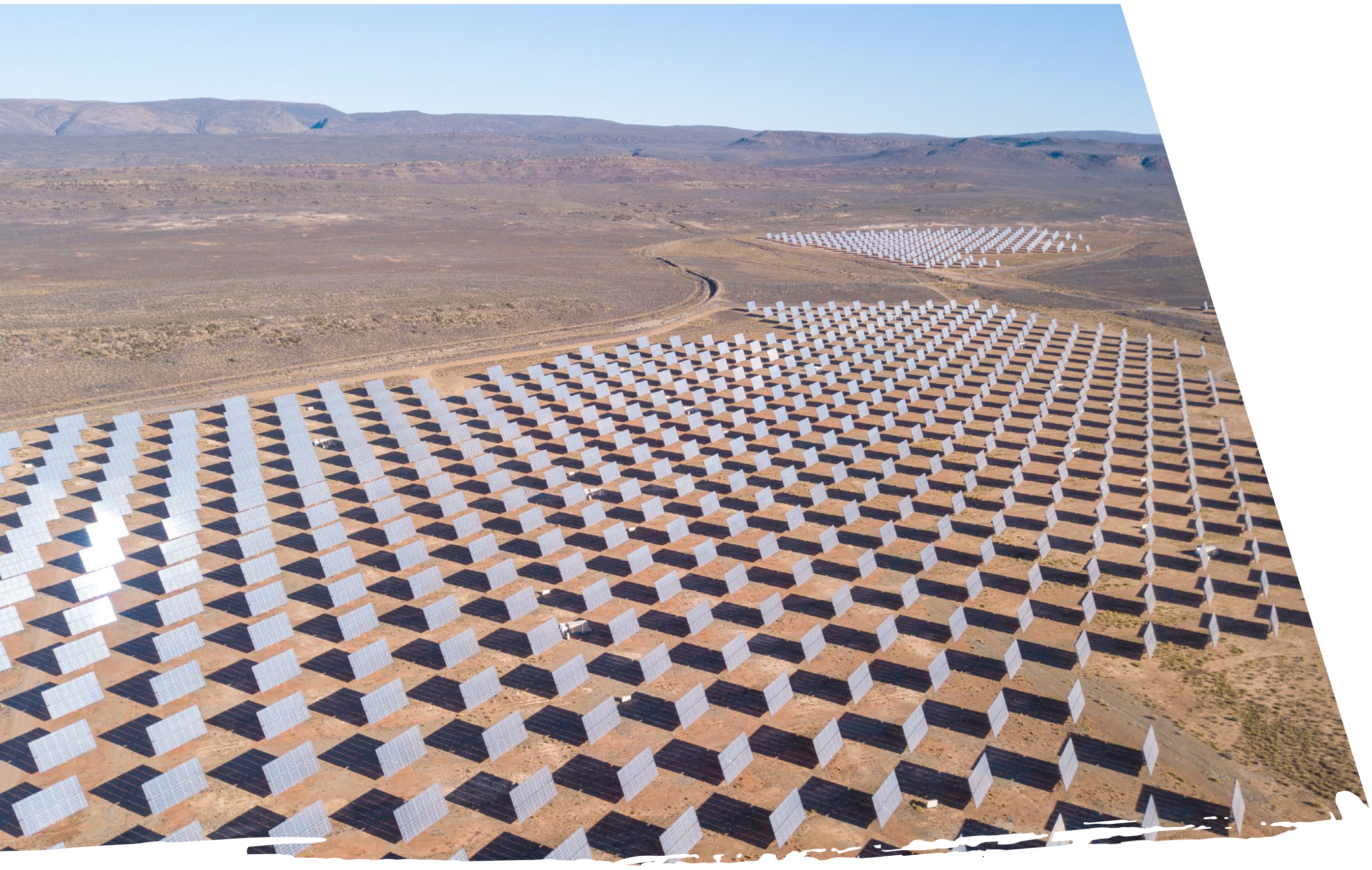


Saldanha Bay Industrial Development Zone

Located in South Africa's Western Cape, the port is a key opportunity due to its export commodities and established trade routes, favorable location to nearby renewable potential, land availability for port expansion and development, synergies with local industries, its status as a Freeport, as well as existing efforts and stakeholder interest in developing green hydrogen and ammonia capacity within the port.

Saldanha Bay has the opportunity to engage in a green corridor for the export of the country's iron ore resources. As South Africa's largest ore exporting port, 77% of the vessels arriving and departing from the port are bulk carriers. As the global demand for green steel increases, South Africa's iron ore industry can directly benefit from Saldanha Bay's capability to produce SZEF and green its supply chains.

Furthermore, leveraging synergies between producing SZEF for the bulk carrier vessels and the local mining industries can aggregate demand and increase economies of scale for local green hydrogen and ammonia production.
This would enable the port to become a green hydrogen hub for the production and export of SZEF.



Boegoebaai

Boegoebaai is a proposed deep water port project planned for South Africa's Northern Cape Province, located close to the Namibia border. It was selected as a key opportunity for South Africa due to its favorable location to nearby renewable potential, large land availability for port development, synergies with regional industries, its status as a planned Special Economic Zone, as well as strong national support for developing green hydrogen and ammonia capacity in the region.

The port has the opportunity to become an export hub for green hydrogen. Plans for this capability are already integrated in the project, which intends to directly integrate the production of green hydrogen to support manufacturing of sustainable goods and services in the Northern Cape and the export of green hydrogen.

Though local industries are scarce due to the undeveloped nature of the area, synergies with established regional industries would see a new commercial corridor for the port. In particular, large iron ore mining sites are located in the Northern Cape, the products for which could be exported through Boegoebaai.

Hydrogen Valley

The initiative proposes a corridor with three hydrogen hubs that would transform the region around Johannesburg, Mogalakwena, and Durban into a Hydrogen Valley. It was selected as a key opportunity for South Africa due to its ambition to facilitate cross-sectoral synergies to aggregate green hydrogen demand, the active involvement and representation of key mining and energy actors, and its scalability and replicability to other areas and regions.

The Hydrogen Valley is an opportunity to aggregate demand in South Africa to kickstart hydrogen production and leverage economies of scale. A maritime component is foreseen as a hub in Durban – Richards Bay, which would in the long-term aim to bunker and export green hydrogen to the maritime market. The port of Durban is one of the busiest ports in South Africa, servicing large containerships and cargo traffic, while Richards Bay is South Africa's largest bulk coal terminal.

Developing a green hydrogen economy would support the region's efforts for a just transition, especially in the development of Richards Bay as a sustainable alternative to the port's heavy reliance on coal handling.

Recommendations

Presently, there is a high awareness in South Africa of the benefits the production and use of SZEF can bring, especially with regards to the country's climate goals and commitments in addition to facilitating a just transition away from its reliance on coal. But to appropriately leverage these opportunities, there are several key actions that can be taken to advance zero emission shipping in South Africa and globally. These actions can be taken by port actors and authorities, governments, financial institutions, as well as maritime and wider industry players interested in leveraging the green hydrogen potential of South Africa. With appropriate incentives and targeted action towards encouraging economy-wide energy, investment, and environmental planning, South Africa can become a first mover in this field and set an example for other countries to follow.

PORTS

Prioritize port electrification as a key first step
Switching port activities wherever possible to rely mainly on electrical energy from renewable sources can reduce local GHG emissions, maintenance, and energy costs.

Increased coordination and guidance to support port development towards decarbonization & a just transition
Increased coordination and national planning could help to align and structure various efforts and initiatives taking place in South African ports today. This would ensure that co-benefits are considered and value is recognized in justifications for sustainable port investments and development.

Prepare to source or produce SZEF for bunkering, port use & export
First movers are already planning to operate ships on SZEF. Preparing to source or produce green hydrogen and ammonia can help the country realize strategic opportunities both domestically as well as a possible export product to other countries or regions.

Become a Green Port
Port authorities could invest in creating an environmentally-friendly port ecosystem through adoption of technology solutions, improved facilities, and optimization of terminal and ports to reduce at berth time. As demonstrated in initiatives such as the UN Environmental Programme's "Sustainable and Clean Port program".

POLICY

National

Align maritime policies with national climate ambition
Aligning maritime policies, in both national and international settings, to the levels of national climate ambition can increase policy coherence and unlock investment. The maritime sector should be included within the larger decarbonization agenda and explicitly addressed within national policies.

Exploit synergies between shipping's decarbonization & coal phaseout
Setting a timeline for coal phase out in South Africa, would send a strong market signal to renewable energy and by association SZEF producers. South Africa's government could consider how maritime decarbonization can create new jobs that can support the transition away from fossil fuel jobs.

Encourage public-private collaborations
Authorities and stakeholders could develop integrated roadmaps that include future infrastructures, transition pathways, ways of working between the involved parties, governance structures, and business models.

POLICY

International

Collaboration to secure effective GHG policy at the International Maritime Organization (IMO)
Unlocking investment could be enabled through effective policy at the IMO and working with other countries on the adoption of new policy, e.g. market-based measures, South Africa can better enable shipping's just and equitable transition.

Support the development of SZEF standards & authorizations
Such standards and labels are required to harmonize technology specifications for the industry and monitor safety of hydrogen production and transport.

Sign the Declaration on Zero Emission Shipping by 2050 to increase climate ambition
South Africa could commit to strengthen global efforts to achieve zero emissions from international shipping by 2050, including at IMO. This would signal political ambition to adopt goals for 2030 and 2040 that place the sector on a full decarbonization pathway.

Sign the Clydebank Declaration & develop Africa's first green corridor
Based on its renewable energy potential, trade relations with other regions, and location along busy shipping routes, South Africa could sign the Clydebank Declaration to signal its interest in international collaboration international collaboration on early adoption.

FINANCE

Create the conditions to enable first mover projects
Infrastructure upgrades are costly and lengthy procedures, which often demand the mobilization of private capital. It's important to design an environment that triggers investments and unlock further finance towards a high renewables-based system.

Boost private renewable electricity generation
Spending on renewable energy infrastructure could focus on building a smart, reinforced distribution grid that integrates both public and private sources of renewable energy, which can help manage local congestion and support grid resilience.

Work bilaterally with countries to reduce SZEF investment costs & risks
Similar to the development of wind and solar technologies, new SZEF technology will need financial support and structures to ease their adoption. Bilateral relationships could help incentivize and accelerate action on this front.

Enable a just transition
South Africa's SEZs offer important growth incentives to strengthen commitment to sustainable development goals, job generation, and innovation.

INDUSTRY

Aggregate SZEF demand
Maritime industries, though substantial offtakers themselves, could look to coordinate with other sectors across the value chain, especially mineral mining and steel production, in order to aggregate SZEF demand.

Public-private collaboration & engagement
Local stakeholders also emphasized the need for more collaboration between public bodies and industry to fill knowledge gaps, de-risk early innovation efforts, and align on new standards and regulations.

Build alliances to drive market change
Gathering industry actors into a non-competitive fora for collaboration can send a collective demand signal to fast track decarbonization action.

Explore alternative business model options
Industry actors could seek new and alternative business models – such as book and claim systems, subscription services, and amending shipping contracts – that reduce high barriers to entry or adoption for SZEF technology.

It is clear that South Africa can play a strong role in building the global momentum towards zero emission shipping, leveraging its own development goals while preparing to meet the future demands of the maritime industry. Unlocking international finance, establishing national and international cross-sectoral partnerships, easing financial and regulatory hurdles, and investing in climate-proof projects will be fundamental in the years to come.

To get there, strategic and decisive action can enable South Africa to become a competitive producer and exporter of SZEF. Investing in key renewable energy and SZEF infrastructure would have significant benefits for the country's economy and society, reducing national emissions, improving air and water quality, creating sustainable jobs and skills expertise as part of a just transition, and developing new supply chains. The actions outlined above could support South Africa in its continued journey towards decarbonization and becoming Africa's first zero carbon bunkering hub.

Glossary

AIS	Automatic Identification System
BC	black carbon
CH_4	methane
CO	carbon monoxide
CO_2	carbon dioxide
CO_2e	CO_2 equivalent
EEZ	exclusive economic zone
EF	emission factors
GHG	greenhouse gas
GWh/y	Gigawatt hours per year
HFO	Heavy Fuel Oil
HFO_{eq}	Heavy Fuel Oil equivalent
HySa	Hydrogen South Africa
IDZ	Industrial Development Zone
IHS	Information Handling Service
IMO	International Maritime Organization
IPCC	Intergovernmental Panel on Climate Change
LHV	low heating value
LNG	liquified natural gas
MCR	Maximum Continuous Rating
MBM	market-based measures
MDO	Marine Diesel Oil
N_2O	nitrous oxide
NMVOC	non-methane volatile organic compounds

NO_x	nitrogen oxides
PM	particulate matter
SEZ	Special Economic Zone
SGM	Shipping Geospatial Model
SO_x	sulphur oxide
SZEF	scalable zero emission fuels
TWh	Terawatt hours
QA	quality assurance
QC	quality control

Section 1

The Need for Maritime Decarbonization

Climate change is one of the biggest challenges faced by humanity this century. The work of the Intergovernmental Panel on Climate Change (IPCC) has highlighted and evidenced the severe impacts of climate change that are occurring all over the world. These impacts are expected to increase in intensity, frequency, and danger unless an energy transition is implemented across all sectors [1]. The IPCC suggests that avoiding the worst-case scenarios means limiting the rise in global temperature to around 1.5°C. To do so, "Global net human-caused emissions of carbon dioxide (CO_2) would need to fall by about 45% from 2010 levels by 2030, reaching at least 'net zero' around 2050" [2][3].

In 2015, the Paris Agreement set the goal to limit global warming to well below 2.0°C and preferably 1.5°C. More recently, at the 2021 United Nations Conference of Parties (COP26), shipping and its contribution to international climate change was highlighted as a key sector to tackle in the coming years. Indeed, the IPCC's most recent work highlights the role of the shipping sector and actions needed to enable its decarbonization [4]. It is clear shipping, as a sector, will need to play its part in global decarbonization and energy transition if this goal is to be achieved.

Regional and global maritime transport effectively connects economies through the efficient movement of goods, accounting for 80%-90% of the world's trade [5][6]. Fueling this movement is a $140 billion USD per year energy industry that supplies the shipping sector with 4-5 million barrels of oil every day[1] [7]. In so doing, the shipping sector emits between 2-3% of the annual global greenhouse gas (GHG) emissions – and contributes between 12-13% of sulfur and nitrogen oxides emissions to global air pollution [8][9].

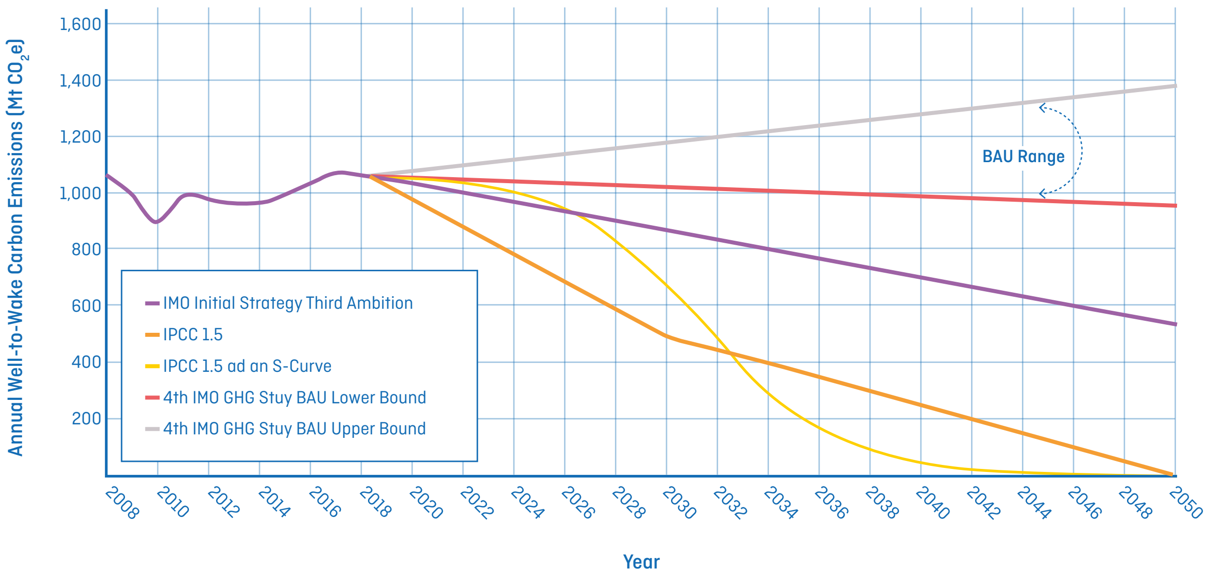
Seaborne trade has seen an average annual growth of about 3.2% between 2011 and 2019, meaning that more than 13,000 new commercial ships[2] have entered into operation in the past decade [10], the majority of which are powered by fossil fuels. Recent projections indicate that by 2050, shipping emissions will increase by between 90-130% from 2008 levels [8] (see Figure 1). With an average lifespan of around 25 and 30 years, ships are considered to be long-life assets. Depending on the type of engine used in these vessels, the cost of retrofitting them to run on alternative fuels can be substantial. To avoid fossil-fueled ships becoming stranded assets, there is an urgent need to implement measures to facilitate shipping's transition and reduce emissions substantially as soon as possible [11]. Actions to support this will be both manufacturing zero emission vessels as well as retrofitting existing assets.

1 Barrel contract price taken on the 17/01/2022 which was $84.20 USD.

2 Above 100 gross tonnage and typically with a length larger than 25 m depending on vessel construction.

Importantly, increased energy efficiency and natural gas-based fuels alone will be inadequate to meet the Paris climate goals [4]. Thus, the future of international shipping will rely on the production and use of new scalable zero emission fuels (SZEF), a subset of fuels with (i) the potential to have zero GHG emissions on a lifecycle basis taking into account the emissions from production, transport, storage, and use; and (ii) production processes capable of competitively supplying expected future demand. The scale of demand for such fuels is estimated to be around 200-300 Mt of Heavy Fuel Oil equivalent (HFO_{eq}) energy per year [12].

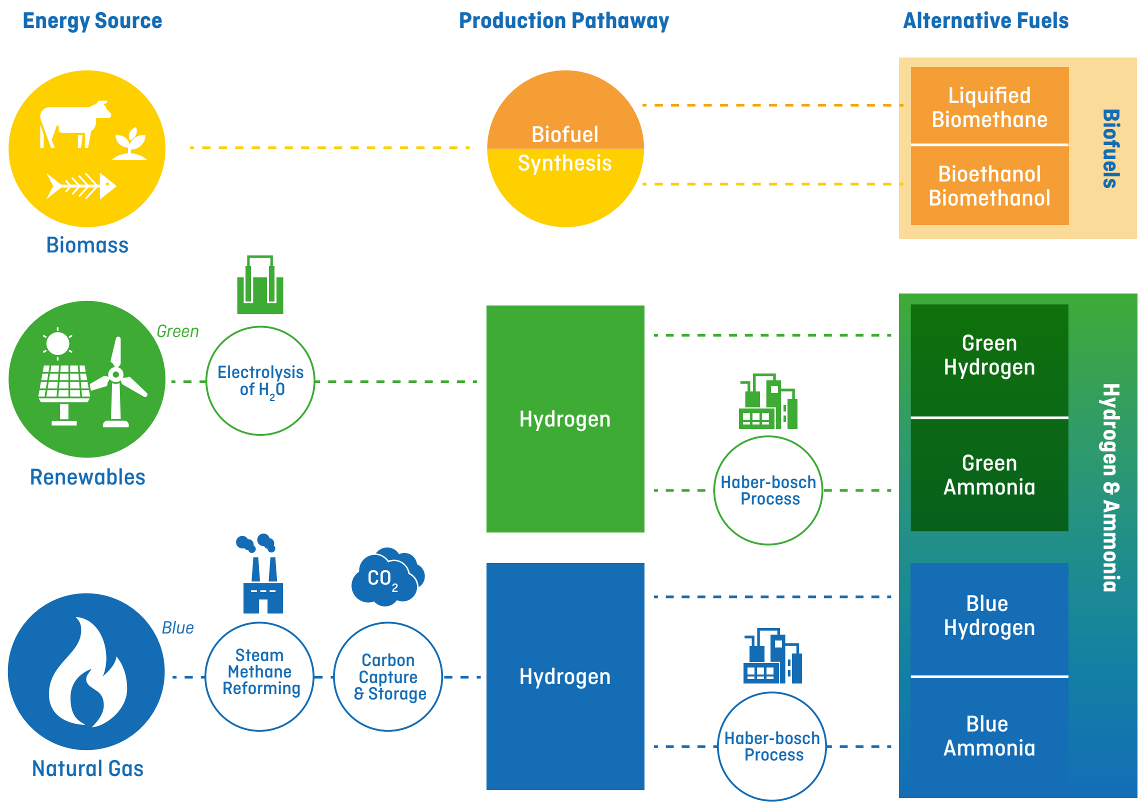
Figure 1: Potential maritime Well-to-Wake[3] carbon equivalent emission pathways based on different scenarios, ambitions and climate change objectives. The grey area represents the emission range for the BAU case [based on 8].



As shown in Figure 2, there are multiple new fuel types with the potential for use in the shipping industry. Biofuels are unlikely to be the main fuel choice, as they suffer from scalability challenges as well as competitive demand from other sectors. Rather, the most promising long-term options for shipping include green hydrogen and green ammonia for deep-sea going vessels as both can be used through fuel cells of internal combustion engines. Green ammonia, in particular, is thought to be the most suitable long-term option for decarbonizing international shipping [13] [14]. Smaller domestic vessels may also make use of green hydrogen, although other power options such as electrification is attractive.

3 They are the aggregation of upstream (i.e. well-to-tank) and downstream (i.e. tank-to-wake) emissions.

Figure 2: Alternative fuels and their production pathways (inspired by World Bank [15]).



Source: Inspired by the World Bank

Clearly a challenge and yet also an opportunity, the fuels transition in shipping can trigger investment, catalyze innovation, and create sustainable economic growth. This will require the sector to develop and build new vessels, integrate and adopt innovative technology solutions, develop new fuel supply chains and land-based infrastructure while leveraging synergies with other sectors seeking to decarbonize their commercial activities. In such a way, shipping itself can be seen as both a driver and consumer of these new fuels [16].

Steps are already being taken to build, demonstrate, and pilot new SZEF technology and prototypes. Large-scale SZEF marine engines are expected to be commercially available by the mid-2020s, while large-scale fuel cell arrangements will likely be available later in the decade [17]. The costs of these new engines and fuel cells will initially be more expensive than the traditional fossil-fuel based ones currently used, but will become more competitive over time as economies of scale are leveraged. Zero emission vessels are expected to enter into service on a relatively small scale by or before 2030 and will become the mainstream option for new ship orders over the following two decades. To prepare for this future, action is needed now, especially the expediated creation of SZEF infrastructure [18].

«There is a clear need for unprecedented progress globally to scale up the production of green fuels for international shipping. South Africa has the definite potential to become one of the leading supplier of these fuels.» – Simon Bergulf (A.P. Moller-Maersk)

Section 2

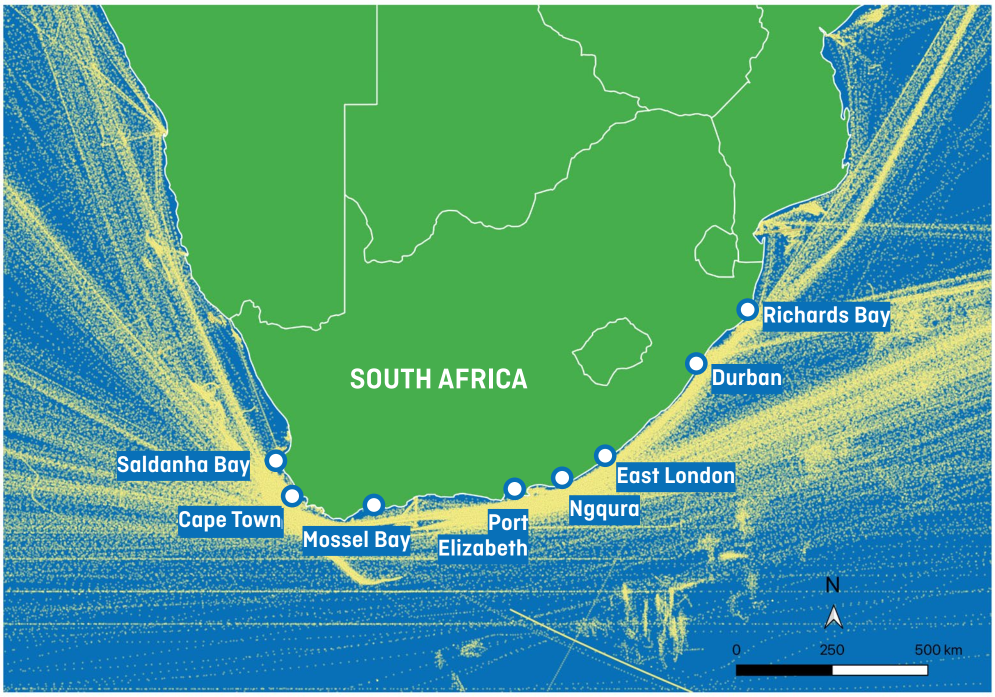
South Africa: a Maritime Nation

South Africa is situated on one of the busiest international sea corridors critical to international maritime transportation. Its geographical location along the South-South and the North-South trade corridors presents a huge opportunity for investing in a diversified maritime market that needs to reduce its GHG emissions (see Figure 3).

South Africa's ocean economy is estimated to contribute $6.3 billion USD, of which the country plans to expand this potential in the coming years through strategic investments and expanding capacities [19]. The country has a relatively small fleet of around 100 vessels. Its eight key ports include one of world's biggest coal terminals, the deepest and largest natural harbor in the Southern Hemisphere, and two of the world's top container ports [19][20]. These ports include Cape Town, Durban, East London, Mossel Bay, Ngqura, Richards Bay, Port Elizabeth, and Saldanha Bay [21].

About 4% of the world's containerized trade volume pass through African ports [22] and about 96% of South Africa's imports and exports are moved on ships at some point along the supply chain [23]. In 2020, when considering the liner shipping connectivity in the continent, South Africa is considered the third best connected country, with their bilateral connectivity index scoring the highest with China, Singapore, Sri Lanka, Malaysia, Republic of Korea, Mauritius, Ghana, Spain, Hong Kong, and Togo [20][22].

Figure 3: Maritime activity around south africa's coastal waters (2018).



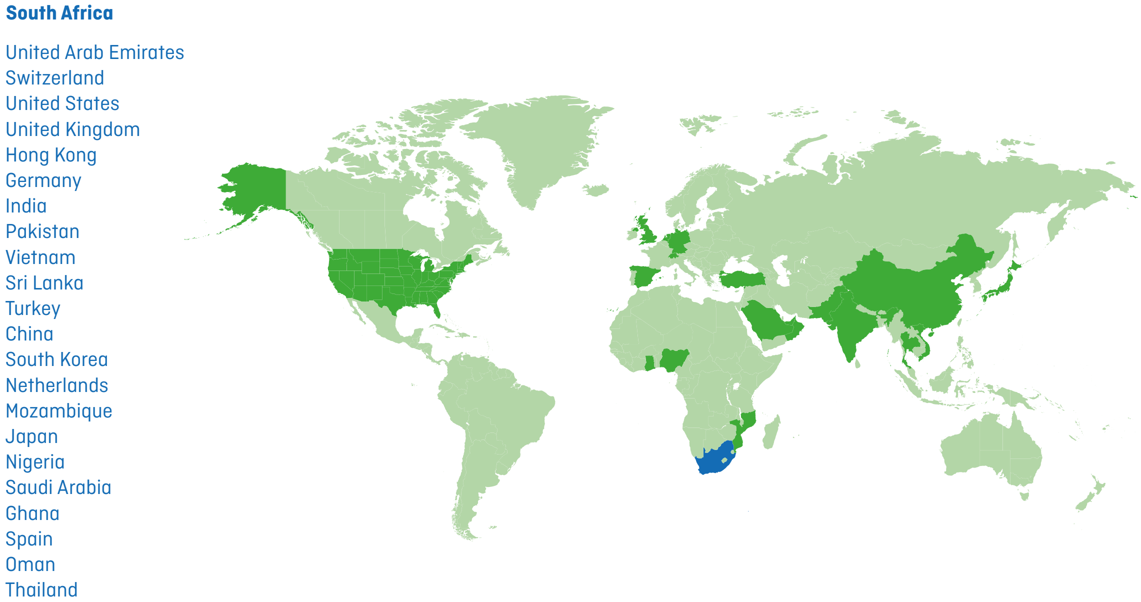
In 2020, of the 7,836 vessel arrivals in South Africa, the majority were from dry bulk carriers (2,912), container ships (1,840), and liquid bulk carriers (1,715) [20]. With such traffic, South Africa also stands as one of the top 20 countries regarding international marine fuel sales, which underpins the substantial demand of maritime energy. This could explain why South Africa imported $8.7 billion USD worth of crude and refined petroleum in 2020 [24].

This import of petroleum also supports vessels arriving in South Africa that go on to deliver the country's mineral resources (see Table 1). Mining is a key economic sector in South Africa, due to the country's large reserves of gold, coal, platinum, and diamonds [25]. Moreover, South Africa's substantial reserves of platinum group metals – accounting for over 80% of world's platinum reserves – are crucial for the electrolyzers needed to produce green hydrogen and fuel cells [26]. Consequently, in 2020, South Africa exported roughly $102 billion USD in goods, primarily platinum, gold, coal briquettes, and iron ore. From Figure 4, the main export destinations were to the United States, China, Germany, and Japan [24].

Table 1: South Africa's Key Imports and Exports [24].

Imports				Exports			
Product	Value (USD)	% of total imports	Origin & Value (USD)	Product	Value (USD)	% of total exports	Destination & Value (USD)
Crude Petroleum	5.09 B	7.1%	Nigeria (2.14 B) Saudi Arabia (1.87 B) Ghana (506 M) Spain (45.1 M) United Arab Emirates (208 M) United States (114 M)	Gold	13 B	12.7%	United Kingdom (3.36 B) United Arab Emirates (2.1 B) Switzerland (1.72 B) United States (1.47 B) India (1.41 B)
Refined Petroleum	3.51 B	4.94%	United Arab Emirates (756 M) Oman (629 M) India (586 M) Saudi Arabia (395 M) Netherlands (188 M)	Platinum	11.9 B	11.67%	United States (3.4 B) Japan (2.43 B) United Kingdom (2.87 B) Hong Kong (1.8 B) Germany (906 M)
Vehicle Parts	2.45 B	3.45%	Germany (743 M) Thailand (352 M) China (246 M) United States (232 M) Japan (180 M)	Coal Briquettes	6.37 B	6.24%	India (3.82 B) Pakistan (698 M) Vietnam (696 M) Sri Lanka (163 M) Turkey (95.7 M)
Cars	2.14 B	3.01%	India (487 M) Germany (437 M) Japan (300 M) Spain (147 M) China (94.5 M)	Iron Ore	4.06 B	3.98%	China (1.28 B) South Korea (564 M) Netherlands (558 M) Mozambique (418 M) Japan (321 M)

Figure 4: South Africa's Import and Export Relationships (based on OEC [24]).



Section 3

Maritime activity and shipping emissions

South Africa is a trading nation located on key shipping routes. As such, there is significant maritime activity within the country's waters. South Africa's shipping activity is dominated by bulk carriers, tankers, and containerships which are mainly on international voyages. The majority of the domestic traffic is offshore support vessels, fishing ships, and small boats. Using an activity-based approach[4], Table 2 breaks down the vessels that departed from South Africa's ports[5] in 2018 and shows the energy used in Gigawatt hours per year (GWh/y) by all ships in each ship type category. Bulk carriers account for 48% of the total annual energy demand, while tankers and containerships account for 22% and 20%, respectively.

Table 2: The fossil fuel energy demand from different types of vessels that have departed South Africa's ports [27].

Vessel category	Fossil Fuel energy demand 2018 (GMWh/y)	Share of Grand Total (%)
Bulk carriers: Large	12,652	29.7%
Bulk carriers: Large	7,126	16.7%
Tankers: Large	6,027	14.2%
Tankers: Small	3,035	7.1%
Containers: Large	5,509	12.9%
Containers: Small	2,726	6.4%
People & Vehicle Carrier: Large	114	0.3%
People & Vehicle Carrier: Small	1,846	4.3%
Offshore and services	757	1.8%
Fishing	2,088	1.4%
Small boats: Industrial	580	4.9%
Small boats: Fishing / Other Small Boats	91	0.2%
Grand total	42,556	100%

4 In an activity-based approach, also known as bottom-up approach, ships are aggregated by their design specifications using technical information sourced from ship registry databases such as Clarkson's Shipping Intelligence Network. This is combined with activity data that can be extracted from vessel operator surveys, port authorities, and Automatic Identification Systems.

5 The annual energy is based on all the shipping energy demanded for voyages that departed a South African port to its next port of call in 2018. This accounts for international and domestic voyages.

3.1 South Africa's National GHG Emission Inventory

In 2021, the government of South Africa published its 7th National GHG Inventory for the period between 2000 and 2017. Annual emissions growth averaged 0.6% in the years considered. Total GHG emissions[6] amounted to 512,660 kt CO_2 equivalent (CO_2e) in 2017 [28], placing South Africa as the 16th largest GHG emitter globally in the same year [29].

The national GHG inventory follows the 2006 IPCC Guidelines for National Greenhouse Gas Inventories [30]. Under these, international bunker fuel emissions, comprised of emissions from international aviation and maritime transport, are calculated as part of national GHG inventories, but are excluded from national totals and reported separately [31]. Furthermore, a country only needs to account for domestic maritime emissions in their national inventories, of which fishing activities should be aggregated under the *Agriculture/Forestry/Fishing category of the Energy sector* [31].

Of these, *Domestic water-borne navigation* contributed 356 kt CO_2e in 2017 (0.07% of South Africa's total GHG) and *International bunkers* accounted for 6,634 kt CO_2e (1.3%), while *International water-borne navigation* accounted for 1,692 kt CO_2e (0.3%) [32]. A more detailed presentation of the 2006 IPCC Guidelines for water-borne navigation can be found in Annex I.

3.2 Shipping Geospatial model: A new Approach for estimating maritime emissions

The Shipping Geospatial Model (SGM) is a new activity-based approach created by the UCL Energy Institute shipping group. The approach estimates maritime air pollution and GHG emissions inventories based on the energy demanded by the global fleet[7] and can segregate emissions by ship type and size, operational mode, route or geographical location (e.g. near a port). This versatility allows nuanced analysis of the sector's GHG emissions for any country.

Such analysis can illustrate the GHG emissions on specific voyages or in geographical regions or to estimate air pollution and the resulting health impacts in a region.

To study the maritime emissions during 2018 in South Africa through different lenses, the SGM aggregated hourly ship data[8] as follows:

- **Departures** Shipping activity is aggregated for the complete voyage leg that starts from the country's port. The voyage could be either domestic or international (see Figure 5).

6 Excluding forestry and other land use.
7 With the vessel classification based on Carpenter-Lomax et al. [27].
8 It only accounts for the activity of ships above 100 gross tonnage, the small boat fleet activity and emissions are not considered.

- **Arrival** Shipping activity is aggregated for the complete voyage leg that ends at the country's port. The voyage could be either domestic or international

- **Geofenced Exclusive Economic Zone (EEZ)** All shipping activity that occurred within the country's EEZ (i.e. 200 nm which includes the Territorial Sea) is aggregated. It includes the international shipping, domestic navigation, and domestic fishing. It also captures ships that are passing through the EEZ but not calling at any of the country's ports. The EEZ digital geographical region was taken from Flanders Marine Institute [33].

Figure 5: Approaches to the aggregation of vessel ship activity.

In general, the SGM approach should be seen as complementary to South Africa's National GHG Inventory. While the latter captures the complex interaction between its economic activities, society, and the environment, the SGM considers in great detail the spatial and technological differences of the maritime sector. The geofencing component of SGM, in particular, illustrates the environmental, economic and health impacts of emissions from ships transiting to, from and through South African waters and makes the case for decarbonization of shipping, especially considering that not all emissions are resulting from South Africa's imports and exports. In summary, the SGM can illustrate the opportunity of SZEF that South Africa has on the international shipping activity occurring within its waters and ports.

The results of the SGM approach show that internationally departing vessels generated the greatest quantities of CO_2e in 2018 at 11,733 kt while international arrivals contributed 10,192 kt CO_2e[9] (see Table 3). The total GHG emissions inside South Africa's EEZ is estimated to be around 11,516 kt CO_2e, which is similar to the GHG emissions from international departures. Roughly 12.3% of the total EEZ air pollution emissions take place within South Africa's territorial waters[10] which negatively and disproportionately affect coastal communities.

Table 3: GHG and air pollutant emissions associated with contrasting inventory methods. Domestic navigation is as well presented.

Pollutant[11]	International Departures	International Arrivals	Domestic Navigation	Domestic Fishing	EEZ (200 nm)
GHG (kt)					
CO_2	10,797.81	9,369.60	610.56	98	10,517.20
CH_4	1.15	1.44	1.06×10^{-2}	1.69×10^{-3}	3.65
N_2O	0.61	0.53	3.44×10^{-2}	5.45×10^{-3}	0.59
BC[§]	0.82	0.71	6.08×10^{-2}	1.48×10^{-2}	0.82
CO_2e	11,733.92	10,192.27	674.72	112.78	11,515.94
Air Pollutants (kt)					
SO_x	167.71	144.51	8.41	5.47×10^{-2}	155.43
NO_x	278.6	240.28	13.47	1.89	249.85
CO	10.58	9.25	0.56	8.87×10^{-2}	10.48
PM_{100}	25.77	22.2	1.29	3.04×10^{-2}	23.66
PM_{25}	23.71	20.42	1.18	2.80×10^{-2}	21.77
NMVOC	11.75	10.16	0.62	8.10×10^{-2}	11.01

‡ To convert CO_2 to Heavy Fuel Oil equivalent (HFO_{eq}) divide the CO_2 emissions by the HFO carbon factor which is 3.114 kt CO_2/kt HFO [8].
§ A value of 900 was used for black carbon 100-year Global Warming Potential [34] .

The emissions captured by the SGM were produced from the 4,913 domestic voyages[12] occurring in 2018 and amounted to 675 kt CO_2e while domestic fishing was estimated to be emitting 113 kt CO_2e. The difference with South Africa's 2017 National Inventory is about 87.4% or 315 kt CO_2e caused mainly by the fuel consumption databases used for the estimation of GHG.

9 The main reasons for the differences between these two approaches are related to the length of voyage leg, ship type and size, fuel usage (i.e. type and quantity), speed profile, ship age and ship cargo loading. Furthermore, the number of arrivals and departures has an impact on the GHG estimations with 6,349 internationally arriving voyages in 2018 and 6,383 international departures.

10 This includes all shipping activity that occurred within the country's territorial seas, up to 12 nm offshore

11 CO_2: carbon dioxide; CH_4: methane; N_2O: nitrous oxide; BC: black carbon; CO_2: carbon dioxide equivalent; SO_x: sulphur oxide; NO_x: nitrogen oxides; CO: carbon monoxide; PM: particulate matter; NMVOC: non-methane volatile organic compounds.

12 The SGM considers a domestic voyage as a voyage that starts and ends in the same country. If it is a multi-stop voyage, it will only consider as domestic the leg that starts and ends in the same country. If there are more than one domestic legs, each one will be treated as independent domestic voyage.

Some considerations regarding this are as follows:

- The National Inventory's Water-borne navigation fuel consumption data source is left empty [32]. Normally, as seen from other countries' National Inventories, the maritime activity data is based on annual fuel sales of the domestic fleet [35][36].

- The method used in SGM is an activity-based method so it includes emissions from domestic voyages of international ships (e.g. from one South African port to another) which would not be captured in the statistics of fuel sales for domestic use. This explains why a larger total emission is found from the SGM than is reported in the National Inventory. Finding a discrepancy in GHG when calculating with the two methods is common and has occurred in other countries (e.g. UK) which have since switched to use the activity based method [37].

- Differences between National Inventories data based on fuel sales to international shipping and activity-based methods also have explainable differences. Fuel sales are only recorded if a ship bunkers (takes on fuel) in South Africa. In practice ships calling at South Africa may not need to bunker (some ships have fuel storage for up to three months so do not refuel for each voyage) and will purchase fuel in South Africa only if its competitive to fuel available at other port calls they will make. The SGM captures all shipping activity regardless of whether it is associated with a purchase of fuel. The statistics estimated here suggest that only a portion of the fuel associated with South Africa's shipping activity is purchased in South Africa and so the activity-based method is helpful for giving an estimated of the potential bunker sales market - should South Africa want to expand its opportunity, especially for SZEF.

- Fuel sale databases can capture the fuel being consumed of the small boat fleet which tend not to have onboard tracking systems (e.g. AIS transponder). This is a limitation from the SGM but which points to the SGM results on domestic shipping GHG and air pollution to be a conservative estimation.

Now, looking at the SGM aggregation of all maritime activity in 2018 to, from, and within South Africa the total GHG emissions amounts to 22,713 kt CO_2e – representing 7,295 kt HFO_{eq} – which represented about 4.4% of South Africa's National GHG inventory and 2.1% of the total global shipping GHG emissions in 2018 as reported by the International Maritime Organization (IMO)[13]. Employing the SGM clearly shows the important opportunity South Africa has in supporting shipping decarbonization in the decades to come and emphasizes the importance of international collaboration between South Africa and its commercial partners.

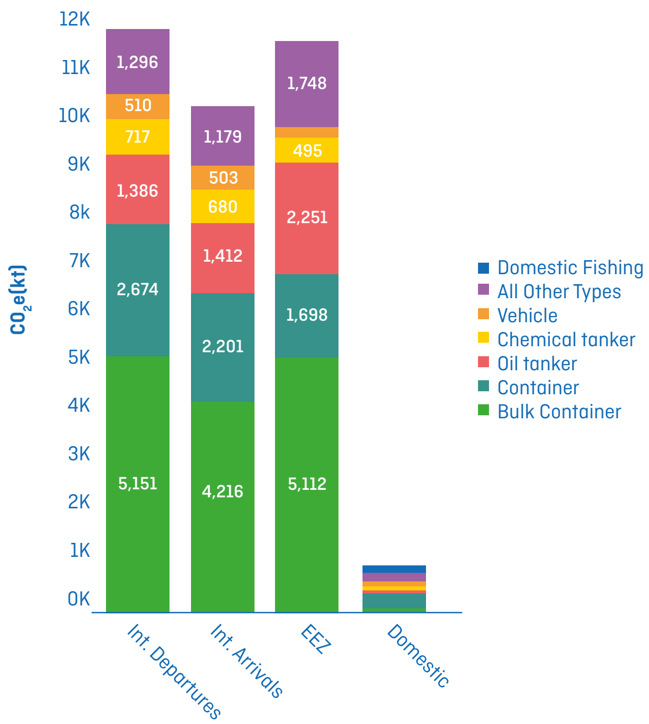
Further details on the SGM methodology can be found in Annex I with details of the different root causes between the emission inventories presented in subsection Sensitivity Analysis.

13 The total GHG emissions in 2018 was 1'076,000 kt CO_2e formed by international and, domestic shipping and fishing [8].

3.2.1 Analysis by ship type

In this section the SGM analysis is disaggregated by ship type (see in Figure 6). Across the approaches considered, the most pollutant ship types for South Africa are bulk carriers, containers and oil tankers emitting on average 76.8% of the 2018 GHG emissions. This is in line with the level of activity observed in Table 2 where bulk carriers, tankers and container ships demanded about 37,100 GWh/y (i.e. 3,322 kt HFO_{eq}[14]) of fossil fuel energy. The domestic navigation GHG emissions represented about 5.7% and 6.5% of the total CO_2e generated by international departures and arrivals respectively. Domestic fishing represented about 1.0% of the total GHG from international departures and 1.1% of international arrivals.

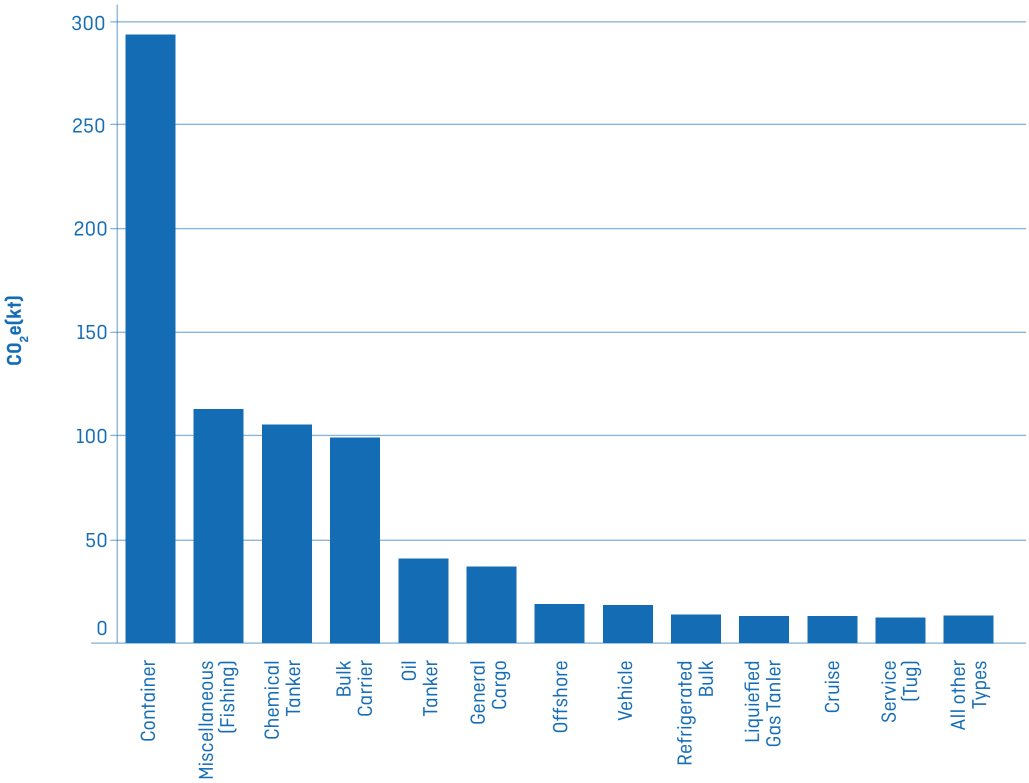
Figure 6: CO_2e inventories by ship type for South Africa In 2018.



A detailed disaggregation of domestic shipping by vessel type is presented in Figure 7 which shows that domestic shipping emissions are dominated by containerships at around 275 kt CO_2e followed by chemical tankers with about 98 kt CO_2e and bulk carriers with around 90 kt CO_2e. Therefore Figure 7 shows that domestic fishing is the second source of national shipping GHG with 113 kt CO_2e during 2018, which is not apparent from the IPCC method simply due to fishing being aggregated into a different sector from transport.

14 To convert from GWh to TJ a multiplying factor of 3.6 is used. For HFOeq the Low Heating Value (LHV) used was 40.2 TJ/kt [8].

Figure 7: Share of domestic emissions by vessel types. Domestic fishing is added for comparison purposes only.



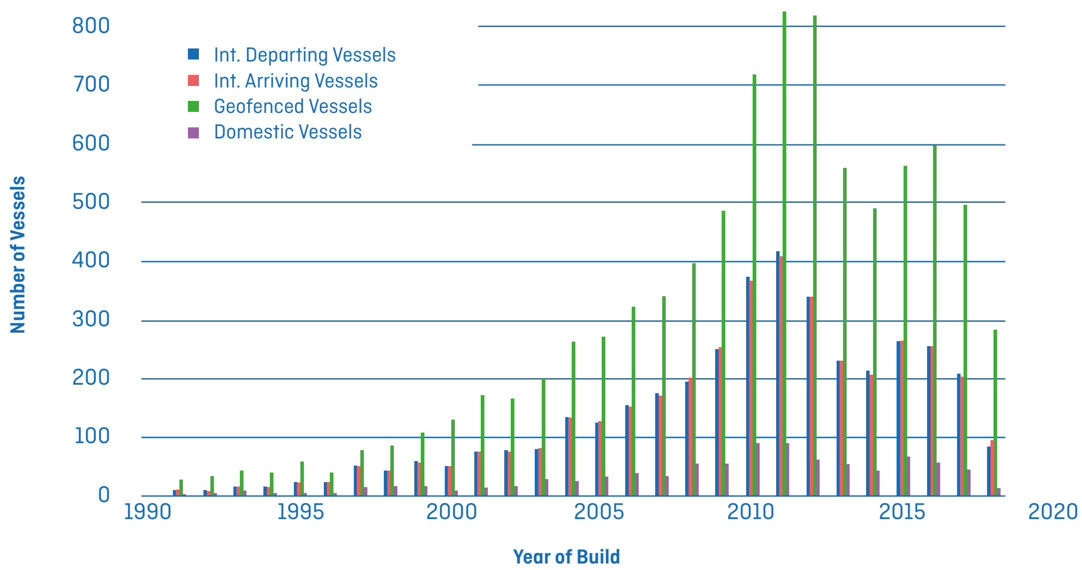
3.2.2 Analysis by age

An important aspect to consider when analyzing shipping emissions is the fleet characteristics and in particular age, which has a strong correlation with fuel efficiency and emission production. Figure 8 presents the spread of build years for vessels navigating South Africa's after 1990. The greatest share of vessels operating in 2018 were built between 2010 and 2013. This implies that the largest share of shipping activity occurring in South Africa is coming from relatively new ships which will tend to have good fuel efficiency and pollution control measures in accordance with IMO regulations.

Of the 4,289 unique vessels to depart South Africa's ports, 1.4% (57) were built before 1988 making them 30 years old or more throughout 2018. This compares with 8.5% of domestic vessels (90 of 1,065) and just 2.3% (205) of the 8,896 vessels that traversed South Africa's EEZ during the same year. This vessel age class will tend to be the most inefficient and polluting due to their old machinery systems.

There is a slight difference in the year of build of each inventory approach. For the geofencing EEZ approach, the average build year is 2009, the same as international arrivals, while international departure ships had an average of 2008. However, domestic ships formed the oldest category with an average build year of 2006. Under this lens, one can see that the international fleet tends to be younger than the domestic fleet, but the average year difference puts them under the same regulatory period for carbon intensity and air pollution from the IMO. This means that future international regulations brought in at IMO level would likely have a significantly positive effect on the emissions experienced by South Africa, shown in the ship type and geofencing sections. In the short term, the domestic fleet, administered by the South African maritime authority and in cooperation with relevant government departments, would benefit from energy efficiency improvements.

Figure 8: Build years for vessels contained in the 2018 dataset. Domestic fishing is not included.

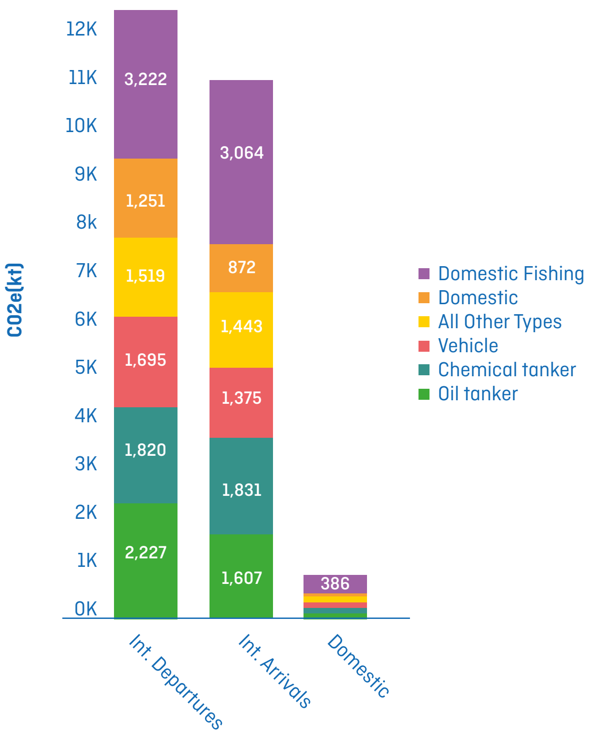


3.2.3 Analysis by port arrivals and departures

Using the SGM to focus on port-based activity allows a clear picture of emissions which can affect port communities and local populations. Figure 9 presents the breakdown of CO_2e emissions from international voyages departing and arriving into five main South African ports, namely Saldanha, Port Elizabeth, Cape Town, Island View and Richards Bay while simultaneously aggregating the rest of the ports in a single class.

The greatest contribution to the international departures inventory is Richards Bay which generated 19.6% of the total annual emissions from international departures (2,091 kt CO_2e) in 2018, followed by Island View with around 15.6% (1,820 kt CO_2e) and Cape Town with around 14.4% (1,695 kt CO_2e). Ports outside the top five were responsible for 27.3% of emission generation from international departures (i.e. 3,222 kt CO_2e). From the international arrival point of view, Island View produces the largest amount of CO_2e at 1,831 kt that represented 18.0% of the total in 2018. This is followed by Richards Bay and Cape Town with a share of 15.8% and 13.5% respectively. The All Other Ports class has a larger share of the total international arrivals with 30.0% or 3,064 Mt of CO_2e.

Figure 9: Maritime ghg emissions produced from south africa's ports international departures and arrivals in 2018.



3.2.4 Geofencing around large port cities

In an effort to capture the implications of maritime emissions on South Africa's coastal populations, three cities with sizable populations and with active ports have been selected for further analysis. It has been established that air pollutants can travel hundreds of miles [38] and therefore regions of 100 km radius surrounding South Africa's ports of Cape Town, Port Elizabeth and Durban were chosen to estimate the emissions generated by shipping activity[15] during 2018 (see Figure 10).

Port Elizabeth had the highest exposure with 11 kt SO_x, 17 kt NO_x and 70 t of BC generation. In regards to maritime CO_2e, emissions for *Port Elizabeth* amounted to 871 kt. *Cape Town* 100 km radius geofence approach had a total annual GHG emission of 692 kt CO_2e and an annual emission of SO_x of about 8 kt and 14 kt NO_x. For *Durban*, shipping activities amounted to 501 kt CO_2e, 6 kt SO_x and about 8 kt NO_x. The total annual BC emission for the three port cities was estimated to be over 174 t BC (see Table 4).

15 The emission quantified here only considered the activity performed by the ships present in the regions. This does not account the emissions produced by the port and its systems (e.g. cranes, forklifts).

Figure 10: Polygon representing South Africa's 100 km polygon and the shipping activity inside it during 2018.

Table 4: GHG and air pollutant emissions generated within 100 km of the ports of Cape town, Port Elizabeth and Durban during 2018.

Pollutant	Cape Town	Port Elizabeth	Durban
GHG (kt)			
CO_2	627.09	7990.83	449.03
CH_4	0.24	0.19	3.73×10^{-2}
N_2O	3.84×10^{-2}	4.37×10^{-2}	2.44×10^{-2}
BC	5.47×10^{-2}	7.02×10^{-2}	4.99×10^{-2}
CO_2e	692.24	870.8	501.46
Air Pollutants (kt)			
SO_x	8.36	11.1	6.44
NO_x	14.24	17.34	7.56
CO	0.62	0.74	0.34
PM_{100}	1.28	1.67	0.86
PM_{25}	1.18	1.54	0.79
NMVOC	0.63	0.77	0.34

While *Port Elizabeth* did not appear on the most polluting ports in Figure 9 due to a lower GHG emissions from ships arriving or departing from it, when a geofencing approach is used, it shows how maritime activity near the ports[16] drives up the regional GHG emissions and air pollution.

The creation of focused inventories for port cities through the SGM can aide in their efforts to decarbonize regionally and can support the mitigation of air pollution

16 Maritime activity around the ports only considers the ship side activity and are based on the Fourth IMO GHG Study and they are: Normal Cruising, Slow Steaming, Maneuvering, Anchoring and Berthing.

and its health effects on local populations. Furthermore, populations within 5 nm of an air polluting source – in this case a port – possess a 50% higher likelihood of developing cardiovascular issues and cancer as a result of exposure to these pollutants for extended periods of time [39]. However, since 2020 the IMO Regulation 14 entered a new phase limiting the sulphur content to 0.50% of the mass of any maritime fuel [40]. This implies that the values for SO_x and PM presented in Table 3 will be significantly lower after 2020.

3.3 Implications for South Africa

National GHG inventories present estimates of emissions that are used by governments when formulating and implementing mitigation measures, taking respective national circumstances and capabilities into account. South Africa's National Inventory, using the widely-accepted IPCC methodology, is presented in section 3.1 and reports the *Water-borne domestic navigation* emissions. Although emissions from the international shipping sector are acknowledged, they are not quantified in the National Inventory under the IPCC methodology. Given that national inventories drive the government's national strategic aims, objectives and policies, the exclusion of international shipping creates an artificially narrow framing in terms of GHG emission from both a climate change and air pollution perspective.

To counter this, and to present a more detailed quantification of shipping emissions, this report employed the SGM as a granular activity-based methodology to understand maritime emissions both in South Africa's national waters and at its ports. The SGM complements South Africa's National Inventory by presenting domestic and international maritime emission under a voyage definition and inside geographical regions all while being able to disaggregate the results by ship types and age. The results from the SGM method showed that:

- Domestic emissions and fuel demand, which are more likely driven by national legislation, are a lot smaller than the international arrival/departure emissions and fuel demand. The IMO regulation will be key in driving change in the ships that call at South African ports.
- Bulk carriers, containerships and tankers are the type of vessels that emit the most GHG and air pollution from maritime activity to, from and within South Africa's ports and national waters.
- Despite their relative magnitudes, there is still a significant domestic fleet/emission, providing many opportunities for early adoption that might align with other national strategy/priorities to decarbonize.
- Domestic and international shipping contribute significantly to air pollution including in the proximity of large South African centers of population.
- Decarbonization of shipping, if enabled through fuels with lower air pollutant levels, can be a significant driver of air quality improvement in several important locations.

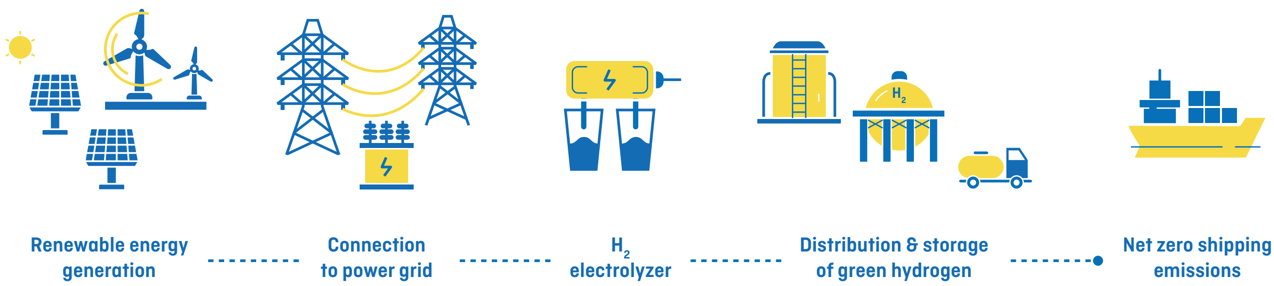
These findings can assist the decision-making process regarding the transition to low- and zero-carbon emissions in the shipping sector and illustrate South Africa's opportunity to participate in shipping's just and equitable transition. As well, they can support in the creation of strategies, solutions and policies that can reduce the national and regional maritime emissions, air pollution and generate green jobs in, and connected with, the oceans economy.

Section 4

Harnessing South Africa's Renewable potential

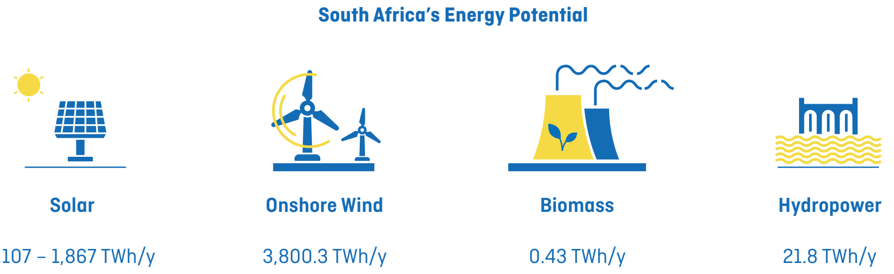
Shipping is heavily reliant on fossil fuels, which produce considerable GHG and air pollution. This in turn increases the global effects of climate change and negatively impacts the health socio-economic wellbeing of nearby coastal populations. While energy efficiency and short-term mitigation solutions play a role in the maritime sector's transition, this will not be enough to achieve the Paris Agreement target [4]. The need for green SZEF and its required infrastructure is critical to enable maritime decarbonization. Large amounts of renewable energy are needed to produce these fuels and get shipping on track to meet global climate change goals (see Figure 11).

Figure 11: Illustrative Production Pathway for Green Hydrogen (Source: inspired by Quadrant Smart ***[41]).***



In 2019, only 4% (8.3 TWh) of the country's electricity generation came from renewable sources [42]. In the coming decades, this percent is expected to increase substantially. South Africa's Integrated Resource Plan estimates renewable energy to constitute a third of the country's energy production share by 2030 and around 40% by 2050 [43]. In particular, considering the current technologies available and restrictions regarding land use, South Africa can reasonably produce by 2030 an additional 1,570 and 5,690 TWh/y of renewable energy: 1,100 – 1,860 TWh/y of solar, 250 TWh/y of onshore wind, 190 TWh/y of fixed offshore wind, 3,360 TWh/y of floating offshore wind, and 21 TWh/y of hydropower [27]. When combined with existing renewable generation capacity, South Africa could produce a total of 1,578.3 – 5,698.3 TWh/y by 2030 (see Figure 12).

Figure 12: South Africa's Estimated Total Renewable Energy Potential by 2030.



It is important to note that this figure is only a range estimated on available studies and South Africa's renewable energy potential can be greater. Future research is needed to give a more definitive range and to gain greater understanding of likely scenarios and how improving technology could affect this value.

Furthermore, to ensure a fair and equitable transition, additional renewable energy plans for shipping must be built alongside those estimated by South Africa's Integrated Resource Plan to avoid potential negative effects on domestic decarbonization efforts. The building of renewable generation infrastructure must be done responsibly, wherein environmental and social impacts are considered when planning to leverage South Africa's renewable potential. For example, it is important to investigate potential direct and indirect land use change when building infrastructure in agricultural areas to limit negative environmental and ecological impacts.

South Africa's renewable potential combined with its maritime traffic puts South Africa as a key player in the shipping transition as a potential SZEF producer and exporter [27]. Local stakeholders note that shipping decarbonization is relevant for South Africa, enabled by the current energy transition trend as well as the perceived abundant renewable energy sources in the country. Assuming 5% of the global fleet transitions to SZEF by 2030 then the green energy demanded would represent about 3.9 TWh/y [27].

Conservative calculations show that 3.9 TWh/y represents only 0.2% of South Africa's total renewable potential, comfortably leaving more renewable energy potential than needed for both decarbonizing the national grid and vessels stopping at South Africa's ports. This supports local stakeholder perceptions that the country is well-positioned to produce green hydrogen and its derivatives, where shipping's decarbonization can generate strong synergies with road transportation and other land-based sectors.

Stakeholders also highlighted that if there are solid offtake agreements, wherein a buyer agrees to purchase portions of a supplier's planned production, there is huge potential not only for the production of SZEF, but also the export of these fuels. This is especially the case given that both the EU and Japan have noted that they cannot produce enough SZEF in their countries and would need to import fuels to meet their energy demands. Hydrogen export, however, has been limited to grey hydrogen based on fossil fuels, and the growing interest in the export of green hydrogen will require the development of an enabling trade framework.

«Although South Africa's solar and wind resource, available land and long coastline make for a good green hydrogen export potential, the maritime shipping volumes mean sustainable bunker fuels may well be the largest green hydrogen opportunity for South Africa.» – Thomas Roos (Council for Scientific and Industrial Research)

Hydrogen Trade

As countries like South Africa eye opportunities to export green hydrogen, it is important to consider how cross-border trade of green hydrogen between production points and demand regions across the globe can be enabled [44]. The International Renewable Energy Agency reports that more than 30% of hydrogen produced will be traded internationally by 2050 [45]. This will require international and multi-stakeholder cooperation to prevent interruptions in the clean hydrogen supply chain, ensuring products can freely move across borders.

Standards targeting safety and quality of green hydrogen goods and services is one way to build a resilient global green hydrogen economy and reduce the risk of impeding trade in the future. Questions around classifications of hydrogen using color-schemes or levels for example, based on feedstock and whether or not fuels are derived from renewable energy sources, remain. Nevertheless, there are a number of organizations working to get ISO certification for their green hydrogen exports to increase harmonization and address existing fragmentation in the interim.

The Green Hydrogen Organization is one such actor, looking to establish a standard centered around accurate greenhouse gas emissions accounting, ESG metrics considering broader impacts of hydrogen production, and assessment of hydrogen development with the Sustainable Development Goals in mind [46]. At this early stage, fragmentation from specific arrangements on green hydrogen is a key challenge. To address this, existing models could feed into the development of a common standard in order to avoid further fragmentation and encourage healthy competition.

Bi-lateral and regional trade agreements could also stimulate export of green hydrogen. Germany, for example, is looking to partner with South Africa specifically for this purpose [47]. Tariffs on hydrogen however are very low or non-existent for most key producers and consumers of hydrogen. Rather than having a separate tariff line for green hydrogen, it would make sense to have production and process methods in place that can be certified.

Industry players and governments could also draw on best practices from trade in other relevant green goods and services in order to create a level playing field, shape an efficient global green hydrogen economy, and work towards full industry decarbonization by 2050.

Section 5

Policy Framework & Climate Ambition

Climate & Energy Policy

Energy production and climate change present a significant political challenge in South Africa. As previously stated, total GHG emissions from South Africa are estimated to be 512.7 Mt CO_2e in 2017, placing South Africa as the 16th largest GHG emitter globally in the same year [29]. On a national level, South Africa is heavily reliant on coal for electricity generation with about 80-90% of power coming from coal based resources [48]. Unfortunately, this dependence does not generate enough power to satisfy domestic demand, with the country experiencing planned power outages to ease the pressure on the grid. The need for these outages stems from lack of capacity which, in turn, is associated with deteriorating infrastructure and administrative delays for private power generation projects [49]. These outages are set to continue for the foreseeable future, while the air pollution from coal burning and associated effects on health also continue to be felt in communities.

According to Reuters, a 2019 report for the state-owned Council for Scientific and Industrial Research estimates that around 5,000 South Africans die annually in the nation's coal belt through poor enforcement of air quality standards [50]. A South African court upheld a complaint by activists that the poor air quality in the coal belt is a breach of constitutional rights and found that the government plan for cleaner air had been "unreasonably delayed" and subsequently ordered the government to take action to reduce heavy pollution [51]. Furthermore, analysis conducted by the Centre for Research on Energy and Clean Air found that state-owned Eskom is the world's most polluting power company generally, and the largest emitter of sulfur dioxide, "surpassing any country in the world, except India" [52]. In financial terms, the total quantified impact of coal-fired power is valued at $2.4 billion USD annually [53]. Crucially, under its 2019 energy supply strategy the government has restricted solar and wind installations to 1,000 MW and 1,600 MW respectively [43]. This cap has been declared the, "Achilles heel of climate ambition", by Alex Lenferna, secretary of the Climate Justice Coalition, an alliance of civil society groups in South Africa [54].

Despite the challenge presented by national energy generation in South Africa, the adoption of legislation and several policies have signaled a gradual but decisive transition to renewable energy [54], including:

- **National Energy Act** seeks to ensure planning, generation, and consumption of renewable energies [55].
- **National Development Plan** aims to eliminate poverty and reduce inequality by 2030 and includes aims to reduce GHG emissions [56].
- **National Climate Change Response Policy**; a comprehensive plan to address mitigation and adaptation in the short-, medium- and long-term up to 2050 [57] [58].
- **Integrated Resource Plan** which sets out governmental priorities for energy generation against expected demand [43].

- **Low Emissions Development Strategy** lays out a plan to reach net zero by 2050 [59][60].
- **Climate Change Bill**[17] aims at enabling the development of an effective climate change response and a long-term, just transition to a low-carbon and climate-resilient economy and society [61].
- **Carbon Tax Act** started pricing GHG emissions in all sectors other than waste and Agriculture, Forestry and Other Land Use[18] [62][63].
- **National Energy Efficiency Strategy** aims to stimulate energy efficiency improvements through a combination of fiscal and financial incentives and enabling measures [64].
- **Hydrogen Society Roadmap** aims to integrate hydrogen-related technologies in various sectors of the economy and contribute towards the reduction of GHG emissions [65][66].

As part of the Integrated Resource Plan (2019), South Africa demonstrates a prolonged aim for decommissioning coal-based energy production, suggesting that decommissioning of coal plants by 28GW for 2040 would mean that coal will contribute less than 30% of energy supply by then. According to South Africa's first Nationally Determined Contribution, updated in September 2021, the government signed the Paris Agreement and pledged to peak emissions between 2020 and 2025, before declining them the following decade to 2030. The government's goal is to focus primarily on the decarbonization of the electricity sector between 2020 and 2030 and to move to other hard-to-abate sectors in the 2040s, although no specific reference to the maritime sector was made [67].

South Africa also aims for a Just Transition; one which is inclusive for workers and communities and that leaves no individual behind [68]. South Africa was the only country to mention a just transition in its initial Nationally Determined Contribution in 2015. This was followed by a range of national dialogues, assessments and policies, including strong involvement from labor unions. These, combined with the 2020 Presidential Climate Change Coordination Commission's mandate to coordinate South Africa's just transition, shows the importance placed on shifting fossil fuel jobs towards more renewable options. Additionally, decoupling the domestic economy from the consumption of fossil fuels can shelter the country from external geopolitical shocks and fluctuations associated with the oil market.

«Investing into renewable energy and e-fuel production can help to support a just transition in South Africa, in particular offering future avenues of employment for traditional fossil fuel based forms of labour.» – Rebecca Maserumule (Department of Science and Innovation)

17 The Climate Change Bill was first published in 2018, updated in 2021 and on Friday 18th February 2022, was formally introduced to the National Assembly by the Minister of Forestry, Fisheries and Environment.

18 The tax initially excludes the maritime and aviation sectors with the reasoning that these are covered by the IMO and the International Civil Aviation Organisation, respectively. Effective from the 1st January 2022 the carbon tax rate will increase to R144 (about $9 USD). To meet South Africa's COP26 commitments, the rate will increase each year by at least $1 USD until it reaches $20 USD [63].

Linked to this, opportunities relating to new forms of energy production is of key interest. South Africa has been building on its hydrogen strategy for more than a decade. Hydrogen South Africa (HySA) was officially launched by the Department of Science and Innovation in 2008 with the aim of creating knowledge and capacity through local resources in order to enable the development of high-value commercial activities in hydrogen and fuel cell technologies [26].

As such, national ambition, combined with strategic objectives and international partnerships puts South Africa in a promising position to undertake a just transition that will strengthen domestic energy production, decrease pollution, and meet multiple sustainable development goals. As Mandy Rambharos, general manager at Eskom's Just Energy Transition office comments, "We will be left in this little bubble where we are not going to be able to export our wine or our fruit or our cars if we don't transition[...]The whole world is transitioning, we have to get on this bandwagon – for South Africa to remain competitive and for our economy to grow" [69].

Maritime Policy

Despite the growing political ambition around national decarbonization, the incorporation of shipping into this agenda is relatively light. Maritime affairs are overseen by the Department of Transport, the South African Maritime Safety Authority, Transnet National Ports Authority and Transnet Port Terminals. Transnet National Ports Authority manages South Africa's eight major commercial seaports [70].

The Comprehensive Maritime Transport Policy [20], the Revised White Paper on National Transport Policy [71], and the Green Transport Strategy for South Africa: (2018-2050) [72] are the main policies governing the country's maritime activities. In 2014, the government launched Operation Phakisa to unlock the economic potential of South Africa's oceans. In doing so it was estimated that up to R177 billion could be contributed to national GDP by 2033 and between 800,000 to 1 million direct jobs created [73]. This initiative has an economic framing with the environmental focus on oil pollution, ocean related renewable energy, and protection of the marine environment. The decarbonization of shipping and the possible spillover, co- and cross-sectoral benefits it can provide is largely unexplored as of yet. Despite this, there is significant potential to pursuing the decarbonization of shipping and South Africa's role in this transition. It has been estimated that investments up to R175 billion could be attracted to provide the infrastructure required by 2030 to provide renewable energy/zero carbon fuels to decarbonize just 5% of the vessels that visit South African ports [27].

While the Green Transport Strategy for South Africa does have a section for maritime transport, the main focus is the emissions impact of marine fishing with the strategy noting that maritime transport is a very small contributor to transport sector emissions in South Africa due to maritime transport operating mainly beyond South African boundaries [72]. As demonstrated in Section 3.2, the impact of international shipping under the geospatial lens is more significant than the impact of domestic shipping. The overall focus of the strategy is largely dedicated to other modes of transport; though it does acknowledge the need to reduce GHG emissions from shipping, addressing this in one of four policy statements covering the Maritime Transport Strategic Initiatives. However, in terms of specific steps to achieve this, the strategy takes a light touch which may not provide the clarity needed by industry stakeholders to make investment choices or de-risk new investments.

In the international shipping context South Africa is a member of the IMO, a United Nations agency with over 170 member states that regulates the international shipping industry. The IMO sets global standards for maritime safety, security, and environmental performance. South Africa has adopted, accessed and/or ratified multiple global instruments and conventions pertaining to climate change, marine environmental protection, and a transition to a low-emission maritime sector (see Table 5). The Marine Oil Pollution (Preparedness, Response and Cooperation) Bill was introduced to Parliament on 10th March 2022 and the Marine Pollution (Prevention of Pollution from Ships) Amendment Bill was introduced to Parliament on 31st January 2022. The Marine Oil Pollution Bill seeks to give effect to the International Convention on Oil Pollution Preparedness, Response and Cooperation, 1990; and to provide for matters connected therewith. The Marine Pollution Amendment Bill seeks to amend the Marine Pollution (Prevention of Pollution from Ships) Act, 1986, so as to give effect to Annex IV of the International Convention for the Prevention of Pollution from Ships, to incorporate the 1997 Protocol in order to give effect to Annex VI of the Convention; and to provide for matters connected therewith. The translation of these bills into the domestic parliamentary process has taken a significant time and indeed there is a present backlog of MARPOL domestication bills. This highlights the tension between international agreements and domestic enforcement.

Table 5: South Africa's Commitment to International Maritime Policies.

United Nations Convention on the Law of the Sea (UNCLOS Convention) (1984)
International Convention for the Prevention of Pollution from Ships (MARPOL Convention), particularly its Annex VI for Air Pollution (1997)
Initial IMO Strategy on Reduction of GHG Emissions from Ships (2018)

The IMO has successfully adopted multiple instruments and policies aimed at reducing GHG emissions from ships[19]. The IMO's Initial GHG Strategy sets a minimum target of reducing emissions by at least 50% by 2050 compared to the 2008 baseline year while generally pursuing the reduction of GHG emissions as a matter of urgency and consistent with the Paris Agreement temperature goal. In addition to its reduction target, the strategy sets out a timeline for consideration and selection of different short-, mid- and long-term policy measures [74]. Short-term measures focus primarily on energy efficiency improvements for the global fleet with current discussions of potential mid-term measures centering on the possibility of a basket of measures combining a fuel standard and market-based measures (MBM). There is also a growing realization among Member States of the need to enable a just, fair, and equitable transition. Furthermore, momentum has been building for a higher level of ambition, as part of the IMO Strategy Revision, with over 240 signatories from the maritime value chain calling on the IMO to set a target of full decarbonization by 2050 [75].

The forthcoming year is crucial in the IMO regulatory timeline. In the upcoming meetings, the Revision of the Initial GHG Strategy will be addressed with a large focus likely to be setting a new ambition level that is aligned with a 1.5°C temperature goal and potentially the inclusion of interim milestones. Additionally, further discussion of the tabled mid-term measures proposals will take place. Multiple proposals for MBMs have been submitted for consideration at the upcoming meetings. How these proposals proceed and in particular how a revenue generating measure is designed will have significant bearing on the shape of the transition. Funding created from a price on GHG emissions could be used in a variety of ways, inter alia:

19 Including the Energy Efficiency Design Index (EEDI), the Ship Energy Efficiency Management Plan (SEEMP), the Data Collection System for fuel oil consumption of ships, and the Energy Efficiency Existing Ship Index (EEXI) and Carbon Intensity Indicator (CII).

- Enabling an internationally equitable and socially just transition by supporting the most climate vulnerable States,
- Closing the competitiveness gap[20] between new alternative fuels and incumbent fossil fuels through revenue recycling,
- Addressing disproportionately negative impacts on States,
- Capacity development and technology transfer,
- Climate finance, and
- Training and education for seafarers and workers in the shipping industry [76].

Work by the World Bank finds political viability in a scenario where a portion of revenue is allocated for out-of-sector use [77][78]. Revenue generation, collection and deployment are dependent on the policy design and therefore uncertain as yet. However, given the recent IPCC reports on climate change impacts, adaption and vulnerability [1], some Members emphasize the need for a significant portion of revenue to support the most climate vulnerable [79].

The upcoming regulatory discussions at the IMO may set the shape of the transition for years to come. It is imperative that policy objectives for any country at the IMO level should be as ambitious as possible to align with IPCC climate science and send strong policy signals to drive long-term investment in the production and provision of alternatives fuels that emit zero-GHGs on a life-cycle basis and to enable an equitable transition for all.

The currently adopted IMO measures have yet to achieve sufficient reductions to put the sector on a trajectory that is compatible with the goals of the Paris Agreement. Although strong policy signals can be sent at upcoming meetings, it will be some years before new measures have been agreed and implemented. As a result, national action and public-private collaboration have a key role to play at this moment to facilitate shipping's transition [12]. Examples of such activity in the international maritime space can be seen in Figure 13.

20 Estimates suggest that across the 2030s and 2040s SZEF may be approximately double the price of conventional fossil fuels [18].

Figure 13: International Maritime collaborations and Initiatives to support decarbonization.

Getting to Zero Coalition Call to Action

More than 240 signatories have urged governments to:

1. Commit to decarbonizing international shipping by 2050
2. Support industrial scale zero emission shipping projects through national action
3. Deliver policy measures that will make zero emission shipping the default choice by 2030

Find out more

Uptake MOUs

Memorandums of Understanding (MoU) or partnership agreements can be signed by parties interested in exploring the establishment of large-scale green fuel production and accelerating the supply of green fuels for shipping. These agreements facilitate investments by ensuring uptake demand.

Example MoU signed in 2022

Clydebank Declaration for green shipping corridors

Launched at COP26, currently 24 countries have pledged to:

- facilitate the establishment of partnerships, with participation from ports, operators and others along the value chain, to accelerate the decarbonization of the shipping sector and its fuel supply through green shipping corridor projects
- identify and explore actions to address barriers to the formation of green corridors. This could cover, for example, regulatory frameworks, incentives, information sharing or infrastructure
- consider the inclusion of provisions for green corridors in the development or review of National Action Plans
- work to ensure that wider consideration is taken for environmental impacts and sustainability when pursuing green shipping corridors.

Mission Statement:

'....to support the establishment of green shipping corridors – zero-emission maritime routes between 2 (or more) ports. It is our collective aim to support the establishment of at least 6 green corridors by the middle of this decade, while aiming to scale activity up in the following years...'

Find out More

Furthermore, while an MBM adopted at IMO level may offer in-sector financial support at some stage, in this initial phase private sector investment, as well as public-private partnerships, collective action by the maritime industry, the energy sector, financial institutions, and governments/ intergovernmental organizations need to provide significant funding. Indeed, in consideration of the competitiveness gap between fossil fuels and alternative SZEFs [76], it has been highlighted that the production costs for the new fuels will influence the magnitude of the price gap, which is an argument in favor of future fuel production investments being focused on competitive locations such as South Africa [80].

In the evolving policy landscape, combining a focus on domestic ambitions which are aligned with renewable energy production and GHG emissions mitigation, with international engagement in IMO discussions and public-private collaboration provides a promising outlook for South Africa's role in the transition.

«A meaningful price on carbon implemented globally would help close the competitiveness gap between fossil fuels and zero emission fuels, and accelerate the uptake of the latter. It could also raise significant revenues, part of which could be used to fund related projects in countries such as South Africa.» – Richard Martin Humphrey (World Bank)

Section 6

Strategic Business Opportunities in South Africa

6.1 Ports as opportunities

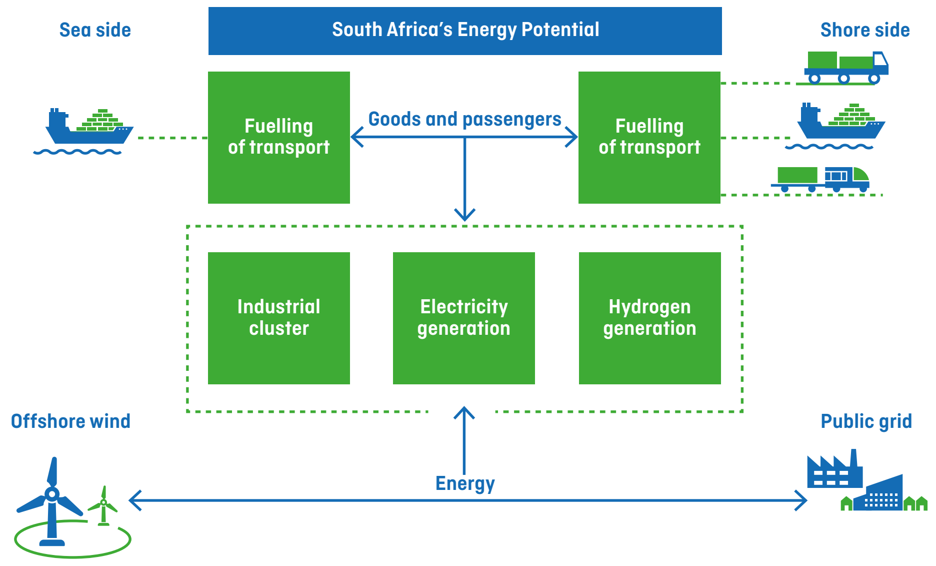
Ports play an important role in connecting shipping to the hinterlands of various countries, acting as both gateways and refueling stations for the international movement of goods and commodities. As the maritime industry transitions to SZEF, it is apparent that new infrastructure will be needed to produce, store, and provide these fuels to the industry. Ports, in particular, will require significant infrastructure investment to meet the bunkering needs of new or retrofitted ships running on alternative fuels.

To this end, ports can be both suppliers of these new alternative fuels as well as offtakers to decarbonize their own activities. Port operations produce substantial emissions and pose a number of environmental issues stemming from port activities, marine vessels calling at ports, and intermodal transport networks serving the port hinterland [81]. Ships operating near a port burning fossil fuels emit significant air pollution that affects coastal populations as well as communities living hundreds of miles inland [39]. Given the proximity of the human population to marine and port-related emissions, reduction of pollution emissions from ports and maritime sources will, in the first instance, greatly improve the air quality for millions of people [82].

Furthermore, decarbonization of ports can have several benefits. For instance, it can promote the creation of green jobs in the production of alternative energies, bunkering and storage, and for the provision of green port services. Capitalizing on their established hinterland connections, ports can act as nodes to facilitate decarbonization synergies between the energy sector to the transport sector. This would harness the local deployment of renewable energies at a large scale for electricity and alternative fuel production used in port bunkering.

«There is an increasing need to better understand South Africa's potential to develop green ports, ensuring that infrastructure is capable of facilitating a national transition to clean maritime transportation.» – Nelson Mbatha (Transnet National Ports Authority)

Figure 14: Ports as Nexus between Land & Sea [83].



Saldanha Bay Industrial Development Zone

Located in South Africa's Western Cape, Saldanha Bay is a key deep-water commercial port for the country and one of the largest ore exporting ports in Africa [27]. The Saldanha Bay Industrial Development Zone (IDZ) is the first port in South Africa to become a Special Economic Zone (SEZ) focusing on both the maritime and energy sectors. It operates as a Freeport with streamlined investor procedures that incentivizes innovation, development, and manufacturing for the maritime and energy industries.

The IDZ plays a supportive role in developing catalytic infrastructure for industry, and thus the Saldanha Bay IDZ has the potential to support the export and bunkering of SZEF fuels, and by stimulating investment in zero-emission vessels, could become a hub for decarbonization, modernization, and job creation as South Africa progresses towards a low-carbon economy. The port is a key opportunity for South Africa due to its export commodities and established trade routes, favorable location to nearby renewable potential, land availability for port expansion and development, synergies with local industries, its status as a Freeport, as well as existing efforts and stakeholder interest in developing green hydrogen and ammonia capacity within the port.

Saldanha Bay is located next to large solar resources, and there is significant fixed onshore and offshore wind potential to the north of Saldanha as well as floating wind potential over a wider area surrounding the coast [27]. With 180 ha of lettable land, the installation of a desalination plant would be needed to ensure adequate water supply in the relatively water-stressed area, not only for the production of green hydrogen but also for local communities during drought periods. Capturing this potential, studies have conservatively estimated that Saldanha can competitively produce green hydrogen and ammonia at $3 USD/kg [84].

Offtakers for SZEF are expected to be both local and export markets. In 2018, 828 vessels stopped at the port, the majority of which were bulk carriers (686 vessels). The annual energy usage of these vessels visiting Saldanha Bay was 7.14 TWh, with an estimated emissions of 2,151 kt CO2e. The adoption of green ammonia in particular would be appropriate for these vessels due to its relatively high energy density compared with hydrogen. A conservative estimate for large vessels running on green ammonia from both Saldanha Bay and nearby Cape Town would require 504 kt/y of hydrogen [84].

Table 6: Potential local offtakers for green hydrogen produced at Saldanha Bay Industrial Development Zone

Offtaker	Hydrogen Demand
Transnet - bunker fuel	504 kt/y
Transnet - port equipment	(unknown)
Airports Company of South Africa – airport ground vehicles	0.96 kt/y
Passenger Rail Agency of South Africa – Cape Town Metrorail locomotives	6.6-11.0 kt/y
City of Cape Town – MyCiti buses	1.2 kt/y
ArcelorMittal – iron ore	104 kt/y
Astron Energy – refinery	(unknown)

As the demand for green steel increases, South Africa's iron ore industry can directly benefit from Saldanha Bay's capability to produce SZEF and green its supply chains. In 2021, ore exports from Saldanha Bay were mainly shipped to China, South Korea, India, Japan, and the Netherlands [85]. 77% of the vessels arriving and departing from the port are bulk carriers. Leveraging synergies between producing SZEF for the bulk carrier vessels and the local mining industries can aggregate demand and increase economies of scale for local green hydrogen and ammonia production. Similar to the recently announced Australia-East Asia iron ore green corridor [86], Saldanha Bay can explore options to either build on or establish a similar green corridor. Notably, this would also benefit the local steel mill — ArcelorMittal's Saldanha Steel Mill — which has been mothballed. This stems from issues with local electricity and port tariffs making the steel uncompetitive to products from China. The mill is currently deliberating the potential use of green hydrogen, but a decision has not been officially reached.

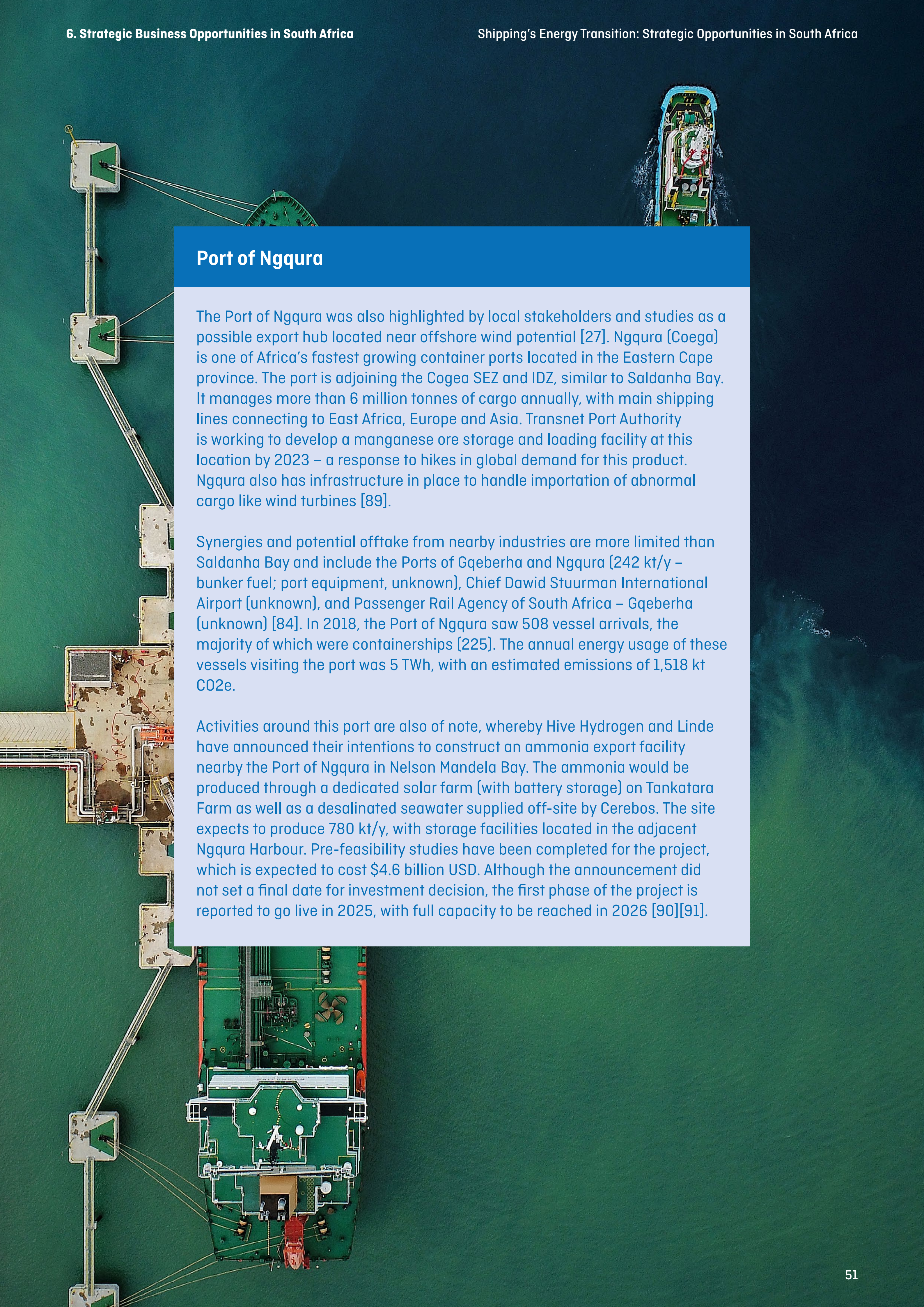
Current discussions at the port are aimed at further exploring the potential for Saldanha Bay IDZ to become a green hydrogen hub. To this end, Saldanha Bay IDZ has actively pursued partnerships and dialogues with both national and international actors directly and indirectly — including South Africa's Council for Scientific and Industrial Research, Mineral Council, Transnet National Ports Authority, the Department of Trade Industry and Competition, KfW, GIZ, Development Bank of Southern Africa, the World Bank, among other public and private industry players. As a large iron ore and manganese exporting port, the companies of Anglo American and Sedibeng Iron Ore are key actors within the port and stand as representatives on Saldanha Bay's Port Consultative Committee. Nearby cement industries AfriSam and PPC Cement could also play a role as green hydrogen offtakers, as they seek to reduce their scope 3 emissions [87][88].

Stakeholders have indicated that Saldanha Bay Municipality has expressed priorities for energy and financial resilience and are actively working to understand and support where possible gas-to-power and renewable investments in the region. Green hydrogen is on the municipality's radar; however, practical aspects of who, where, how, and the costs and benefits to the municipality and residents remains unclear. Nevertheless, the Saldanha Bay Municipality is keen to contribute to the business case and permitting process where possible. This is especially relevant regarding the need of a desalination plant in the region, for which environmental authorization has already been received though high costs stalled implementation at the time.

Supported through funding by the German KfW, the zone has also received numerous project bids to develop green hydrogen in or around the port, two of which have been shortlisted. To date, none of these have been confirmed as final or given the green light to proceed. The zone has also received interest from significant industrial companies to commence prefeasibility studies – aside from the KfW participants.

Overall, the next steps will necessitate pre-feasibility and feasibility studies for the proposed projects, and the business cases which can be supported through concrete offtake agreements with local industries and exports. In conjunction, as part of the Innovation Campus at Saldanha Bay, there has been interest to make the energy transition a key priority for the port and Saldanha Bay region. Discussions are ongoing, though there has been a proposal to establish a working group and undertake a participatory roadmapping process to gather interested stakeholders and explore concrete options and required next steps to implement SZEF production near the port.

«Saldanha Bay, with its strong connections to the mining sector and international markets is well placed to become a hub for green marine fuels in South Africa.» – Kaashifah Beukes (Saldanha Bay Industrial Development Zone)



Port of Ngqura

The Port of Ngqura was also highlighted by local stakeholders and studies as a possible export hub located near offshore wind potential [27]. Ngqura (Coega) is one of Africa's fastest growing container ports located in the Eastern Cape province. The port is adjoining the Cogea SEZ and IDZ, similar to Saldanha Bay. It manages more than 6 million tonnes of cargo annually, with main shipping lines connecting to East Africa, Europe and Asia. Transnet Port Authority is working to develop a manganese ore storage and loading facility at this location by 2023 – a response to hikes in global demand for this product. Ngqura also has infrastructure in place to handle importation of abnormal cargo like wind turbines [89].

Synergies and potential offtake from nearby industries are more limited than Saldanha Bay and include the Ports of Gqeberha and Ngqura (242 kt/y – bunker fuel; port equipment, unknown), Chief Dawid Stuurman International Airport (unknown), and Passenger Rail Agency of South Africa – Gqeberha (unknown) [84]. In 2018, the Port of Ngqura saw 508 vessel arrivals, the majority of which were containerships (225). The annual energy usage of these vessels visiting the port was 5 TWh, with an estimated emissions of 1,518 kt CO2e.

Activities around this port are also of note, whereby Hive Hydrogen and Linde have announced their intentions to construct an ammonia export facility nearby the Port of Ngqura in Nelson Mandela Bay. The ammonia would be produced through a dedicated solar farm (with battery storage) on Tankatara Farm as well as a desalinated seawater supplied off-site by Cerebos. The site expects to produce 780 kt/y, with storage facilities located in the adjacent Ngqura Harbour. Pre-feasibility studies have been completed for the project, which is expected to cost $4.6 billion USD. Although the announcement did not set a final date for investment decision, the first phase of the project is reported to go live in 2025, with full capacity to be reached in 2026 [90][91].

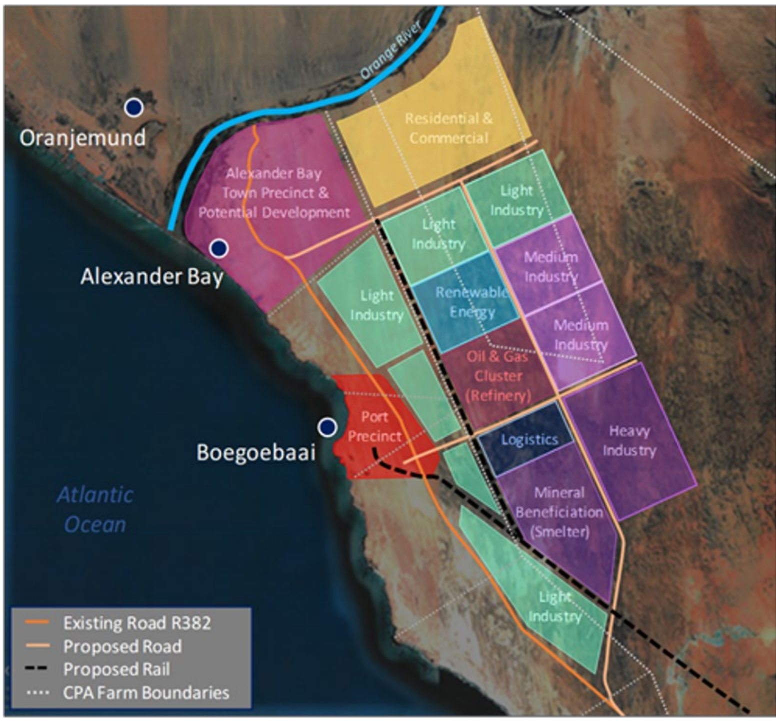
Boegoebaai Port

Boegoebaai is a proposed deep water port project planned for South Africa's Northern Cape Province, located close to the Namibia border and just north of Port Nolloth in the Richtersveld Local Municipality. In 2018 the project was approved in terms of the South African Treasury Public Private Partnership and, in 2020, the project was gazetted as a Strategic Infrastructure Priority Project.

The Boegoebaai Port, rail, and infrastructure project aims to generate local job opportunities and stimulate economic development in the Northern Cape Province. This will be done through establishing a deep-sea commercial hub to transport Northern Cape mining, hydrogen, and agricultural commodities via a 550km railway line, a dry bulk terminal for exports, liquid bulk terminal to handle various bulk liquid products, and a multi-purpose container terminal (see Figure 15) [92].

The Port intends to directly integrate the production of green hydrogen through a dedicated green grid and electrolyzer park to support manufacturing of sustainable goods and services in the Northern Cape and the export of green hydrogen [93] [94]. Boegoebaai port was selected as a key opportunity for South Africa due to its favorable location to nearby renewable potential, large land availability for port development, synergies with regional industries, its status as a planned SEZ, as well as strong national support for developing green hydrogen and ammonia capacity in the region. The added benefit is the extent of greenfield investment that will enable a complete green status orientation.

Figure 15: Planned layout for Boegoebaai port [92].



«Boegoebaai is a key enabler for the South African and SADC Just Energy transition by optimizing the tremendous energy resource, creating dedicated green infrastructure combined with a green port and industrialization strategy via a Special Economic Zone will be a world first and the way of the future of green industry and industrialization synergies at source» – Hendrik Louw (Northern Cape Economic Development Trade and Investment Promotion Agency)

Nearby solar and wind potential is estimated to potentially generate green energy between 16 and 24 hours per day, a 30 GW capacity and more [94][95]. As a greenfields project, all proposed buildings and infrastructure will be newly constructed on undeveloped and mine scarred land. With the 300,000 ha of land available – partly owned by people of the Richtersveld through the Community Property Association, other private owners, and government – there's adequate space and coastline to install renewable energy infrastructure as well as a desalination plant to supply water for the production of green hydrogen and ammonia [94][96].

Development is also expected to benefit local employment through the direct construction jobs (2,971), operational jobs (400), and indirect and induced jobs (13,819). Though local industries are scarce due to the undeveloped nature of the area, synergies with established regional industries would see a new commercial corridor for the port to handle 5-10 Mt/y of mineral resources, 0.6 Mt/y of Zinc and Sulfur, 1.3 Mt/y of Diesel, and 0.2 Mt/y of agricultural products [96]. In particular, three large iron ore mining sites — Kumba, Sishen and Kolomela — operated by Anglo American are located in the Northern Cape [97]. Though export of these products are mainly through Saldanha Bay, Boegoebaai port presents an opportunity to be considered as an alternative and closer export hub.

Importantly, Boegoebaai's development has strong government support, including the Presidency, Sasol, the Northern Cape Provincial Government, and the Gauteng Provincial Government. The project also aligns with South Africa's Department of Forestry, Fisheries and Environment, which declared in 2021 the expanded western Strategic Energy Corridor in the Northern Cape [93]. Signed agreements in support of these green hydrogen ambitions include:

- A Memorandum of Agreement between the Northern Cape Provincial Government and Sasol, for Sasol to be the anchor developer of the planned Boegoebaai Green Hydrogen Special Economic Zone, pending a detailed feasibility study;
- A Heads of Agreement between the Northern Cape Provincial Government and the Port of Rotterdam for the latter to act as a demand aggregator for green hydrogen into Europe; and
- A Memorandum of Agreement between Gauteng Provincial Government and Sasol for Sasol to develop green hydrogen production facilities in Gauteng aimed at decarbonizing the domestic industry [98].

Capital costs of the project require an investment of over R13.8 billion Rand ($863.7 million USD), which is expected to be financed based on a public-private partnership with an uptake driven investment. The project is currently in its inception phase and efforts are focusing on rounding up a potential coalition of investors. To date, R80 million Rand ($5 million USD) has been spent by the provincial government on the harbor studies and design, and this will be expanded on by the Provincial Government and Sasol for the green hydrogen cluster feasibility study. Once complete and additional administrative elements are addressed, construction of the project is expected to begin in 2024 [99]. This should be facilitated through the projects status as a Strategic Infrastructure Project, which allows for expedited timeframes for permitting and licensing. Business case and feasibility studies reports have been completed and a conditional approval from the National Treasury has been obtained with the request to proceed with a Request for Qualification process [95][96].

6.2 Linking industries through Energy Production

An alternative to focusing on port development as a catalyst for shipping decarbonization is to take a regional approach in generating momentum towards SZEF production. Though the global maritime industry can act as a significant offtaker for new zero emission fuels, the combination of factors needed to have a major commercial port with nearby renewable energy resources, high volumes of large vessel traffic, and space for development is not always feasible.

Rather than looking at shipping within a sectoral silo for the uptake of zero emission fuels, a more holistic perspective can be taken wherein shipping is only one offtaker for these new fuels and acts as a complement to other, additional sectoral demands for green energy. Such thinking is echoed in industry roadmaps that encourage international and national cooperation across sectors in order to reach global climate goals [83][99][100].

Combining maritime energy needs with other hard-to-abate sectors such as mining, cement, fertilizer production, chemical manufacturing, etc. can provide the support needed to invest into green fuel production. Importantly, aggregating sectoral demand – both within and outside the maritime field – strengthens the business case for SZEF producers by lowering their investment risks and diversifying target markets [12]. Importantly, aggregating cross-sector demand enables large-scale and long-term investment, which is needed to capitalize economies of scale and reduce the overall cost of SZEF production. This, in turn, will support the adoption and uptake of SZEF by multiple industries as they become more cost competitive if not cheaper than traditional fossil fuels.

Hydrogen Valley

In a joint partnership, South Africa's Department of Science and Innovation, Anglo-American, Bambili Energy, and ENGIE explored opportunities to kickstart a hydrogen economy in South Africa. The study was intended to complement South Africa's National Hydrogen Society Roadmap, providing a geographic focus area and concrete projects for further development. What was proposed and identified was a corridor with three hydrogen hubs that would transform the Bushveld complex and larger region around Johannesburg, Mogalakwena, and Durban into a Hydrogen Valley (see Table 7). A maritime component is foreseen as a hub in Durban – Richards Bay, which would in the long-term aim to bunker and export green hydrogen to the maritime market [102].

As demand aggregators, Hydrogen Valleys can lead to cost savings through shared infrastructure investments, which lowers the cost of hydrogen production through economies of scale and enables higher production within a region (see Table 8). The Hydrogen Valley project was selected as a key opportunity for South Africa due to its ambition to facilitate cross-sectoral synergies to aggregate green hydrogen demand, the active involvement and representation of key mining and energy actors, and its scalability and replicability to other areas and regions.

Richards Bay has reasonable solar potential, however there is limited land availability in the area, and offshore wind production is possible [27]. Using these energy inputs, the cost of producing green hydrogen in the Durban – Richards Bay hub is estimated to be $4.25 - 4.55 USD/kg. Given the estimated demand of 39-70 kt/y by 2030, the optimal and cost-efficient transport of green hydrogen would be via hydrogen trucks from the production site to offtakers, as building a dedicated pipeline for this specific opportunity would require higher demand volumes [102].

Table 7: Overview of South africa's hydrogen valley three proposed hubs [102].

Johannesburg	Mogalakwena – Limpopo	Durban – Richards Bay
Hydrogen Demand = 42-74 kt by 2030	Hydrogen Demand = 15-40 kt by 2030	Hydrogen Demand = 39-70 kt by 2030
Sector synergies: • Sasolburg's chemical and iron and steel sectors • Heavy Duty trucks servicing the N3 freight corridor • Public buses and buildings within the Johannesburg/ Durban metropoles	Sector synergies: • Heavy- and Medium-duty trucks via N1 freight corridor • Mining haul trucks (in Limpopo) • Limpopo Science and Technology for fuel cells to power its building stock	Sector synergies: • Fuel cell Heavy and Medium-duty trucks along the N3 freight corridor • Ports of Durban and Richards Bay for in port operational vehicles (forklifts), cold ironing from fuel cells, and marine bunkering • Pulp and paper factories, and public building

Table 8: Potential Offtakers for Green Hydrogen near proposed Durban – Richards Bay Hydrogen Hub [102].

Offtakers	Hydrogen Demand	Offtakers	Hydrogen Demand
BHP Billiton - Hillside Aluminum Smelter	1,740 t/y	City of Durban Buses	692 t/y
NPC - Durban cement plant	602 t/y	Freight trains in Durban	287 t/y
NPC - Port Shepstone cement plant	508 t/y	Freight trains in Richards Bay	287 t/y
Sapref - oil refinery	444 t/y	Heavy-duty trucks - incl mining trucks of Richards Bay Mineral, Tronox KZN Sands, & Anglo American	19,741 t/y
Mondi - pulp & paper	1,149 t/y; 3,525 t/y	Port of Durban - port logistics (forklifts)	3,768 t/y
Mpact felixton - pulp & paper	530 t/y	Port of Durban - berthing	441 t/y
Sappi Saiccor - pulp & paper	3,406 t/y	Port of Durban - marine bunkering	10,605 t/y
Sappi Stranger Mill - pulp & paper	319 t/y	Public buildings in Durban	228 t/y
Sappi Tugela - pulp & paper	553 t/y	King Shaka Airport	47 t/y

The port of Durban is one of the busiest ports in South Africa, servicing large containerships and cargo traffic, while Richards Bay is South Africa's largest bulk coal terminal [103][104][105]. In 2018, the Port of Durban saw 1,130 vessel arrivals, the majority of which were containerships (307); while Richards Bay saw 2,226 vessel arrivals, mainly bulk carriers (1,902). The annual energy usage of these vessels visiting the ports of Durban and Richards Bay was 7.84 TWh and 12.9 TWh, with an estimated emissions of 2,388 kt CO2e and 3,893 kt CO2e, respectively.

Both ports are considered in the study, but only Richards Bay is considered a suitable port for possible export of SZEF. This is due to the opportunity for a just transition in the development of Richards Bay as a sustainable alternative to the port's heavy reliance on coal handling [27]. Indeed, the Hydrogen Valley is estimated to potentially add $3.9-8.8 billion USD to GDP by 2050 and generate between 14,000 - 30,000 jobs per year across all three hubs [102].

These developments offer interesting potential for shipping decarbonization in South Africa as relevant synergies exist between shipping, mining, and the power sector, which allow for the transfer of technologies and human capital [102]. Currently, the Hydrogen Valley project is in the application process to become a Strategic Infrastructure Project, allowing for expedited timeframes for permitting and licensing. Recent efforts by Anglo American, Bambili Energy, and ENGIE have focused on inland mobility projects, mainly gathering a consortium to pilot hydrogen-fueled heavy-duty trucks along South Africa's N1 and N3 freight corridors and fuel cell buses within Johannesburg and Durban. This project, dubbed Project Rhynbow, has been shortlisted for KfW grant funding.

The project's focus on its maritime component, however, is still nascent and requires further elaboration and planning. It remains unclear who will drive this initiative forward for the Durban – Richards Bay hub, especially considering the export potential of SZEF identified. Transnet was involved in the feasibility study as a qualitative data contributor as well as a workshop participant, though their role and possible enthusiasm for the project and its plans for the two ports are unknown.

«The Hydrogen Valley project is strategically important for South Africa, providing a means to aggregate hydrogen demand from multiple industries and kickstart their hydrogen economy. This will help scale the use of this technology and provide significant benefits both in reducing air pollution and providing green jobs.» – Jonathan DeBasc (Engie)

Section 7

Finance and Investment Requirements

To meet global GHG reduction requirements, a market and infrastructure for SZEFs and zero emission-ready ships must be created. SZEF will require, inter alia, the development of new bunkering infrastructure, deployment support, production scale-up, a decrease in renewable electricity prices, and the development of new regulatory safety measures [18]. In other words, the fuel transition in shipping is linked to the evolution of global energy systems and renewable capacity, which must increase in order to drive down the price of renewable energy [11].

In terms of financial investment to achieve this transition, a significant amount of funding is needed. Globally, estimates suggest that $1.4-1.9 trillion USD will be needed to fully decarbonize by 2050, with the majority of funds (87%) needed for land-based infrastructure [106]. In particular to South Africa, the development of zero-carbon fuels manufacturing and its associated infrastructure to cover shipping's energy demand around South Africa could attract investment of between between R34 and R49 billion Rand (around $2.2-3.2 billion USD) in onshore infrastructure by 2030 [107]. Mobilizing this investment and securing finance for green energy projects is feasible, though comes with its own challenges.

Given the relatively high price gap between SZEF and conventional fossil fuels, the private sector generally struggles to justify finance for large scale first mover projects without some type of public or developmental support. South Africa, as an upper-middle income country [108], is unable to access large amounts of grant-based development funding, particularly through larger financial institutions. This means that most available international finance will come in the form of low interest loans, with some scope for accessing grant financing where certain conditions are met.

South Africa is eligible to take out large loans from multilateral development banks, such as the World Bank Group, the African Development Bank, and the New Development Bank [109]. The World Bank offers loans from the International Bank for Reconstruction and Development at market rates of interest or the International Development Bank at concessional rates. It can also assist private individuals in securing loans, loan guarantees, and equity financing through the International Finance Corporation [110]. The African Development Bank and New Development Bank also offer similar access to loan funding at concessional rates. In particular, the African Development Bank recently announced a large funding package for South Africa totaling $2.8 billion USD, largely focused on decarbonization and phasing out coal from Eskom's operations ($400 million USD) [111]. The New Development Bank, to which South Africa is a founding partner, is also responsible for providing large loan amounts to South Africa, including a recent agreement for providing an additional R21.7 billion Rand ($1.4 billion USD) in financing [112].

Multilateral banks also offer grant funding, which for South Africa are more limited in scope. Grants are possible for direct feasibility and technical support funding from, for example, the Public-Private Infrastructure Advisory Facility [113] that can be employed to help develop technical capacity building and regulatory infrastructure. This type of funding is particularly relevant for project development, especially for pre-feasibility studies. Some stakeholders further raised the relevancy of pre-feasibility funding in relation to assisting with permits, approvals, and supporting the development of effective regulatory frameworks. In addition to feasibility funding, there are several multilateral sources of grant funding such as Climate Investment Funds and Green Climate Fund, which can provide finance for projects specifically addressing efforts to tackle climate change [114][115].

Through securing large sources of funding from multilateral banks, South Africa typically enters long-term partnerships, for example the World Bank's South Africa Country Partnership Framework 2022-2026 [116]. These types of agreements are between a country and funder, setting priorities for investment over the agreed period. These fund volumes are generally already agreed, defining a set of priority areas. Explicitly recognizing maritime decarbonization as a priority under these frameworks would allow for projects to access funds under already agreed programs and future frameworks.

Key factors to attract institutional finance:

- Demonstration of Government support
- Mobilization of private investment
- Showing climate impact
- Scalability of the project

Bilateral agreements with other countries and national development programs provide additional avenues to access needed finance. South Africa's Hydrogen Partnership with Germany, administered through the GIZ[21], focuses specifically on the development of hydrogen in South Africa for export to Germany. Under this partnership, the German BMZ[22] has pledged around €40 million EUR (R700 million Rand; $42 million USD) in grant funding to promote South Africa's hydrogen-based economy. This is in addition to around €200 million EUR (R3.3 billion Rand; $211 million USD) in concessional loan finance for green hydrogen projects [117]. Stemming from COP26, the Just Energy Transition Partnership with France, Germany, UK, US, and EU pledged $8.5 billion USD over the next three to five years in the form of grants, loans, guarantees and private investments to facilitate South Africa's transition to a "low carbon, climate resilient society that promotes employment and livelihoods" [118]. These types of specific hydrogen partnerships offer a chance to link South Africa to demand centers where an incentive for preferential financing is present. This provides a way to develop technical and infrastructural capacities through linking to partner countries with expertise in the development of hydrogen infrastructure, as well as support a just transition in the context of transitioning existing coal jobs [119].

21 Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH, Germany's development agency.
22 German Federal Ministry of Economic Cooperation and Development.

Other streams of international grant finance specifically target climate impact and other philanthropic causes, given that the objectives of the funders are demonstrated. Examples of relevant institutions include ClimateWorks Foundation [120] and the African Climate Foundation [121], which set funding objectives and can provide channels for philanthropic funding to flow towards projects. For these types of funds and in general, South Africa's demonstration of climate action and alignment through international commitments and collaboration can hugely support its ability to attract funding.

Additionally, national funds, such as the Green Fund, established through the Department of Environmental Affairs has transitioned to a low carbon economy in South Africa as a main thematic area for investment [122]. The Green fund provides access to grants and loans and can be leveraged towards projects at an early stage of development. The Development Bank of Southern Africa, wholly owned by the South African Government, helps to mobilize funding across South Africa and the wider Southern African region. Through this South Africa can also access further regional funds through institutions like the Southern Africa Development Community [123]. Mobilization of pension funds are another avenue that could support the long-term transition to a hydrogen-based economy in South Africa. Despite not generally offering concessional forms of finance, these funds adopt a long-term strategy that may be more capable of taking on long-term risk than traditional private lenders. An example of these funds is the Government Employees Pension Fund, which is the largest pension fund in Africa [124].

Overall, due to the nascency of the business cases for projects addressing maritime decarbonization, there is a clear need for blended finance to leverage and mobilize private capital. At the outset, industry stakeholders stressed the importance of initial grant and pre-feasibility funding to de-risk larger future investments. In unlocking concessional finance, South Africa already benefits from strong Government support for the development of green hydrogen, in addition to defined funding priorities surrounding climate action and supporting a just transition. Building on this, South Africa could seek to further define maritime decarbonization as a specific priority, establishing a national roadmap and including domestic shipping in its Nationally Determined Contribution.

Section 8

Recommendations

It is clear that South Africa, a maritime nation with high GHG emissions, has the potential to be a leader in the maritime industry's decarbonization journey. The country's vast renewable energy potential has the capacity to not only supply its electrical demand but also produce zero-carbon fuels to cover shipping's energy needs through its ports as well as support decarbonization of other land-based sectors. At present time, South Africa's government and its departments have a high awareness of the benefits these new fuels can bring, especially with regards to the country's climate goals and commitments in addition to facilitating a just transition away from its reliance on coal. With appropriate incentives and targeted action towards encouraging economy-wide energy, investment, and environmental planning, South Africa can become a first mover in this field and set an example for other countries to follow.

The suggested recommendations below represent a cumulation of the work for this project and stem from the evidence base reported in preceding sections, multiple stakeholder interviews, scoping exercises, a collaborative workshop, a roundtable with the project's National Committee for South Africa. Where appropriate, the synthesis produced from these inputs is also supported by additional references from literature. These recommendations are by no means prescriptive nor exhaustive, but present starting points for key actions to be taken in the coming years to support the country's journey in shipping's decarbonization as part of a just and equitable transition.

Ports

Stakeholders have highlighted that South Africa's port infrastructure requires upgrading [125][126]. Part of Operation Phakisa, a government-led initiative to unlock South Africa's Blue Economy, targeted key projects to address this need for development; however, the country's ports still suffer from aging infrastructure, causing additional supply chain and logistics challenges. According to the global Container Port Performance Index, South Africa's container ports were ranked at the bottom of 351 container ports with the port of Durban among the worst-performing ports in the world in terms of operational efficiency [126][127].

In 2021, South Africa's government announced partial privatization of harbor infrastructure with a planned R100 billion Rand ($6.55 billion USD) investment to address port performance issues [126]. As part of these planned upgrades, it would be prudent to build port facilities that are climate proof and support national decarbonization goals. This can include the preparation of South Africa's ports for the bunkering of SZEF, facilities to offer renewable shore-based power supply (i.e. cold ironing), and electrification of port operations.

Suggested Actions

Prioritize port electrification as a key first step

Electrification of existing fossil fuel use of ports is an immediate step towards maritime decarbonization, wherever this change is possible. Switching port activities to rely mainly on electrical energy from renewable sources can reduce GHG emissions. Electrification can also reduce local air pollution emissions and maintenance and energy costs. Options for switching to electrification include electrifying docks for cold ironing; installing charging infrastructure to power logistics and freight handling with cranes and logistical onshore vehicles; cold storage; service vessels, such as harbor tugs and pilot vessels; and offices and buildings [83].

Increase coordination and guidance to support port development towards decarbonization & a just transition

As discussed in Section 3, there is a high significance of passing and calling ships on air quality and GHG emissions in South Africa. Furthermore, Sections 5 & 6 show that ports can be areas of opportunity for employment and investment. As such, it is clear that ports are both a critical enabler of emissions reductions and socio-economic opportunities. Therefore, increased coordination and national planning from the Department of Transport and associated port authorities, such as Transnet National Ports Authority, could help to align and structure various efforts and initiatives taking place in South African ports today. This would also make sure that wherever appropriate the broadest co-benefits are considered and ensure that value is recognized and used in justifications for sustainable port investments and development.

Prepare to source or produce SZEF for bunkering, port use & export

Shipping will need to rapidly transition away from fossil fuels, particularly during the 2030's. Due to the large quantity of international ships calling and passing, evidenced in Section 3, South Africa is one of the leading fossil fuel bunker suppliers globally and is currently associated with large volumes of fossil fuel imports. Analysis in Section 4 shows, however, the excellent potential for this energy import to be switched to domestic production, thereby adding significant additional jobs and direct investment. Indeed, planning is already underway for the three strategic business opportunities identified (Section 6). As SZEFs move to implementation, all aspects of ports need to be prepared to switch – opportunities exist both as a bunker fuel, for use in port (e.g. new vessel designs such as the Port of Antwerp's 'Hydrotug' which is powered via a dual-fuel combustion engine that burns hydrogen in combination with diesel [128]), as well as for export.

Become a Green Port

Ports are nodes of multiple sources of pollution, from arriving and departing vessels, onshore trucks and rail, as well as their own operations. Port authorities could invest in creating a port ecosystem that positively contributes to air and environmental quality through adoption of technology solutions (e.g., smart sensor systems to monitor air and water quality and automated mooring systems), improved facilities (e.g., waste collecting and recycling), and optimization of terminal and ports to reduce at berth time [83][129]. Initiatives like the UN Environmental Programme's "Sustainable and Clean Port program" offer best practices and a framework to guide port actors [130].

Policy

South Africa has an advanced political framework and national ambition relating to climate change policy. Through the publication of the Hydrogen Society Roadmap as well as the clear national interest in devesting the energy grid from its current reliance on coal, there are concrete signals in favor of a sustainable and just transition. However, stakeholders noted the need for further government support in aligning policies, providing guidance and clarity in relation to key implementation aspects of the hydrogen economy, as well as the need to raise awareness, increase training and capacity building.

Emphasizing the importance of shipping decarbonization is an important first step that the South African government can take now. Actions on this front can be at both national and international levels and would clearly align the nations' maritime sector with its broader climate change goals and ambitions. Policy and regulatory enablers can ease deployment of SZEF innovative technology, encourage its applications and future demand, formalize standards and labels, and harmonize coherence with land and water use [102].

Suggested Actions

National

Align maritime policies with national climate ambition

As shown in Section 5, South Africa has ambitious national climate policy. Maritime climate policy is split between national policy acting on domestic emissions (the minority of GHG emissions and investment opportunities), and international policy acting on international emissions (the majority of GHG emissions and investment opportunities). Aligning maritime policies in both national and international settings, to the levels of national climate ambition can increase policy coherence and unlock investment. Reviewing inventories of South African shipping emissions is needed, given the findings in Section 3 that current figures may be underestimated. The maritime sector should be included within the larger decarbonization agenda and explicitly mentioned within national policies. The upcoming revision of the Comprehensive Maritime Transport Policy is an opportunity to address this as well as the next submission of South Africa's Nationally Determined Contribution.

Exploit synergies between shipping's decarbonization & coal phaseout

South Africa's reliance on coal is strong, and shipping and shipping emissions are intrinsically connected to coal, as an important traded commodity. It remains unclear when, exactly, South Africa plans to decommission its coal plants and fully switch to a sustainable energy system. As this decommissioning happens it will also create opportunities and risks for South African shipping that are maximized/reduced if there is a clear plan and timeline. Setting a timeline for a complete phase out of coal in South Africa, would serve the purpose of sending a strong market signal to renewable energy and by association SZEF producers [60] [131]. South Africa's government could consider how maritime decarbonization can help to create new jobs that can support the transition of fossil fuel jobs as coal is phased out.

Encourage public-private collaborations
Authorities and involved stakeholders (energy producers and industry representatives, system operators, regulators) could develop integrated roadmaps that include future infrastructures, transition pathways, ways of working between the involved parties, governance structures, and business models showing how stakeholders will be rewarded for supporting and using the energy ecosystem [83]. This will be especially important when it comes to the need of training and skill development, which can benefit from government investment and leveraging best practices developed by industry. These collaborations can be catalyzed by making information characterizing the scale and nature of South African shipping widely available to relevant public and private sector stakeholders.

International

Collaboration to secure effective GHG policy at the IMO
The market for South African SZEF, and therefore the business case to unlock deep investment, can be most strongly enabled by the timely adoption of effective policy at the IMO. International policy measures such as a potential MBM need to be developed to support investment and jobs in South African SZEF. South Africa can advance investment by supporting the IMO to work towards zero emissions by 2050, and working with other countries on the adoption of policy measures to achieve that outcome and shipping's just and equitable transition.
Support the development of SZEF standards & authorizations
Supporting environmental authorizations and setting standards for new bunkering facilities and processes will be crucial in the near future. South African authorities should engage with or closely follow advancements in this space, such as the work by Korea Shipbuilding & Offshore Engineering and the classification society Korean Register who are working on developing hydrogen ship standards [132], as are other classification societies. Such standards and labels are required to harmonize technology specifications for the industry and serve to guarantee safety of hydrogen production and transport [102].
Sign the Declaration on Zero Emission Shipping by 2050 to increase climate ambition
South Africa should continue to represent national ambition and climate priorities in international fora. The current climate ambition of the IMO – to reduce GHG emissions by 50% by 2050 – is not aligned with the Paris Agreement's goals [133]. To grasp the potential related to SZEF for shipping, there needs to be a clear signal from the IMO to work towards zero emissions by 2050. Signing the Declaration on Zero Emission Shipping by 2050, which aligns with the Paris Agreement, would further emphasize South Africa's commitment to reduce shipping emissions and signal political ambition to adopt goals for 2030 and 2040 that place the sector on a full decarbonization pathway [134].
Sign the Clydebank Declaration & develop Africa's first green corridor
Green corridors are touted as an innovative method to initiate early action along a specific international shipping route between two major port hubs and can be leveraged to serve national interests in the transition to zero emission shipping [12]. Based on its renewable energy potential, trade relations with other regions, and location along busy shipping routes, South Africa could sign the Clydebank Declaration to signal its interest in international collaboration on this front.

Finance

Though South Africa already exhibits strong political ambitions to realize its potential as a hydrogen economy, many efforts are still needed to overcome financial barriers to achieve this sustainable transition. As studies and stakeholders have noted, many of these barriers relate to the sourcing of green electricity, scaling electrolyzer use for hydrogen production, and transport and storage infrastructure, among others [102]. South Africa has large platinum reserves that are crucial for the manufacturing of electrolyzers needed to produce green hydrogen [26]. Creating a framework that sustainably leverages the nation's inherent natural resources, both in terms of renewable energy and minerals, can create substantial export opportunities for both and create new revenue streams for the country. Hence, supporting shipping's decarbonization can in turn capitalize on both the export of green hydrogen as well as the manufacturing of electrolyzers.

As shown previously, South Africa has multiple options and avenues the country can pursue to leverage development finance to fund strategic projects and innovations. Financial frameworks play a large role in facilitating markets and enabling the emergence of innovative clusters. So far, international funding is limited due to the nascent business cases for SZEF; hence, available financing could prioritize reducing major investment risks, improving the strongest business cases, and supporting a just transition through green job growth. Though the maritime industry and local stakeholders have confirmed their commitment to investing in new infrastructure and R&D, they highlighted the need for a funding framework that supports them in undertaking demonstration projects and pilots.

In understanding and demonstrating how maritime decarbonization can contribute towards both national and financing priorities, South Africa could create a path for additional sources of finance towards projects like those explored in this report. This will ultimately accelerate the realization of a business case for relevant projects, enhancing South Africa's abilities to take advantage of the resulting opportunities and develop renewable generation supply chains, skills, and economies of scale that support wider adoption of these new SZEF technologies.

Suggested Actions

Create the conditions to enable first mover projects

South Africa's experience in receiving development bank support for its energy transition could be leveraged to access concessional funding, which can help develop more detailed proposals, technical capacity building, and regulatory infrastructure that in turn can unlock further finance (see Section 7). Infrastructure upgrades are costly and lengthy procedures, which often demands the mobilization of significant private capital. It is important to create an environment that triggers investments in a high renewables-based system. One suggestion could be to explore how shipping decarbonization could be facilitated through fiscal incentives, such as including electric power for the production of marine fuels in the category of special taxation measures or accelerated depreciation. To support first movers, government interventions like funds for the unprofitable top or contracts for difference[23], buy-back arrangements, public credit guarantees, and green bonds could also be used [83].

Boost private renewable electricity generation

Removing barriers to the production of large-scale renewable electricity is essential to build South Africa's green energy capacity and scale its potential, including in SZEF production. Spending on renewable energy infrastructure could focus on building a smart, reinforced distribution grid that integrates both public and private sources of renewable energy, which can help manage local congestions and support grid resilience [83]. Note, to leverage this, South Africa would need to push its embedded generation threshold ceiling further than 100MW.

Work bilaterally with countries to reduce SZEF investment costs & risks

Financial investments into SZEF infrastructure are currently difficult to justify based on current business models. Similar to the development of wind and solar technologies, new SZEF technology will need initial financial support and structures to ease their adoption. Section 7 identifies several examples of developed economies seeking to partner bilaterally with countries who are able to produce/export SZEF. One example enabling this is the concept of Green Corridors (identified as a policy recommendation, through the Clydebank Declaration). Bilateral relationships could enable funding for (pre-)feasibility studies, financial incentives to lower CAPEX, subsidies to lower CAPEX and/or OPEX, guarantees to de-risk larger future investments, and fast tracking deployment through simplified permitting procedures [102]. Ultimately, closing the competitiveness gap between SZEF and conventional fossil fuels is essential, which can be supported through international regulation that supports a price on carbon.

23 Subsidizing the 'unprofitable top' or a 'contract for difference' can be used by financial intitutions to bridge the gap between using more expensive but sustainable sources of energy generation compared to cheaper but less sustainable fossil fuel options. Renewable suppliers are therefore ensured a steady revenue stream that supports their deployment at scale and improves their project's bankability.

Enable a just transition

South Africa's SEZs offer important growth incentives to strengthen business opportunities, job generation, and innovation. There is a large potential to unlock shipping decarbonization and the low-carbon economy by working with SEZs to create sustainable green jobs. Investments into relevant renewable energy projects hold the potential to create more near-term jobs than fossil fuel investments, in addition to providing comparable forms of employment for transitioning away from fossil-fuel related jobs. Financing requirements and approvals for new projects could include a thorough assessment on how future investments into relevant infrastructure will serve existing objectives like regional development, green growth, and the creation of quality jobs [135].

Industry

Lastly, it is important to note that South Africa's government is not alone in its task to decarbonize its maritime sector and that industry actors have a role to play in pushing this agenda forward. As seen in the Call to Action for Shipping Decarbonization, launched in September 2021, over 240 industry actors representing the full maritime ecosystem publicly called on governments and international regulators to take decisive action in support of making zero emission shipping the default choice by 2030 [75].

As part of this call, companies volunteered information about their own actions, targets, and plans towards shipping's decarbonization. Industry actions to date include investments into RD&D and pilot projects, ordering and building zero emission ready vessels, purchasing zero emission shipping services, investments into SZEF production and port and bunkering infrastructure, among other actions [136].

Continued efforts by industry actors, both within the maritime sector and in other areas such as transport and energy, will be essential in the coming years. Actions South Africa's industry members can take to support national and international maritime decarbonization include aggregating demand for SZEF, engaging in cross-sectoral collaborations and alliances, as well as exploring new business models and operational practices.

«South Africa has the potential to emerge as a first mover and ultimately drive the transition to a hydrogen based economy across Africa. To realize this opportunity, increased private and public collaboration across the whole value chain is needed to ensure that efforts are coordinated and that learnings are shared as widely as possible.» – Catherine Scholtz (African Hydrogen Partnership)

Suggested Actions

Aggregate SZEF demand

Maritime industries, though substantial offtakers by themselves, could look to aggregate SZEF demand across the value chain as well as other sectors, especially mineral mining and steel production. Cross-sectoral collaboration can generate effective synergies between shipping, mining, other transport sectors, and energy. Key industries that can aggregate their demand for green hydrogen and its derivatives include fertilizer producers, ammonia and steel producers, mining industries, among others. Increasing the volume of demand for new zero-carbon fuels, supported through offtake agreements, strengthens business cases for investors and capitalizes economies of scale to reduce overall cost of production. This is especially important when it comes to extending the asset life of existing infrastructure, such as natural gas pipelines which can be repurposed for power to gas and hydrogen transport and storage [83][102][137].

Public-private collaboration & engagement

Local stakeholders also emphasized the need for more collaboration between public bodies and industry to fill knowledge gaps, derisk early innovation efforts, and align on new standards and regulations. Governments are limited in their ability to drive market-changing innovations and rely on industry support to develop, pilot, and demonstrate new solutions to challenging problems [12]. Indeed, South Africa's Hydrogen Society Roadmap explicitly states that public-private partnerships are needed to reach its climate goals [138]. Industry actors can engage with public bodies through public-funded technology partnerships between suppliers and offtakers to not only share the risks of new projects but also help educate government on the barriers and challenges facing the private sector [16][102].

Build alliances to drive market change

No single maritime actor has sufficient market influence to enable shipping decarbonization alone. Gathering industry actors into a non-competitive forum for collaboration can send a collective demand signal to fast track decarbonization action [137]. This can be seen in the Cargo Owners for Zero Emission Vessels [139] as well as buyers alliances and green investor alliances, such as the Sustainable Freight Buyers Alliance, which serve to pool market influence [140]. Interested industries could join initiatives like the African Hydrogen Partnership Trade Association, which is dedicated to the development of green hydrogen and related business opportunities in Africa [141].

Explore alternative business model options

Industry actors could seek new and alternative business models that reduce high barriers to entry or adoption for SZEF technology, both onboard vessels as well as shoreside [137][142]. Book and claim systems, subscription services, wholesale power purchase agreements, leasing models, private-issued green bonds, and reverse auctions can act as new ways the maritime and energy sectors do business [143]. Shipping contracts could also use rethinking in this new decarbonization era, potentially building in flexibility into time charter contracts and reducing incentives related to demurrage in voyage charter contracts [144][145][83].

In conclusion, South Africa is well positioned to be a leader in the global maritime transition towards decarbonization, and exploit synergies with its own national transition away from fossil fuels. Its strategic geographic location adjacent to key shipping lanes, strong renewable energy potential, and government support towards achieving its climate change ambitions create an ideal environment to capitalize on emerging business opportunities.

Global momentum towards zero emission shipping is currently building, with new alliances, initiatives, demonstrations, and pilots taking place. South Africa has the chance to leverage its own development goals as it adapts to meet the future demands of the maritime industry. Unlocking international finance, establishing national and international cross-sectoral partnerships, easing financial and regulatory hurdles, and investing in climate-proof projects will be fundamental in the years to come.

With targeted and decisive action by multiple actors, South Africa can become a competitive producer and exporter of SZEF. Investing in key renewable energy and SZEF infrastructure would have significant benefits for the country's economy and society, reducing national emissions, improving air and water quality, creating sustainable jobs and skills expertise as part of a just transition, and developing new supply chains. The actions outlined above could support South Africa in its continued journey towards decarbonization and becoming Africa's first zero carbon bunkering hub.

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Annex I

SHIPPING GEOSPATIAL MODEL: Technical Information

This annex presents supplementary information to Chapter 3 on South Africa's Shipping Activity and its Maritime Emissions. It provides a more detailed look at the methodology employed in this report to generate Shipping Geospatial Model (SGM) for South Africa, including the assumptions and limitations of the approach.

It is structured in three sections:

1. Shipping Geospatial Model
2. South Africa's National GHG Inventory
3. Comparison between this report's SGM and South Africa's National GHG Inventory

Shipping geospatial model

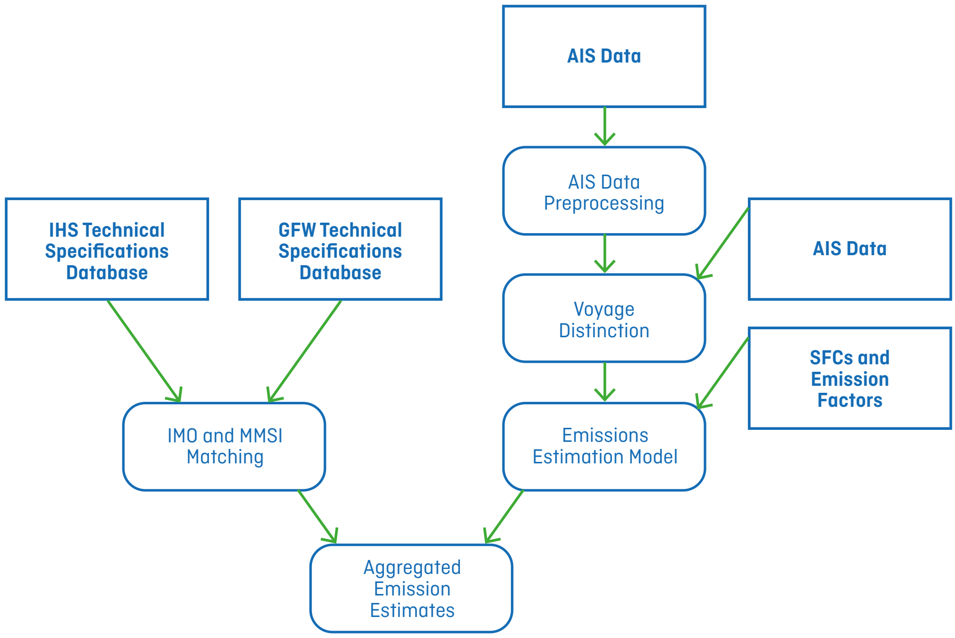
This report provides an estimation of GHG emissions and air pollutants from shipping in South Africa using an activity-based approach.

The SGM for South Africa were estimated from a two-step methodology that allows for the aggregation of data at different levels. The first step is based on the Fourth IMO GHG Study methodology, focusing on the shipping activity in South Africa. The second converts the first-step results into discrete voyages and their geographical location thanks to the ship's Automatic Identification System (AIS) granular data. In this case the AIS data used refers to the ship's hourly records for the whole global fleet operating in 2018. The latter step aims to provide a fair and representative reflection of the emissions associated with South Africa's maritime economic activity.

Step I: Building from the fourth IMO GHG Study

The Fourth IMO GHG Study [8] provides an inventory of GHG emissions from international shipping between 2012 and 2018. While the study provides two different approaches (i.e. top-down and bottom-up) to estimate shipping emissions, this report utilized the bottom-up approach, also known as activity-based (seen in Figure 16).

Figure 16: Flow diagram representing the Fourth IMO GHG Study Methodology with the dataset used.



In the bottom-up approach, operational information captured by AIS data is matched with static technical information contained in Markit's Information Handling Service (IHS) and Global Fishing Watch databases [146][147]. The design specifications contained in the datasets are used in the calculation of fuel consumption and emission factors over an hourly, per-vessel basis. Consistent with *2006 IPCC Guidelines for National Greenhouse Gas Inventories* [30], the Fourth IMO GHG Study builds on the methodology presented in the Third IMO GHG Study [148] to incorporate the identification of port calls from which an allocation of discrete voyages can be made, and a distinction drawn between international and domestic shipping.

The strong advantage of using the IMO methodology is that it contains the latest maritime GHG and air pollution research for domestic and international shipping above 100 gross tonnage [8]. It contains the state-of-the-art technical detailing, fuels and emission factors that allows for the estimation of the country's maritime sector GHG and air pollution.

IHS, IMO and Maritime mobile service identity matching

Raw AIS data from terrestrial and satellite sources were obtained from the provider exactEarth and individual vessel data taken from the IHS dataset [146]. The datasets were combined based on each ship's IMO identification number and Maritime Mobile Service Identity. Resampling of the data into hourly time intervals allows for the extrapolation of the activity data for the entire year. This step ensures that the increasing coverage and number of AIS data points generated year on year does not result in an associated artificial growth in estimated emissions. The resampling step also serves to remove or correct invalid and spurious data points, while assessing the quality of AIS datasets for each IMO number in the process.

Following the Fourth IMO GHG Study methodology, this report considered 19 different vessel types – 70 when considering the ship sizes; 13 different propulsive systems with three different generations – based on the ship year of build; auxiliary engines and boilers; four fossil fuels[24]; 10 different GHG and air pollutants and two fugitive emissions (i.e. refrigerants and Non-Methane Volatile Organic Compounds (NMVOC)).

AIS Data pre-processing

Linear interpolation is applied to the vessel GPS coordinates to account for Earth's spherical curvature and the accurate application of location dependent emission factors such as Emission Control Areas. Anomalies can be generated by the linear interpolation method and their numbers are known to correlate with the number of contiguous hours where no GPS data was observed. However, anomalies were found to decrease substantially over the years of the study as a result of increasing AIS coverage. Each hour where an activity report exists is allocated as port phase (operating at less than three knots and near the geographical location of a port), voyage phase or transition phase. Port activities are used to split vessel activity datasets, thereby generating a sequence of individual voyages. Where contiguous missing periods are determined greater than a missing period threshold, that voyage is removed and replaced using backward and forward infilling.

24 Fully-electric, coal, non-propelled and nuclear-powered vessels were removed.

Distinction between international and domestic voyages

Building on the methodology employed in the Third IMO GHG Study for generating bottom-up fuel estimates based on vessel type and size, the Fourth IMO GHG Study applies a new approach to discretizing voyages from continuous data using the geospatial and temporal information contained in AIS data. Central to the Fourth IMO GHG Study is a port database containing the name, coordinates and country of close to 13,000 ports around the world.

Individual port calls are identified using reported speed over ground values and a spatial nearest neighbor algorithm to compute the distance of vessels to their closest port. AIS data points with average speed over ground values of below one knot are grouped into clusters representing potential stops. The clusters are assigned as port stops if the distance to nearest port is sufficiently small, time at port is sufficiently large and the distance between the cluster and any neighboring clusters is sufficiently large. Consecutive clusters located close to one another whilst assigned to the same port are merged into one, however for those with different port assignments one of the clusters is removed. For vessels where AIS coverage is particularly poor, a second stop identification method is employed relying on proximity to port and eliminating the dependence of the stop identification algorithm on accurate speed over ground records alone. Using the definition of international shipping as that which takes place between ports of different countries, emissions may then be allocated to international or domestic categories in line with IPCC definitions. This distinction enables quantification of the voyage-based inventories presented in the main body of this report.

Fuel consumption, Emissions and Energy estimation

The hourly main engine power demand of any given vessel is established by using Admiralty formula where the AIS speed and draught reported is combined with the ship design characteristics taken from IHS data. The formula was complemented with speed, fouling and weather factors. For the auxiliary machinery power demand was established depending on the ship type, size and operational mode occurring at each hourly observation.

To transform from power demanded of the main engine to hourly fuel consumption, the power demanded was matched to a specific fuel consumption curve which used the engine and fuel type baseline specific fuel consumption and the engine loading (i.e. how much power is being demanded against the maximum installed power) as independent variables. The multiplication of estimated specific fuel consumption and main engine power demand yields the hourly fuel consumption. For the auxiliary machinery, the specific fuel consumption were given as constant and their hourly fuel consumption was obtained by multiplying the power demanded and the specific fuel consumption. The vessel total hourly consumption was the aggregation of the fuel consumed by the main engine and auxiliary machinery.

The estimation of hourly GHG and air pollution emissions is dependent on how much fuel is being consumed, fuel type, fuel sulfur content, main engine loading and power output, main engine type, machinery (i.e. auxiliary engine or boiler) and geographical location (i.e. if navigating inside or outside an Emission Control Area).

As in the Fourth IMO GHG Study's activity-based methodology, two different approaches to emission factors (EF)[25] were used: energy-based and mass-based. The energy-based EF are given as mass of air pollutants by energy demand – normally given as g pollutant/kWh. The mass-based EF is given as mass of pollutant per mass of fuel – normally given as g pollutant/g fuel. The hourly emissions were obtained by multiplying energy-based EF by hourly energy demanded for each onboard machinery type. For the GHG and air pollutants using fuel-based EF the hourly fuel consumption was multiplied by the EF[26]. To convert GHG emissions into CO2 equivalent (CO2e), the Global Warming Potential over a 100-year period of each compound is used. As reference, the Global Warming Potential over a 100-year period is taken from 2006 IPCC guidelines[27].

To convert annual fuel consumption to energy demand, hourly fuel consumption was converted to a common fuel equivalent unit (Heavy Fuel Oil in the Fourth IMO GHG Study). This conversion is achieved by using the IMO Heavy Fuel Oil (HFO) low heating value (LHV) of 40,200 kJ/kg and the fuel being consumed (e.g. Marine Diesel Oil (MDO) which has a LHV of 42,700 kJ/kg). However, for Ricardo's and this report the shipping energy demanded is given in MWh. To achieve this, the HFO equivalent unit needs to be converted to kJ using the HFO LHV to then converting the hourly energy demanded to MWh[28].

The annual fuel consumption, energy demand and emissions by ship type and size (or shipping as a whole) is the aggregation of each hourly observation within the observed year (i.e. 2018).

Quality Assurance and Control

Comprehensive quality assurance (QA) and quality control (QC) efforts were undertaken to ensure accuracy in the inputs, method, and results of the bottom-up study. State-of-the-art Monte Carlo uncertainty analysis applied in the Third IMO GHG Study is was replicated in the Fourth Study and used to show that uncertainty has dropped from close to a third in 2012 to <10% in 2018, with ongoing uncertainty reductions expected as overall coverage of AIS data increases. Overall, difference in total fuel consumption figures of 2012 deviated just 3% away from the Third IMO GHG Study, indicating the quality and coherency of methodologies contained in both. Of three vessel types responsible for close to two-thirds of the total international CO2 emission for 2018, there was a maximum deviation of 6% between CO2 emissions estimated in the Fourth IMO GHG Study and those presented in the EU's MRV scheme [149]. Further, continuous monitoring data was used to validate the model's speed, main and auxiliary engine models with a good correlation on speed, draughts, main engine power and fuel consumption with the largest uncertainty on the auxiliary engine model due to the assumption of a constant power generation for the different operational modes for all ship types.

25 The EF are given as tank-to-wake emissions. This means that it quantifies the emissions produced by the onboard systems. It does not consider the upstream emissions produce due to the extraction, production and distribution of the fuel.

26 A more specific explanation of the EF can be found in the Fourth IMO GHG Study subsection Emission Factors or Appendix B and M.

27 For CH^4 is 28 and N_2O is 265.

28 Conversion factor: 1 kJ equals 2.78x10-7 MWh.

Step II: Voyages and their geographical location

The addition of the stop identification process enables continuous AIS data representing vessel activity as discrete voyages. Emission data with timestamps falling between the start and end times of a given voyage is pulled by the algorithm. Emission data associated with voyages where vessels depart from a South African port and arrive in international destination ports is used to formulate the international departures inventory. Where a voyage originates in the port of another country and arrives into a South African port, emissions associated with this journey are added to the international arrivals inventory. Where source and destination ports are both South African, voyage emissions are allocated to the domestic inventory, whilst the emissions of voyages that feature no interaction with South Africa's ports remain unused.

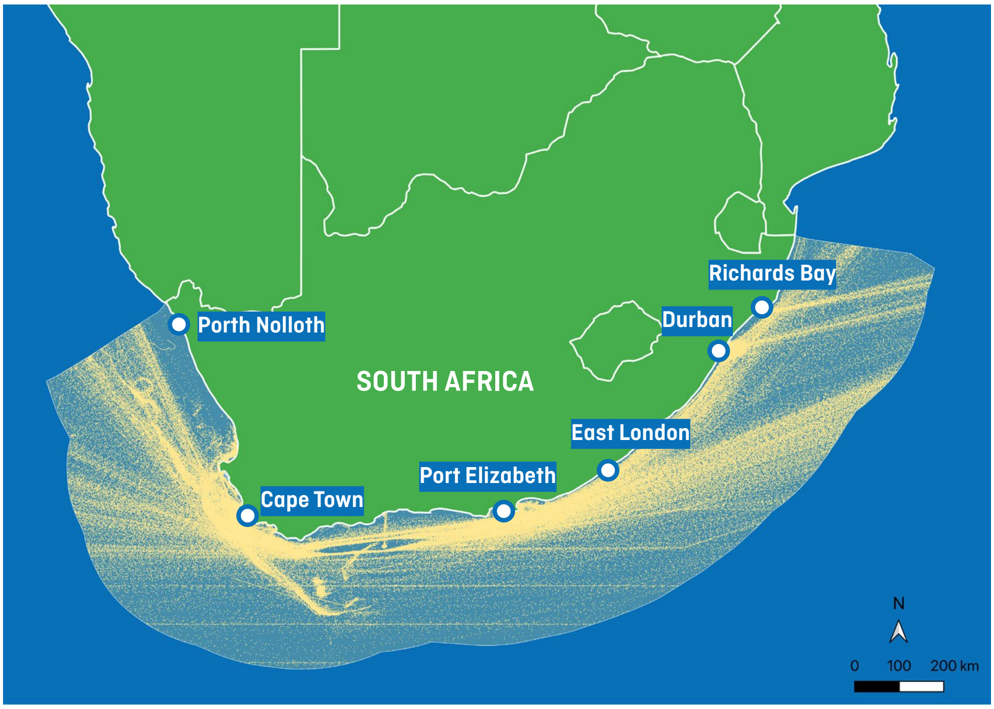
When adding up international departures and arrivals with domestic activities there are two important caveats:

- Not all ships arriving or departing South Africa are fully unloaded or loaded, meaning that part of the cargo contained in any given vessel – and the main reason for the ship to navigate – does not have South Africa as its final or origin destination.
- Taking the first or last voyage leg does not mean that the cargo coming or going from South Africa is fully loaded in the last port before arriving to South Africa or fully unloaded at the first port of call after leaving South Africa. Indeed, different ship types tend to have multiport call voyages which reflects on the fact that 96% of South Africa's imports and exports are transported on ships [104].

However, the aggregation of these different approaches allows for a fuller picture of how shipping activities from, to and within South Africa occur and shows the important role that South Africa has on the transition of this transport sector.

For the geofenced emission inventory approach, the geographical location of all the activities for all 72,000 vessels contained in the 2018 dataset is checked for its position with respect to the national Exclusive Economic Zone (EEZ) and radius around port cities. Using the shapefiles provided by the Flanders Marine Institute [33] for the EEZ approach, activity-related emission data that falls within the region is pooled to form the geofenced inventory whilst outlying data is left out (see Figure 17). A similar method has been applied within the localized emission analysis of port regions whereby geographical coordinates of each port are used to generate a surrounding area of 100 km radius from the port centroid using a Geographical Information System software. Aggregating the hourly activity data that occurs in the immediate area surrounding each port, an indication of the exposure of local populations to pollutants arising from vessel activity can be generated. The method results are summarized in Figure 10, whereby only the activities of vessels captured within 100 km of each port are used.

Figure 17: Polygon representing South Africa's EEZ polygon and the shipping activity inside it during 2018.



Quality assurance and control

After obtaining complete results using the Fourth IMO GHG Study activity-based methodology to calculate emissions , remaining sources of error are limited to the methods of data extraction used to access the study's results and aggregations as explained before. These are summarized in Table 9 with their QA and QC to minimize their impact.

Table 9: Potential sources of error in the SGM for South Africa.

Inventory Method	Potential Issue Identified	QA/QC Procedure
Voyage-based	Inaccuracy in copying data from the Fourth IMO GHG Study	Select 10 rows at random and validate data selected
Voyage-based	Inclusion of data lying outside voyage time windows	Select 10 voyages at random and validate voyage
Geofenced	Inaccuracy in copying Fourth IMO GHG Study data	Plot sample of 10,000 hourly events location against the geographic polygons
Geofenced	Inclusion of data lying outside EEZ	Take sample of 10, 000 hourly events location against the geographic polygons

All checks were completed with no errors detected indicating reliability in the SGM for South Africa presented in the main body of the report.

South Africa's national GHG inventory

South Africa's Ministry of Forestry, Fisheries and the Environment coordinated and compiled the country's National GHG Inventory for 2017. The inventory follows the 2006 IPCC Guidelines. It should be noted that the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories were adopted after the publication of South Africa's national inventory.

More information on the 2006 IPCC Guidelines that the South African government followed to prepare its inventory will be presented below.

2006 IPCC Guidelines: A brief overview

Intergovernmental Panel On Climate Change in its 2006 IPCC Guidelines for National GHG Inventories for the Energy sector and in Chapter 3 sets out a framework of good practice for the quantification of GHG emissions and air pollutants resulting from mobile combustion. Guidelines for water-borne navigation are included, encompassing emissions generated from all forms of water-borne transport (international and domestic), fishing, military and multilateral operations [31]. For shipping the GHG accounted for are CO_2, CH_4 and N_2O.

Methods

There are two tiers (1 and 2) for the evaluation of GHG emissions from water-borne navigation where both tiers apply emission factors to fuel consumption figures independently across all fuel and transport vessel types.

Tier 1 is the simplest approach which can use default or country-specific values. The EF are fuel-type specific for the data the country has. To estimate the annual GHG emissions it is required to multiply the fuel data – by fuel type – by the corresponding EF.

The difference with the Tier 2 approach is that the annual GHG emissions need of more specificity by adding classification modes (e.g. ocean-going ships) and, if available, engine type. Further, if the country has availability to access ship movement data it is recommended that the guidelines from the EMEP/CORINAIR emission inventory guidebook are followed [150]. This reference is recommended to estimate EF for NO_x, CO and NMVOC in both approaches.

For both tiers the shipping category is divided in four distinct classes:

1. *Water-borne Navigation*. This can be further subdivided by domestic and international navigation on the basis of the port departure and arrival.
2. *Fishing*. In this category all emissions from fishing vessels that have refueled in the country need to be considered.
3. *Mobile*. All remaining emission from shipping not covered above (e.g. military).
4. *Multilateral Operations*. Emissions produced in multilateral operations (e.g. fuel delivered to the military in the country and delivered to the military of another country).

Fugitive emissions from transport are declared under the category "Fugitive emissions" but they are assumed to be negligible when the ship is navigating.

South Africa GHG inventory report for its water-borne emission estimation used a Tier 1 approach.

Emission factors

The guidelines gives for CO_2 EF a range of acceptable values depending on the type of fuel based. The guidelines recognise 10 different fuels for the water-borne transport.

For CH_4 and N_2O EF under a Tier 1 method the values are given as 7 kg/TJ and 2 kg/TJ respectively. However, these factors are taken from HFO being consumed in diesel engines (no engine speed is stated) and for that reason have a large recommended variation (i.e. +50% for CH4 and from -40% to 140% for N2O).

For a Tier 2 approach the EF should be based, if possible, by the country's testing of fuel and combustion engines and this should be recorded in accordance to EMEP/CORINAIR emission inventory guidebook [150].

In the case of the water-borne transport EF, South Africa used the default values recommended by IPCC.

Activity data selection

The IPCC guidelines offer a wide range of source data to obtain an estimation of the fuel being used for water-borne activity and for what purpose is being used (e.g. domestic or international navigation). However, the selection of the datasets is up to the country and its own circumstances which is recognised to produce results with different levels of accuracy. The IPCC list suggests National energy statistics, surveys of fuel suppliers (i.e. fuel sales), marine authorities and fishing companies to the IMO databases and Lloyd's Register ship movement data, among others. The guidelines recognize that to get a better data resolution of the fuel being used the inventories will need a combination of the recommended databases.

The guidelines recognizes that there are different engine types and fuels being used onboard any given vessel but states that this level of granularity is difficult to obtain. To solve this the guidelines give general statistics of average fuel consumption in percentage per engine type (i.e. main or auxiliary engines) and ship type. As well, the chapter gives average daily fuel consumption and linear regressions to estimate fuel consumption at full power (i.e. 100% the Maximum Continuous Rating (MCR) of an engine) against the ship's Gross Tonnage. This is given for 13 different ship types.

The South African Energy category data providers were Department of Mineral Resources, Eskom, PetroSA, Sasol, South African Petroleum Industry Association and refineries. From Department of Forestry, Fisheries and Environment [32] the data provider for the *Water-borne navigation fuel consumption* is empty.

Completeness and uncertainty

The guidelines depend on the country capacity of accounting for fuel being consumed by shipping. The sources of potential incomplete estimation of fuel used and emissions are:

- Misallocation of navigation emission into another source category.
- When military data is confidential.
- Misallocation between domestic and international voyages.

The guidelines present the difficulty of distinguishing between domestic and international navigation as the highest source of uncertainty in building the water-borne emission inventories. For complete survey data the estimated uncertainty is assumed to be +5% while for incomplete ones it could be as high as +50%. Still, it is recognized that uncertainty could be much larger from country to country. However, as data availability improves, such as in the case of AIS data, the uncertainty levels for this sector will reduce.

South Africa's National GHG Inventory Report [32] recounted that the estimated uncertainty for the domestic navigation is +5.83%, of which the largest source is the activity data at +5.00%. This uncertainty contributes to 0.01% of the total annual GHG inventory. Additionally, the government of South Africa reported to the UN Framework Convention on Climate Change that the main challenge in the compilation of their national inventory was the availability of accurate activity data [28].

Quality assurance and control

The guidelines recommend four different approaches to assure the QA and QC of the water-borne emission inventories but this will depend on the country's capacity to take these steps:

1. Compare emissions using alternative approaches
2. Review of EF.
3. QA and QC of activity data on fuel usage.
4. External review.

For the case of the South Africa's emission inventories the QA and QC were performed by experts on emission inventories with regular checks into the integrity and completeness of the datasets, detection of errors and their correction, and comparison against other studies and research [28][32]. On the QA front, the emissions were reviewed by experts in the field and the general public reviews. Verification is embedded into the inventory process but until the latest report there is not a formal verification process but one is under development.

Reporting

Water-borne emissions are reported in different categories depending on the activity that the ship is doing:

1. *Water-borne Navigation*. Domestic navigation is reported and counts towards the national GHG inventory. International navigation is reported separately and does not count towards the national GHG inventory
2. *Fishing*. It is reported under the Agriculture/Forestry/Fishing category in the Energy class.
3. *Mobile*. In particular to military should be presented for transparency purposes.
4. *Multilateral Operations*. They are not mentioned how to be reported.

The IPCC guidelines recommend as good practice to present the source of the fuel and other data used, method to differentiate domestic and international navigation, emission factors used and their associated references and the uncertainty or sensitivity analysis of the data and assumptions taken.

Emission inventories comparisons

Estimation of GHG emissions per sector support policy processes and decision-making for viable mitigation responses from governments that are in consonance with the UN Framework Convention on Climate Change and its Kyoto Protocol and Paris Agreement's goals. The IPCC Guidelines, assist countries in producing transparent, complete, comparable and consistent over time inventories that do not overestimate or underestimate national GHG emissions.

The SGM developed in this report provides a novel approach to estimate, in a comprehensive matter, the maritime GHG and air pollution emissions of any country. In general, the SGM for South Africa and South Africa's National GHG Inventory need to be seen as complementary. South Africa's National GHG Inventory captures the complex interaction between its economic activities, society and the environment. Balancing the level of granularity between categories due to data availability, modeling, capacity and statistic access is a complex endeavor that has the aim of establishing the country's full picture in a transparent way. On the other hand, the emission inventory provided in this report based on the Fourth IMO GHG Study considers in great detail the spatial and technological differences of the maritime sector during 2018. Further, this report proposed four different methodologies of aggregating the data relevant to South Africa with the purpose of exploring the implications of shipping to, from and within the country and establish their role in the transition of the maritime sector.

The differences between the estimation of GHG come from the way they are reported; the granularity of the fuel used databases; how data is aggregated; assumptions taken; the fact that the latest South African GHG inventory was for 2017 while the activity data used in this report was from 2018; and the SGM considered only ships above 100 gross tonnage, leaving outside the small boat fleet[29] which tend to be activity within the national waters.

Still, some of the elements between the general inventory approaches can be compared to understand the main causes between both inventories differences which for the *water-borne domestic navigation* – without accounting for fishing activity – stood at 87.4% or 315 kt CO2e.

Emission factors

As reported by South Africa's National GHG Inventory for water-borne transport, default Tier 1 EF were used. It is important to mention that methanol EF are not presented in this subsection since it is a fuel not considered by the IPCC 2006 Guidelines for water-borne navigation.

Carbon dioxide

Table 10 presents the CO_2 EF used in South Africa's National GHG Inventory and the ones used in the SGM based on the Fourth IMO GHG Study. After division by the fuel's LHV and conversion to the same unit, the percentage difference between CO_2 EF presented in the two documents has been evaluated with a maximum of 1.33% across fuel types observed. Use of similar emission factors are important to the accurate quantification of GHG generation and give confidence that the results

29 Typically with a length not larger than 25 m depending on vessel construction.

derived in the SGM to generate the emission inventories presented are reliable and representative.

Table 10: Comparison of CO_2 emission factors contained in the SGM and the 2006 IPCC Guidelines for National GHG inventories.

Fuel	IMO Default EF (kg CO_2/ kg fuel)	Converted IMO EF in IPCC-aligned units (kg CO_2/TJ)	IPCC 2006 Default EF (kg CO_2/TJ)	Difference (%)
HFO	3.114	77,463	77,400	-0.08
MDO	3.206	75,082	74,100	-1.33
LNG	2.750	55,000	54,300	-1.27

Methane

Since the Fourth IMO GHG, and hence the SGM, recognizes that methane emissions are different under different fuels, engine technologies and engine loading giving a wide range of values. For the 2006 IPCC Guidelines the methane EF is given as a range but smaller to the SGM. For that reason, the methane EFs will be given in a range to consider all the methane EF (see Table 11).

Table 11: Comparison of CH_4 emission factors contained in the SGM and the 2006 IPCC guidelines for National GHG inventories. It is important to mention that the SGM CH_4 EF are given for design engine loads (i.E. 75% Of the MCR).

Fourth IMO GHG Study EF (g CH_4 /kWh)	Converted IMO EF in IPCC-aligned units (kg CO_4/TJ)	IPCC 2006 Default EF (kg CH_4 /TJ)
0.002 - 5.500	0.560 - 1,527.780	3.500 - 10.500

The large differences seen in the EF between them has to do with two main reasons:

1. The CH_4 EF used in the IPCC 2006 guidelines are based on the numbers given by Lloyd's Register [151] for only diesel engines using HFO while the Fourth IMO GHG Study covers a wider range of engines and fuels. Normally, diesel engines tend to be located in the lower end of the CH_4 EF scale. For the Fourth IMO GHG Study a diesel engine consuming HFO will have an EF of 2.8 kg CH_4/TJ. Still, there is a difference of between of 20% between the EF – using the lowest value given by IPCC. This difference may be due to the age of the literature used for the IPCC 2006 Guidelines. In the past 30 years, maritime diesel engines have improved with better combustion efficiency thanks to the introduction of fuel injection and exhaust gas actuating systems among others [152].
2. The introduction of liquified natural gas (LNG) as fuel for shipping has existed since LNG has been carried in vessels. But in the past, this type of vessel used the boil-off gas from the tank to burn it inside a boiler to produce steam that in turn powered the ship steam turbines. However, since 2010 LNG as fuel has started to enter into the maritime market for all ship types and sizes. Natural gas is mainly composed by CH_4 and when injected into an internal combustion engine part of it may not get combusted, increasing the emission of this GHG. Depending on the LNG engine technology the CH_4 EF could be between 55.56 and 1,574.78 kg CH_4/TJ.

If LNG becomes a more prominent fuel in the shipping sector, it will be important to update the IPCC 2006 CH4 EF to account for this powerful GHG.

Nitrous oxide

Table 12 presents the N_2O EF used in South Africa's National GHG Inventory – given as a range – and the ones derived from the Fourth IMO GHG Study for the SGM. One important difference from the SGM EF is that it recognizes the change of the EF due to engine loading – mainly loads below 20% MCR, engine technology and fuel.

Table 12: Comparison of eEFf contained in the SGM study and the 2006 IPCC Guidelines for National GHG inventories. It is important to mention that the SGM N_2O EF is given for design engine loads (i.E. 75% Of the MCR) .

Fourth IMO GHG Study EF (g N_2O /kWh)	Converted IMO EF in IPCC-aligned units (kg N_2O/TJ)	IPCC 2006 Default EF (kg N_2O/TJ)
0.02 - 0.05	5.56 - 13.11	1.2 - 4.8

The N_2O EF differences are significant between the two approaches. The probable reason for this difference could come from a better understanding in the past three decades on the formation of N_2O in traditional diesel engines. Yoo et al. [153] showed in their experimental study onboard a vessel consuming MDO that the N_2O EF ranged between 0.03 and 0.07 g N_2O/kWh. The highest N_2O EF from the Fourth IMO GHG came from gas and steam turbines.

Black carbon

The IPCC 2006 guidelines do not account for BC as a GHG while the SGM, following the Fourth GHG IMO Study, considers it with a Global Warming Potential over a 100-year period of 900 [8][34]. For all the annual emission inventories produced by the SGM, BC was among the second most powerful maritime GHG with about 8.1% of the total CO_2e for South Africa's the domestic navigation.

Sensitivity analysis

The aim of this section is to estimate what are the impacts on the GHG inventories due to the different EF used between South Africa's GHG inventory and the SGM for South Africa. To do that, the amount of fuel consumed in 2018 by domestic shipping – excluding fishing – from the SGM will be used. Further, a projection using the year-on-year growth of the *domestic navigation subcategory* of the GHG emissions given in South Africa's inventory will be done to match it to the year 2018.

South Africa reported for the domestic *water-borne navigation* GHG emission in 2000 about 224.00 kt of CO_2e while for 2017 358.47 kt CO_2e [28]. This gives an average year-on-year GHG growth of 3.5% - assuming a linear relationship. Using this growth the potential GHG emission for domestic navigation in 2018 was about 371.16 kt of CO_2e. For the 2018 GHG emission coming from the Fourth IMO GHG Study the domestic navigation without counting fishing was about 674.72 kt of CO_2e.

The estimated annual fuel consumption during 2018 from the SGM for South Africa's domestic activity – excluding fishing – was 164.50 kt HFO, 30.60 kt MDO and 0.00 kt LNG. Converting these fuel consumptions into energy using the fuels' LHV[30] gives 6,612.90 TJ for HFO and 1,306.60 TJ for MDO. Now, by using the default and middle EF values from the IPCC guidelines (and not counting BC as a GHG), the annual GHG emission due to domestic navigation is 608.66 kt CO_2, 0.07 kt CH_4 and 0.02 kt N_2O. Converting these quantities to CO_2e gives a total of 615.92 kt CO_2e. This is a difference with the projected South African annual GHG emissions of 64.0% and just -0.6% against the SGM estimation without accounting for the effect of BC as a GHG (i.e. 619.66 kt CO_2e).

From the previous analysis done it can be said that the main root cause of the difference between the National GHG Inventory and the SGM are:

- The National Inventory's *Water-borne navigation fuel consumption* data source is left empty [28][32]. Normally, as seen from other countries' National Inventories, the maritime activity data is based on annual fuel sales of the domestic fleet [35][36]. However, not being able to know the data source for the National Inventory does not allow to observed more granular differences between the fuel consumption databases.
- The method used in SGM is an activity-based method so it includes emissions from domestic voyages of international ships (e.g. from one South African port to another) which would not be captured in the statistics of fuel sales for domestic use. This explains why a larger total emission is found from the SGM than is reported in the National Inventory. Finding a discrepancy in GHG when calculating with the two methods is common and has occurred in other countries (e.g. UK) which have since switched to use the activity based method [37].
- Differences between National Inventories data based on fuel sales to international shipping and activity-based methods also have explainable differences. Fuel sales are only recorded if a ship bunkers (takes on fuel) in South Africa. In practice ships calling at South Africa may not need to bunker (some ships have fuel storage for up to three months so do not refuel for each voyage) and will purchase fuel in South Africa only if its competitive to fuel available at other port calls they will make. The SGM captures all shipping activity regardless of whether it is associated with a purchase of fuel. The statistics estimated here suggest that only a portion of the fuel associated with South Africa's shipping activity is purchased in South Africa and so the activity-based

30 For HFO the LHV used was 40.2 TJ/kt, for MDO 42.7 TJ/kt and for LNG 48.0 TJ/kt [8].

method is helpful for giving an estimated of the potential bunker sales market - should South Africa want to expand its opportunity, especially for SZEF.

- Fuel sale databases can capture the fuel being consumed of the small boat fleet which tend not to have onboard tracking systems (e.g. AIS transponder). This is a limitation from the SGM but which points to the SGM results on domestic shipping GHG and air pollution to be a conservative estimation.
- While the EF differences are large for CH_4 and N_2O, these compounds account for a small share of the total GHG emission. Indeed, CO_2 accounts for 98.9% of the 2018 GHG emissions and the CO_2 EF for HFO and MDO has a difference of -0.08% and -1.33% respectively to the IPCC recommended EF. This explains in its majority the -0.6% observed difference since the majority of the fuel consumed by South Africa's domestic fleet in 2018 was HFO.
- The SGM considers BC as GHG which after CO_2 is the most impactful gas in the total GHG quantification. But this GHG has only an 8.1% influence on the total GHG domestic emission in 2018 and still it is considered that the SGM is on the conservative spectrum on the national GHG emissions.

Under this light, it can be assumed that the differences observed in GHG emissions between both emission inventories for *international water-borne navigation* and *fishing* would be mainly caused by the same root cause seen for domestic shipping.

The interested reader can find further detail on this report maritime activity data in Faber et al. [8] subsections 2.2.2 – 2.2.4 with general areas of improvement in Appendix A.

A source of uncertainty in this short sensitivity analysis is the fuel's LHV used since the IPCC 2006 guidelines does not give these values for the maritime fuels. However, this is thought to have a minimal impact on the annual GHG inventories.

About the Getting to Zero Coalition

The Getting to Zero Coalition is an industry-led platform for collaboration that brings together leading stakeholders from across the maritime and fuels value chains with the financial sector and other committed to making commercially viable zero emission vessels a scalable reality by 2030.

Learn more at:
www.globalmaritimeforum.org/getting-to-zero-coalition