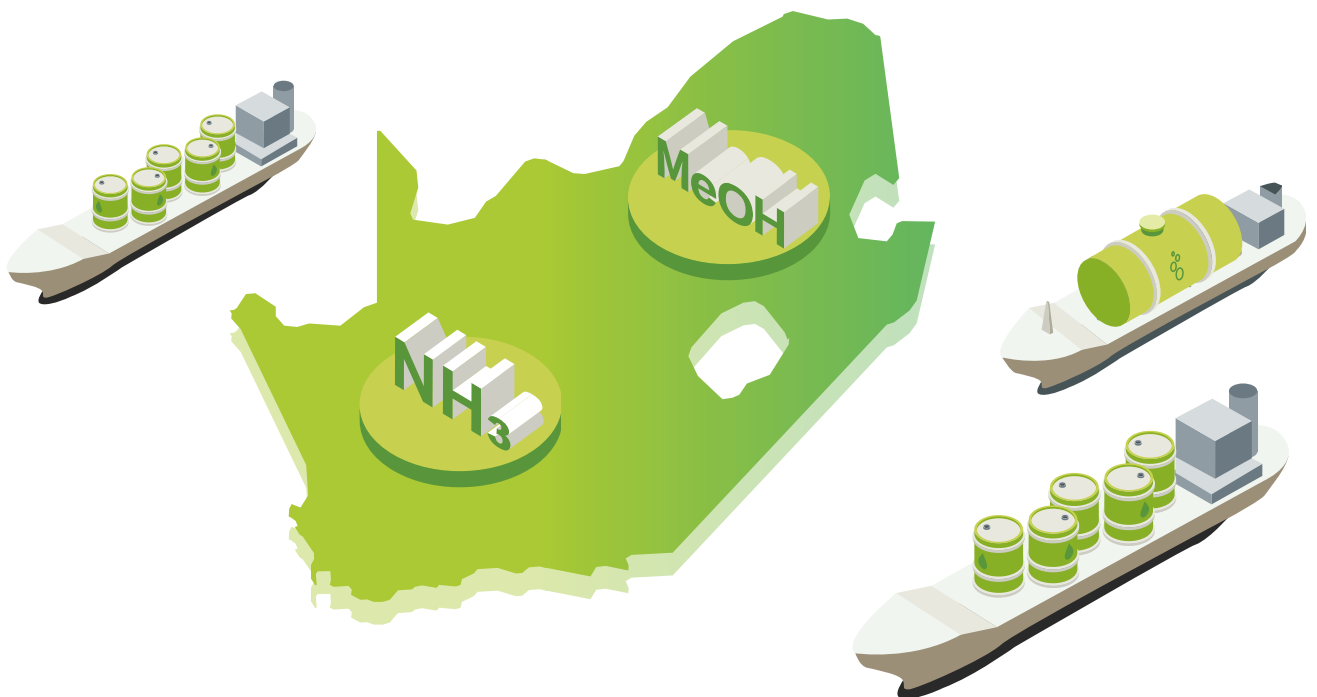


Implications of the EU Carbon Border Adjustment Mechanism (CBAM) for Hydrogen and Power-to-X Development in South Africa

Case Study #1: CBAM and Hydrogen Carrier
Choice for Exports from South Africa to the EU



IMPRINT

As a federally owned enterprise, GIZ supports the German Government in achieving its objectives in the field of international cooperation for sustainable development.

Published by:

Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

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Bonn and Eschborn, Germany

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Acknowledgement:

The International PtX Hub is implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH on behalf of the German Federal Ministry for the Environment, Climate Action, Nature Conservation and Nuclear Safety (BMUKN). Financed by the International Climate Initiative (Internationale Klimaschutzinitiative, IKI), the International PtX Hub is a contribution to the German National Hydrogen Strategy of 2020 and represents one of the four pillars of the BMUV's PtX action programme initiated in 2019. The opinions and recommendations expressed do not necessarily reflect the positions of the commissioning institutions or the implementing agency.

Pretoria, May 2026

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Abbreviations

BMUKN	German Federal Ministry for the Environment, Climate Action, Nature Conservation and Nuclear Safety
BMUV	Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection
CBAM	Carbon Border Adjustment Mechanism
CCS	Carbon Capture and Storage
CCUS	Carbon Capture, Utilisation and Storage
CID	Clean Industrial Deal
CN	Combined Nomenclature
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
DBT	Dibenzyltoluene
EEA	European Economic Area
EU	European Union
EU ETS	EU Emissions Trading System
FID	Final Investment Decision
GH ₂	Green Hydrogen
GHG	Greenhouse Gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GJ	Gigajoule
H ₂	Hydrogen
HS	Harmonised System (codes)
IEA	International Energy Agency
IKI	Internationale Klimaschutzinitiative (International Climate Initiative)
ITC	International Trade Centre

LNG	Liquefied Natural Gas
LOHC / LOHCs	Liquid Organic Hydrogen Carrier(s)
MCH	Methylcyclohexane
MRV	Monitoring, Reporting, and Verification
Mt	Million tonne
Mtoe	Million tonnes of oil equivalent
NH ₃	Ammonia
OECD	Organisation for Economic Co-operation and Development
PPAs	Power Purchase Agreements
PtX	Power-to-X
RE	Renewable Energy
RED	Renewable Energy Directive
RES	Renewable Energy Sources
RFNBO / RFNBOs	Renewable Fuels of Non-Biological Origin
RH ₂	Renewable Hydrogen
SAF	Sustainable Aviation Fuel

Executive Summary

Green hydrogen (GH₂), hydrogen produced with renewable energy (RE), and Power-to-X (PtX) technologies will play a vital role in the transition to a low-carbon economy, especially in hard-to-abate sectors. Many regions, including Europe, lack the RE resources to meet local PtX demand fully. South Africa's extensive RE resources, rapidly increasing RE production, and established industrial base position it well as a future globally relevant exporter of PtX.

The EU Carbon Border Adjustment Mechanism (CBAM), a climate protection measure under the EU Green Deal, applies a harmonised carbon price on emissions of carbon intensive imports of goods under the CBAM scope to the EU to ensure that imported products face equivalent carbon costs to those produced within the EU under the EU domestic carbon market (EU-ETS). Although the EU CBAM applies a harmonised carbon price on goods imported into the EU that fall within the CBAM's scope, different hydrogen carriers and derivatives will be affected in distinct ways under the CBAM. These differences are rooted in various factors such as greenhouse gas (GHG) intensity of production, CBAM product scope and CBAM emissions scope (differences in the type of emissions to which the carbon cost applies).

The CBAM currently only covers CO₂ emissions embedded in imported H₂ and ammonia during production. H₂ is defined as a precursor product to ammonia, and emissions embedded in H₂ thus need to be included in the embedded emissions of ammonia. At present and for the CBAM definitive period, only direct emissions from H₂ production are covered by the CBAM, while both direct CO₂ emissions and indirect CO₂ emissions from electricity used to produce ammonia incur CBAM costs.

Other derivatives of H₂, including methanol, Liquid Organic Hydrogen Carriers (LOHCs) and synthetic hydrocarbon fuels, like Sustainable Aviation Fuelsustainable Aviation Fuel (SAF), are not currently within the scope of CBAM. This may change in the future.

The CBAM rewards the use of Carbon Capture and Storage (CCS) technologies to produce blue hydrogen and ammonia, and sequestered carbon will not be counted as carbon embedded in products if in compliance with the CBAM regulatory requirements for CCS. The use of CCS to produce low-carbon hydrogen, however, is not currently being explored in South Africa, which reduces the extent to which CBAM could favour imports into the EU of low-carbon hydrogen or low-carbon hydrogen-based carriers produced with natural gas and CCS vs GH₂.

The fact that methanol, synthetic hydrocarbon fuels and LOHCs will not incur CBAM costs on embedded emissions, while H₂ and ammonia will, could potentially affect the choice of PtX product to export from South Africa to the EU. In practice, however, there are several reasons why this is unlikely as analysed and explained in this case study.

Ammonia is currently the most-favoured PtX export product internationally by some margin. This is due to the many applications where ammonia can be used directly (thereby avoiding the costs and energy penalties associated with the conversion and reconversion of H₂ relevant to other carriers), its technological maturity, extensive infrastructure to facilitate trade already in place, and the need for a source of sustainable carbon during its production being avoided. These factors also hold in South Africa. The country has significant expertise in producing and transporting ammonia (compared to, for example, LOHCs, where technological readiness is low), and extensive port infrastructure is in place to facilitate its trade. Significant local demand for methanol and SAF to serve maritime and aviation export

markets, coupled with limited supplies of sustainable biomass, makes it unlikely that these products will be used as export GH₂ carriers.

Furthermore, South Africa's fast-evolving renewable energy market enables long-term supplies of dedicated and increasingly cheap zero-carbon electricity to be secured. This not only enhances the price competitiveness of local GH₂, but also mitigates against input cost inflation risks, simplifies regulatory compliance, and removes the risk of high grid carbon-intensity hindering access to lucrative EU GH₂ market development mechanisms. For these reasons, local PtX products for export will be produced using 100% renewable energy in accordance with EU regulatory requirements. These products will thus generate zero or close to zero GHG emissions and will have no embedded production emissions to which CBAM costs could be applied. It is therefore irrelevant from a cost perspective and leaving aside monitoring and reporting obligations, whether PtX export products are included in the CBAM scope or not, since even if they are covered, they will not be burdened by additional CBAM costs. The CBAM will therefore not influence the choice of carriers used for the export of GH₂ from South Africa to the EU. While some compliance costs will have to be incurred for products that are covered by CBAM (monitoring, reporting and potentially verification), like ammonia, these costs will be insignificant compared to the value of GH₂ export projects.

It should be noted, however, that an expansion of the CBAM scope to cover more H₂ carriers, and to include indirect emissions in the calculation of embedded emissions for more carriers, could help to increase the cost competitiveness of PtX exports from South Africa to the EU market relative to more carbon-intensive alternatives from the EU and elsewhere.

1 Introduction

Green hydrogen (GH₂), produced with renewable energy (RE) and Power-to-X (PtX) technologies, will play a vital role in the transition to a low-carbon economy, especially in hard-to-abate sectors. PtX refers to a range of applications where renewable electricity is converted into GH₂ via electrolysis. This hydrogen can then be used directly for energy recovery or transformed into various derivative products such as ammonia, methanol, and synthetic hydrocarbons. These carriers could potentially enable both the storage and transport of hydrogen, as well as serve as key feedstocks and fuels across a range of industrial and energy applications.

South Africa's extensive renewable energy resources, which are a critical input to its production, coupled with its established industrial base, position it well to develop as a globally relevant exporter of GH₂ and PtX derivatives. To understand how its green hydrogen industry might evolve, it is important to keep an eye on the dynamic regulatory landscape, especially the European Union's Carbon Border Adjustment Mechanism (CBAM), a key climate protection measure under the EU Green Deal and the Clean Industrial Deal. The CBAM aims to create a more consistent application of carbon pricing by requiring a selection of imported carbon intensive goods into the EU to pay the same carbon cost as goods produced within the EU under the EU-ETS, thereby limiting carbon leakage (Ward, 2023). The CBAM Regulation was adopted in May 2023, with a transitional phase from October 2023 to December 2025, and a "definitive period" with financial implications which started in January 2026.

Although the EU-CBAM applies a harmonised carbon cost on goods imported into the EU that fall within the CBAM's scope, different hydrogen carriers and products will be affected in distinct ways under the CBAM, as is explained in this case study. These differences are rooted in various factors such as GHG intensity of production, CBAM product scope and differences in the scope of emissions to which the carbon cost applies.

What is the EU CBAM?

- CBAM is a climate protection measure and an important element of the EU Green Deal to help EU member states meet their commitments under the Paris Agreement.
- CBAM aims to prevent the relocation of production facilities – and thus greenhouse gas (GHG) emissions – to jurisdictions with less stringent climate policies (carbon leakage).
- CBAM ensures producers inside and outside the EU are subject to similar carbon costs on products sold within the EU.
- CBAM is based on the „polluter pays principle“. Carbon pricing internalises the external effects of greenhouse gas emissions.
- The Reporting declarant (EU importer or Indirect Custom Representative should the importer be based outside the EU) is subject to reporting and financial obligations under the CBAM.

- As per recent legislative amendments (Omnibus package) CBAM costs for goods other than electricity as a CBAM good can be calculated based on default emissions values for products (published by the European Commission) or based on the actual embedded emissions in products, calculated based on information provided by installations in third countries and verified by accredited verifiers.
- CBAM is being introduced gradually. The previous transitional phase (reporting was mandatory but no CBAM costs were payable) allowed companies to develop monitoring and reporting systems before costs will be applied to emissions embedded in CBAM goods and under CBAM scope.
- Carbon prices effectively paid in third countries can be deducted from CBAM costs payable.
- The distribution of CBAM costs among consumers, importers, exporters, and producers will depend on the dynamics within the markets for the individual products on which the CBAM costs are applied. Several studies point out that ultimately CBAM costs will be borne by the EU consumer.
- As part of the Omnibus package of legislative measures to reduce the CBAM's administrative burden without compromising its climate protection objectives were adopted.
- In December 2025, the European Commission adopted a set of Delegated and Implementing acts defining the rules that will govern the definitive period.
- In December 2025, the European Commission also published a legislative proposal to amend the CBAM regulation with a focus on anti-circumvention practices and a down-stream extension proposal.

This case study examines the implications of CBAM for South Africa's future GH₂ and PtX industries. It begins by providing an overview of different hydrogen carriers and products, including an analysis of technological readiness, transport considerations, infrastructure needs, and EU market dynamics. It then analyses the likely impact of the CBAM on the choice of GH₂ carriers from South Africa to the EU by considering the scope of CBAM coverage, the rules for defining green hydrogen and PtX in the European market and considering the potential impact of the CBAM on the cost of different carriers entering the EU market from South Africa. Finally, it presents a set of conclusions. It is noted that a separate case study, prepared under this same project, explores the implications of CBAM for the use of GH₂ in the production of iron and steel for export to Europe.

2

Overview of hydrogen carriers and products

Hydrogen has various applications in its molecular form; however, storing and transporting it present significant challenges. These include high flammability, low volumetric energy density, and the small molecular size of hydrogen, which increases the risk of leaks (Ocko and Hamburg, 2022). As a result, specialised materials are required for constructing storage and transport infrastructure, and hydrogen must often be maintained at high pressures and/or low temperatures. Hydrogen can be stored and transported either as a gas or as a liquid. Storing and transporting gaseous hydrogen is generally less expensive and complex compared to liquid hydrogen, but the low density of the gas necessitates larger storage volumes for the same tonnage of liquid hydrogen (Borsboom-Hanson et al., 2022). Both the pressurisation of hydrogen gas and the liquefaction process for shipping are energy- and capital-intensive. These factors contribute to the high costs and limited feasibility of transporting hydrogen in either form, particularly over very long distances (European Commission Joint Research Centre, 2021), making the transport of hydrogen in either liquid or gaseous form unviable for exports from South Africa to Europe. As such, these options are not covered further in this study.

Various alternative methods for storing and transporting hydrogen are being considered to address these challenges. These include converting hydrogen into ammonia, methanol, and synthetic hydrocarbons, as well as incorporating it into Liquid Organic Hydrogen Carriers (LOHC). Not only are these forms easier to store and transport, but they may also utilise existing infrastructure (Kass et al., 2023). Moreover, carrier products can often be used directly in current end-use applications with little or no additional investment. However, converting hydrogen into carrier products involves extra costs, energy inputs, and potentially increased feedstock requirements (IEA, 2024). Consequently, the choice of carrier generally depends on the intended end use of the hydrogen.

This section provides an overview of various hydrogen carriers and products (derivatives), followed by an assessment of South Africa's technological readiness, strengths, and weaknesses related to each. The markets for different carriers in the EU are also discussed.

2.1 Overview of hydrogen carriers and South Africa's technological readiness

The four leading GH_2 carriers and derivatives being considered globally are ammonia, methanol, synthetic hydrocarbons, and LOHCs. In this section, a brief overview of each of these carriers is presented, including applications, current experience in South Africa, and potential future production and market considerations. This overview provides a context against which the remainder of the case study is presented.

2.1.1 Ammonia

Ammonia is widely used globally in a range of applications, including in agriculture, industry, manufacturing, metal treating, petroleum, and refrigeration. Around three-quarters of global production is currently from natural gas, with the remainder being produced from coal. Ammonia produced using GH_2 could readily act as a replacement for fossil ammonia. It could also be used in further applications, including storage and transport of chemical energy, as a transport fuel, and to store thermal energy. Ammonia requires an investment of energy for production, potentially representing between 7% and 18% of the energy contained in the hydrogen used in its manufacture.

Ammonia has long been produced in South Africa by Sasol at both its Secunda and Sasolburg plants, indicating a strong capacity in this sector within the country. It is manufactured at Secunda as a co-product of coal gasification. In contrast, production at Sasolburg occurs via the traditional Haber-Bosch process, which would be used in green ammonia production. The Sasolburg facility could thus be relatively easily converted to produce green ammonia, provided that GH_2 can be generated on site and renewable energy is available for air separation to supply the green nitrogen needed for production. While efforts are already underway to explore the implications of repurposing this facility, an increase in ammonia production capacity for export would likely occur at the coast, where seawater is available for GH_2 production, renewable energy sources are accessible, and port infrastructure exists for exporting the product.

2.1.2 Methanol

Methanol can be used directly as an energy carrier in the blending or substitution of petrol and diesel, to displace liquified petroleum gas and in fuel cells to produce electricity. It is also used widely in the petrochemical industry, including to produce fuels (e.g. biodiesel) and fuel additives, building materials, clothing and textiles, and pharmaceuticals.

As with ammonia, current global production is primarily from fossil fuels, with about two-thirds being from natural gas and the remainder from coal (Methanol Institute, 2023; Sollai et al., 2023). Green methanol can either be produced from GH_2 combined with a sustainable source of carbon (e-methanol), or directly from biological sources such as forestry and agricultural waste, biogas, sewage, and black liquor from pulp and paper production (bio-methanol). The key challenge with at-scale production of GH_2 -based methanol (green methanol), specially if compliance with EU regulatory standards is sought, is the requirement for a sustainable source of carbon for its manufacture.

The use of e-methanol as a bunker fuel replacement for maritime fuel is likely to be the main application of methanol from the green hydrogen industry in the near term. While methanol has a comparable energy density to ammonia, which is the other possible option for use as a sustainable bunker fuel, it is less corrosive and toxic than ammonia (Uhorakeye, Kopp-Moini and Cohen, 2023).

Methanol is also currently produced at Sasolburg as one of the outputs from the Fischer-Tropsch process, and is used in various chemical applications. Production of methanol via the other production routes, however, which are more suited to pivoting to use green hydrogen, are not as well established in the country and technology readiness for green methanol synthesis from GH_2 has been indicated to be low. A further critical challenge to local green methanol production is the availability of sustainable carbon for its production (Uhorakeye, Kopp-Moini and Cohen, 2023). Significant demand for sustainable carbon to supply the local aviation and maritime industries is projected for green methanol and Sustainable Aviation Fuel (including serving international demand from local ports and airports (Cohen, Cloete and Uhorakeye, 2023), and it is unlikely that sufficient sustainable carbon will be available to also support exports of methanol purely as a GH_2 export carrier. Together, these factors may ultimately make it a poor contender for export to Europe.

2.1.3 Synthetic hydrocarbon fuels

Other fuels that can be made from GH_2 (in addition to green methanol and green ammonia, which can act as fuels) include petrol, diesel, and kerosene (aviation fuel) produced via the Fischer-Tropsch process. Methane is also produced as a synthetic fuel – either as a (usually undesirable) by-product of Fischer-Tropsch or via other production processes.

Demand for petrol and diesel is projected to decline over time as transportation is increasingly electrified to meet climate targets. However, aviation remains a hard-to-abate sector, with Sustainable Aviation Fuel produced via Fischer-Tropsch being one potential decarbonisation option that is available to this industry.

South Africa is a global leader in the Fischer-Tropsch production process with established production infrastructure that draws on coal and gas as feedstocks. A pivot to the production of renewable synthetic fuels would require not only a supply of GH_2 but also a source of sustainable carbon, given that carbon is a building block of these fuels.

Given volumes required locally, the limited availability of sustainable biomass (which will limit production potential), and transport costs, it is likely that Sustainable Aviation Fuel made in South Africa will not be exported to Europe but will instead be used for refuelling locally for domestic and international flights ([see section 2.1.2](#)). As such, synthetic fuels are not considered further as a hydrogen carrier/product for export to Europe in this study.

2.1.4 LOHCs

Liquid Organic Hydrogen Carriers (LOHCs) bind hydrogen to another organic molecule to facilitate easier transport. When they reach their destination, the hydrogen is then separated from the molecule. Two key LOHC options are currently under investigation (IEA, 2023):

- Methylcyclohexane (MCH), which represents a relatively low-cost option for transporting hydrogen, although toluene, the carrier molecule, is toxic and requires careful handling.
- Dibenzyltoluene (DBT), which is currently significantly more expensive. However, it is less toxic, and scale-up of production could reduce costs over time.

LOHC technology is currently at a pre-commercial demonstration level, with development being ongoing (EPO and IEA, 2023). The implication is thus that at this stage there is also no experience in this area in South Africa either.

2.2 Transport considerations

The cost and practicality of transport options for the different carriers will play a critical part in determining which carriers are best suited for the export of GH_2 from South Africa to Europe. The two broad categories of transport options for hydrogen carriers and products are identified, being continuous (pipelines) and batch (cargo ships, trucks, rail). Factors including the nature of the carrier, available infrastructure, transport distance, conversion requirements, and energy prices determine the relative costs of the different transport options. The following carrier-specific observations are noted.

Ammonia is relatively easy to store and transport because of its low vapour pressure and high boiling point (Chatterjee, Parsapur and Huang, 2021), with transport being well-established globally due to large quantities historically being traded, primarily for use in the fertiliser industry. There are, however, several challenges, including its toxicity, explosiveness, and corrosivity. These are not, however, particular to green ammonia and apply equally to fossil-based ammonia. As with other PtX products, in most cases it makes sense to use ammonia at the destination as a feedstock for further production, including fertilisers. It will typically not make sense to reconvert ammonia back into hydrogen at its destination given a significant energy penalty is incurred for reconversion (IEA, 2023). The energy losses along the ammonia value chain are illustrated in Figure 1, showing the significant penalty of cracking ammonia back into hydrogen.

Figure 1 Energy losses across the ammonia value chain (IEA, 2023)



H₂ export carrier infrastructure requirements

Port and adjacent infrastructure will need to be expanded to facilitate the export and import of GH₂ carriers, if the scales of production required to support the projected European demand are achieved. Infrastructure requirements may include bunkering, storage, conversion infrastructure, and multimodal refuelling stations¹. In some European ports, existing import infrastructure could be used for liquid carriers, although the capacity for green methanol and green ammonia imports may need expansion. In other locations, new port capacity will need to be developed². Further details are as follows:

- **Ammonia:** Future trade in green ammonia will be facilitated by the significant infrastructure that is already available, given that it is a widely traded commodity. Having said that, projections of future ammonia trade indicate that port expansion will be required. The IEA, for example, projects global trade of ammonia representing the equivalent of around 12 Mt H₂ by 2030 (IEA, 2023). Currently trade is around 20 Mt per annum, equivalent to around 3.5 Mt H₂. Some studies suggest that repurposing existing LNG terminals to accept ammonia could be achieved at additional 11% to 20% of the investment costs of a new LNG terminal. Liquid ammonia needs to be stored either at -33°C under atmospheric pressure or alternatively at high pressure at ambient temperature, requiring investment in the storage infrastructure that is suited to these operating conditions.
- **Methanol:** Methanol is one of the top five global export commodities, and around 90 of the 100 top ports already have the infrastructure and experience to handle methanol³. Methanol can be stored at ambient temperature and pressure, making infrastructure requirements less onerous, but it does require safety measures to be put into place to avoid explosions.
- **Synthetic fuels and LOHC:** LOHC have similar properties to petroleum-based liquids, and LOHC are liquids at ambient temperature and pressures. As such, both of these carrier options can use existing unpressurised tanks and equipment that is already in place at many ports around the world (IEA, 2023). Together these factors make their storage and transport simpler and less expensive than ammonia – although infrastructure may need expansion depending on volumes traded. However, in the case of LOHCs, additional infrastructure is required to load the hydrogen onto the carrier, and to separate it again at destination in a dehydrogenation facility.

1 Clean Hydrogen Partnership (2023), Study on hydrogen in ports and industrial coastal areas (Report 2).

2 Global Hydrogen Council and McKinsey & Company (2022), Global Hydrogen Flows.

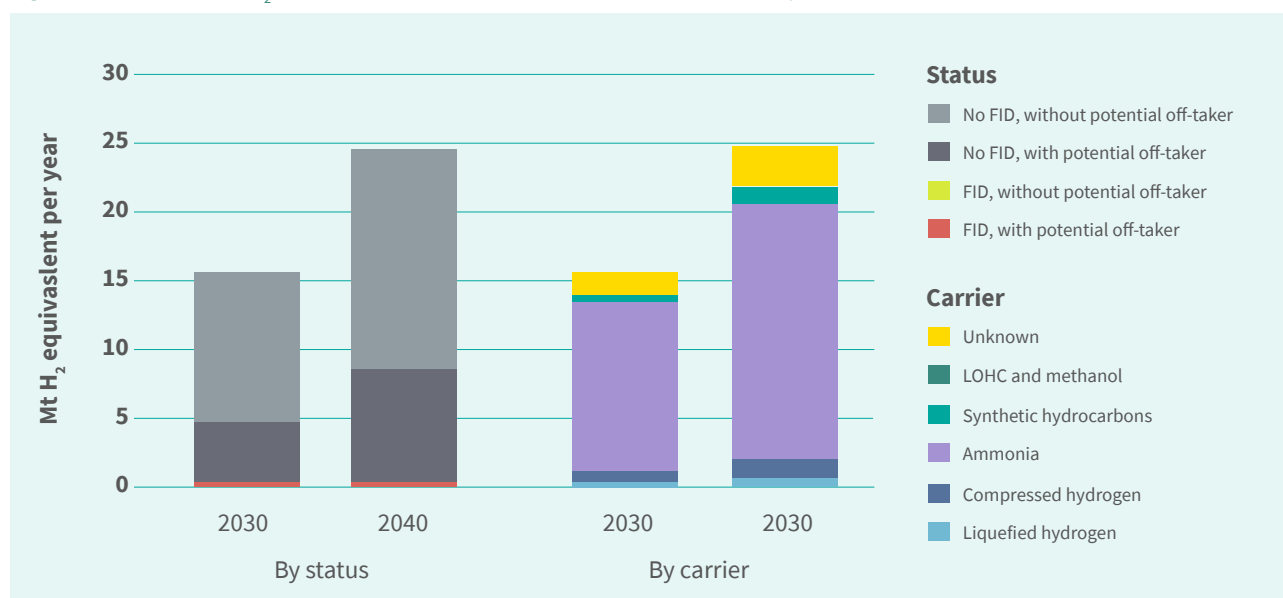
3 Chen et al. (2023), A review on ports' readiness to facilitate international hydrogen trade.

Like ammonia, methanol is highly toxic, flammable and explosive, thus also requiring appropriate safety interventions to be put into place at all stages of the value chain. Having said that, about 30% of global production in 2022 was traded between countries, and so transport processes are well understood and risk management protocols well established (Methanol Institute, 2023). Costs of unloading and loading, storage and transport of methanol are higher than other carriers on a per GJ basis, although the two carriers may be similar on a per kg H₂ equivalent basis (Chen, Fan and Abdussamie, 2025). While methanol is an important commodity for a range of different applications as described previously, its function as a GH₂ carrier (as opposed to chemical feedstock) is considered limited for a variety of reasons, including its lower hydrogen content, the challenges and complexities of sourcing suitable carbon feedstocks for production and accounting for emissions associated with the carbon content of the green methanol, and the low efficiency of recovery of hydrogen during decomposition when compared to ammonia. Furthermore, as indicated previously, South Africa has a lower level of technological readiness for green methanol production than green ammonia.

For LOHCs, a key challenge in their utilisation as a hydrogen carrier is the energy penalty to load and unload the carrier with hydrogen, with loading requiring less energy than unloading. Together, these processes represent an energy equivalent of between 35% and 40% of the energy value of the hydrogen – recognising that efficiency may improve over time, given that processes are still in the early stages of development (IEA, 2023). Apart from the energy investment, other downsides of using LOHC carriers include cost and safety, depending on the carrier to be used. The carrier also needs to be returned to pick up a new hydrogen cargo, which results in additional reverse logistics transport costs.

Considering the above observations, ammonia appears to hold the greatest promise for longer distances where pipelines are not feasible. This is reflected in current global plans, as shown in Figure 2, which indicates the projected dominance of ammonia for future GH₂ projects.

Figure 2 Low-emissions H₂ trade by status and carrier based on announced projects, 2030-2040



Notes: FID = final investment decision; LOHC = liquid organic hydrogen carrier. »Compressed hydrogen« includes both projects aiming to transport gaseous hydrogen via pipelines and projects planning to ship it in compressed hydrogen carrier. »Synthetic hydrocarbons« includes projects aiming to trade synthetic methane or synthetic oil products. »No FID« refers to projects undergoing feasibility study or at early stage, while »FID« indicates projects that have already reached a final investment decision. »Potential off-taker« refers to projects which have identified a potential buyer or end-user, even if a binding off-take agreement has not been signed yet. The amount of hydrogen equivalent traded is computed from the capacity of each plant, by considering average capacity factors (reported in the technical documentation of the IEA Hydrogen Projects Database) and by assuming that a certain share of production would be available for trade, in case of projects aiming at multiple end-uses. For each project, a 50% availability factor is assumed for the first year of operation. Only projects with a disclosed start year are included.

2.3 Trade in potential hydrogen carriers

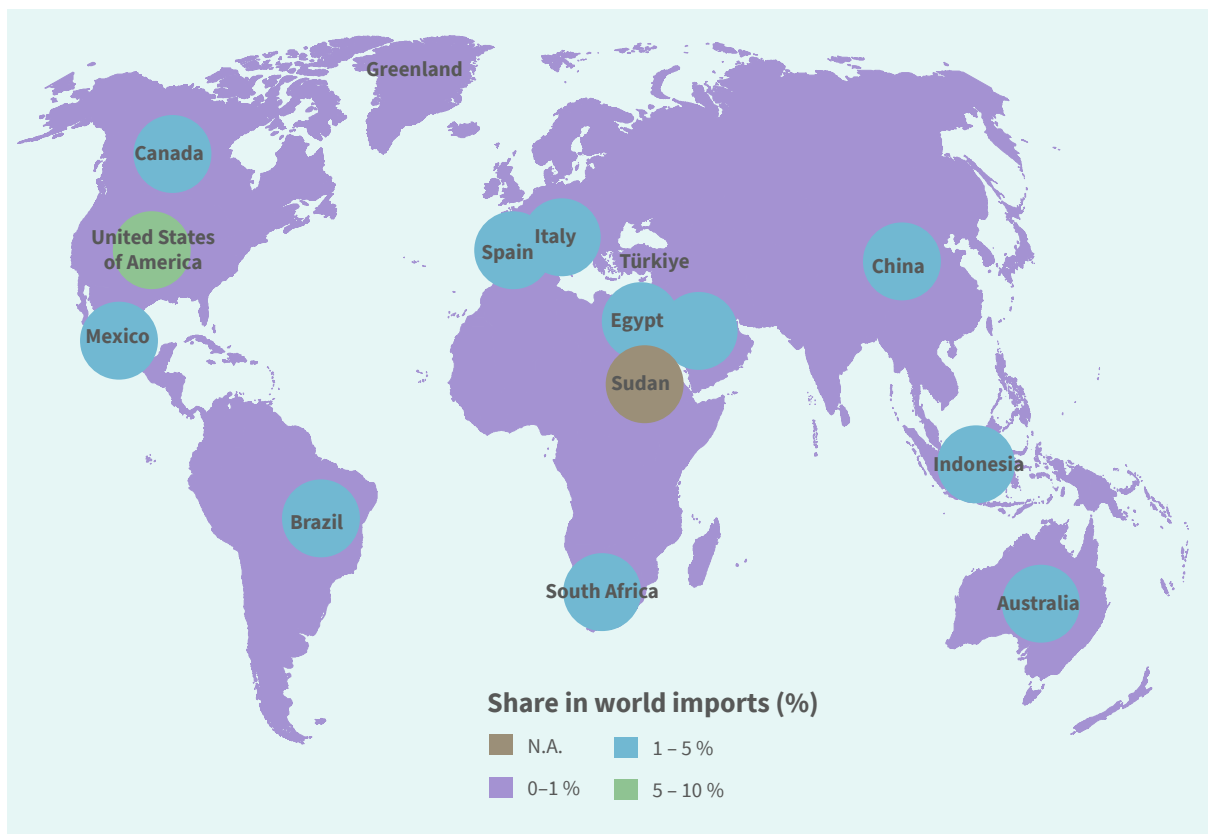
Attention now turns to current trade in the potential hydrogen carriers, as well as projections of potential future demand for the different products from the EU, which could represent a strong market for South African PtX production output.

2.3.1 Current situation

PtX products do not have unique HS codes (HS codes do not differentiate between renewable and non-renewable attributes) and cannot, therefore, easily be identified in global trade data. Furthermore, global certification schemes for identifying renewable or low-carbon PtX products are also not in place (Heinrichs, Ohle and Langenhorst, 2024). Consequently, trade in hydrocarbon fuels, ammonia and methanol in general is considered.

In 2024, global imports of hydrocarbon fuels – such as petroleum oils and oils obtained from bituminous minerals (excluding crude amounted to approximately \$880 billion). Of this, 23% was imported by EU countries. The global distribution of hydrocarbon fuel imports is illustrated in the accompanying diagram. South Africa is a notable net importer of hydrocarbon fuels, with a trade deficit of \$9.3 billion in 2024. Although South Africa registered some exports in 2024, totalling \$2.97 billion, only a relatively small amount of \$64 million was exported to the EU, representing 2.2% of South Africa's hydrocarbon fuel exports. Prices for refined fuels vary considerably across regions and countries, mainly depending on the level of subsidies (relative to crude oil prices) provided or taxes levied to fund transport infrastructure or to internalise the environmental and social costs. An example based on gasoline prices is shown in Figure 4.

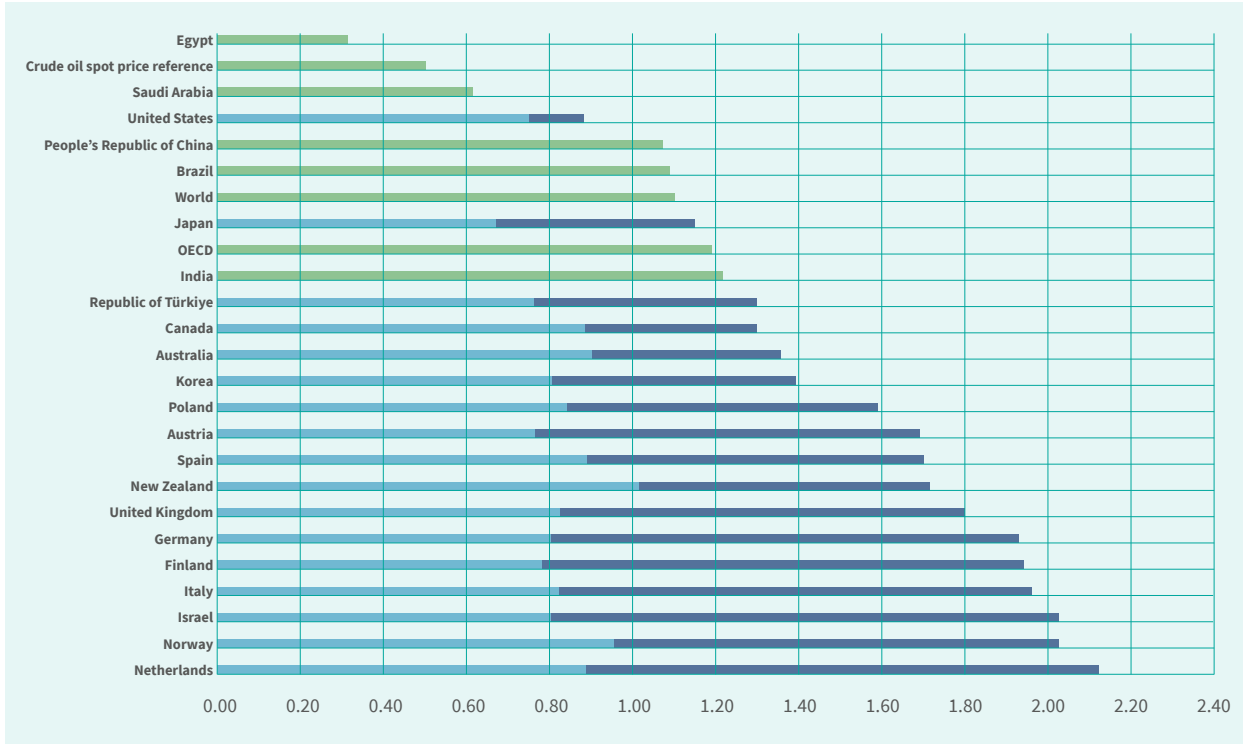
Figure 3 Global imports of refined hydrocarbon fuels (2024)



List of importing countries for the selected product in 2024. Product: 2710 Petroleum oils and oils obtained from bituminous minerals (excl. crude); preparations containing $\geq 70\%$ by weight of petroleum oils or of oils obtained from bituminous minerals. These oils being the basic constituents of the preparations. N.e.s.: wa

Source: (ITC, Undated)

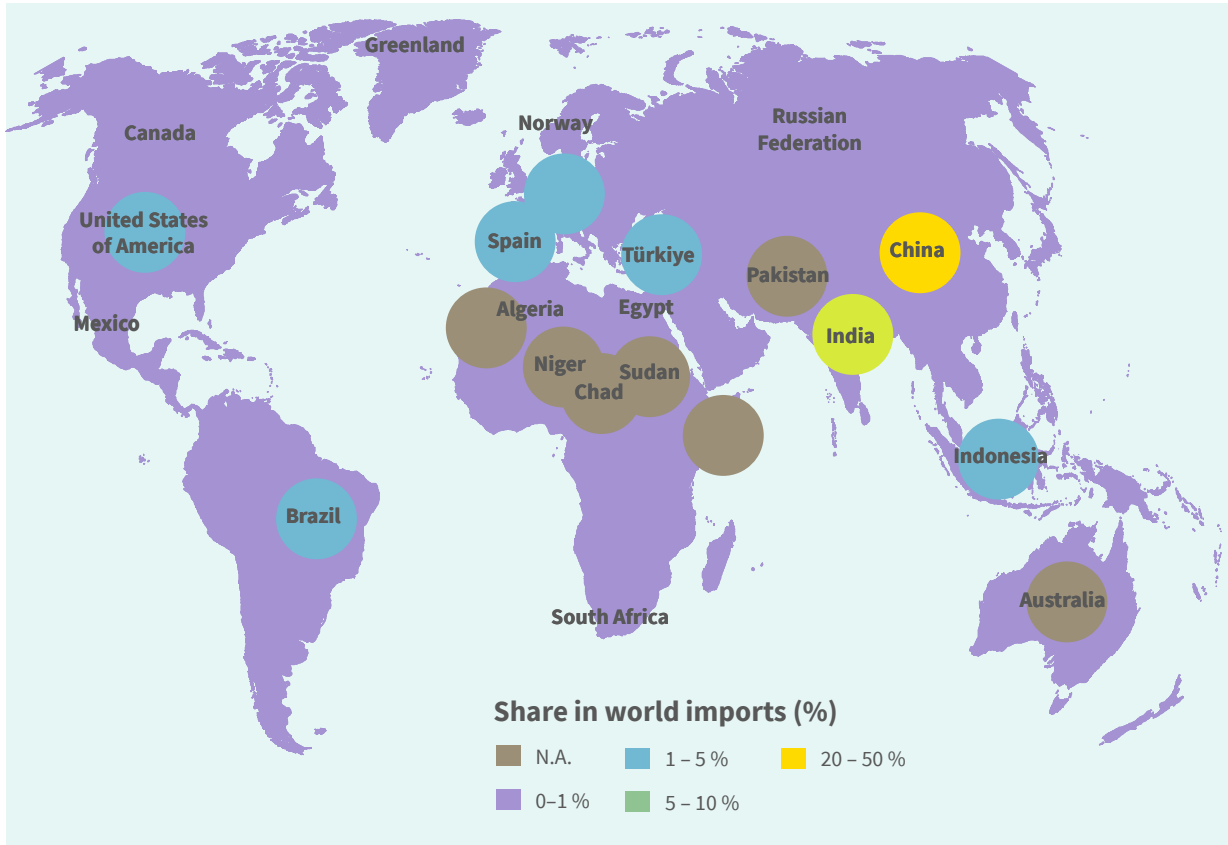
Figure 4 Gasoline prices and taxes for selected countries, 2024 (USD/litre)



Source: (IEA, 2025)

\$13.2 billion of methanol was imported globally in 2024, with the EU accounting for \$3.4 billion (26%) of this total. South Africa is a net importer of methanol and experienced a \$5.6 million deficit in 2024. Although South Africa exported \$5.8 million of methanol, none of these exports went to the EU. The global distribution of methanol imports is shown in Figure 5. Methanol prices vary across regions but have remained relatively stable in recent years, except in the North American market (Methanol Institute, 2025).

Figure 5 Global imports of methanol (2024)

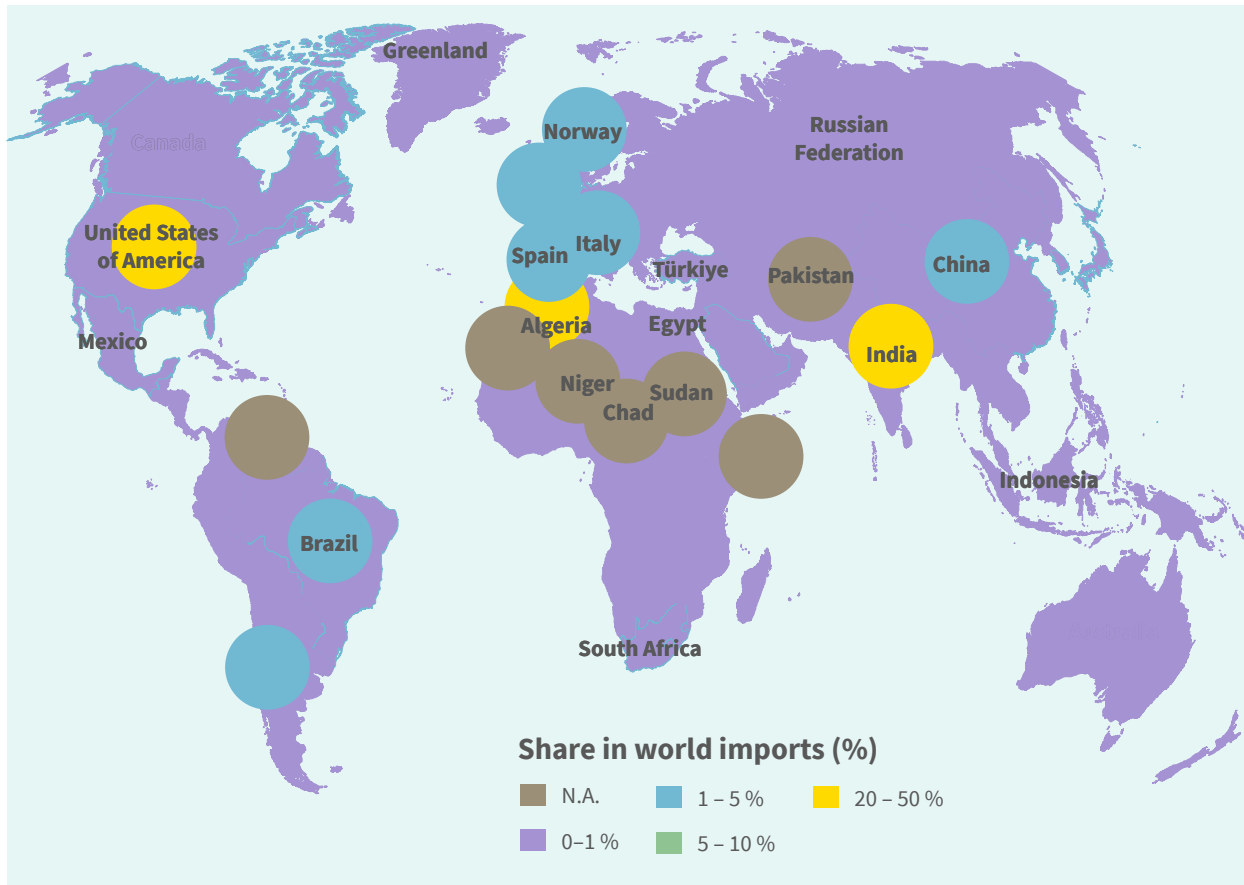


List of importing countries for the selected product in 2024. Product: 290511 Methanol »methyl alcohol«

Source: (ITC, Undated)

\$7.4 billion of ammonia was imported globally in 2024, with the EU accounting for \$1.8 billion of these imports (24%). South Africa is a net importer of ammonia and experienced a \$57.2 million deficit in 2024. The country did export \$4 million of ammonia, but all exports went to countries within Sub-Saharan Africa. The global distribution of ammonia imports is shown in Figure 6. As with methanol, ammonia prices vary by region (Business Analytiq, 2025), and the Russian invasion of Ukraine in February 2022 has had a significant impact on ammonia pricing. Even after prices have returned to relatively normal levels, the relationship between prices in different regional markets remains affected. Ammonia in the European market, for instance, has shifted from being mid-range in price to now representing the most expensive ammonia.

Figure 6 Global imports of ammonia (2024)



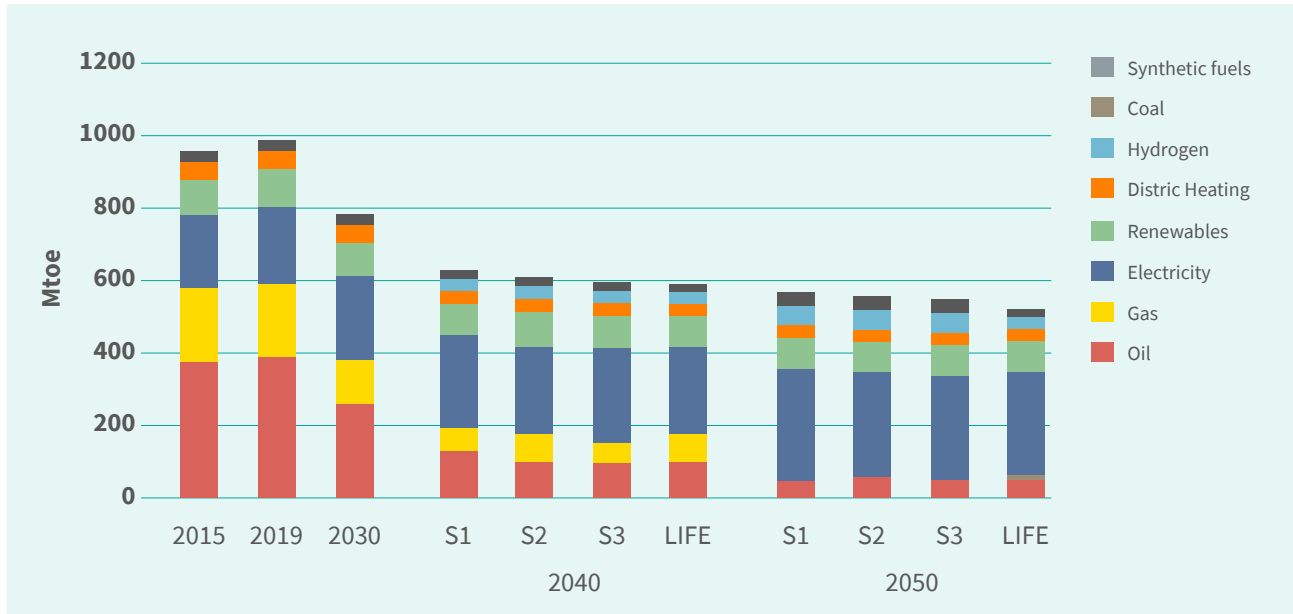
Source: (ITC, Undated)

Grey ammonia is still currently the cheapest form of ammonia, but blue ammonia is starting to become price-competitive in certain markets. Green ammonia, however, is still significantly more expensive in all markets (Burgess, 2025).

2.3.2 Future EU demand

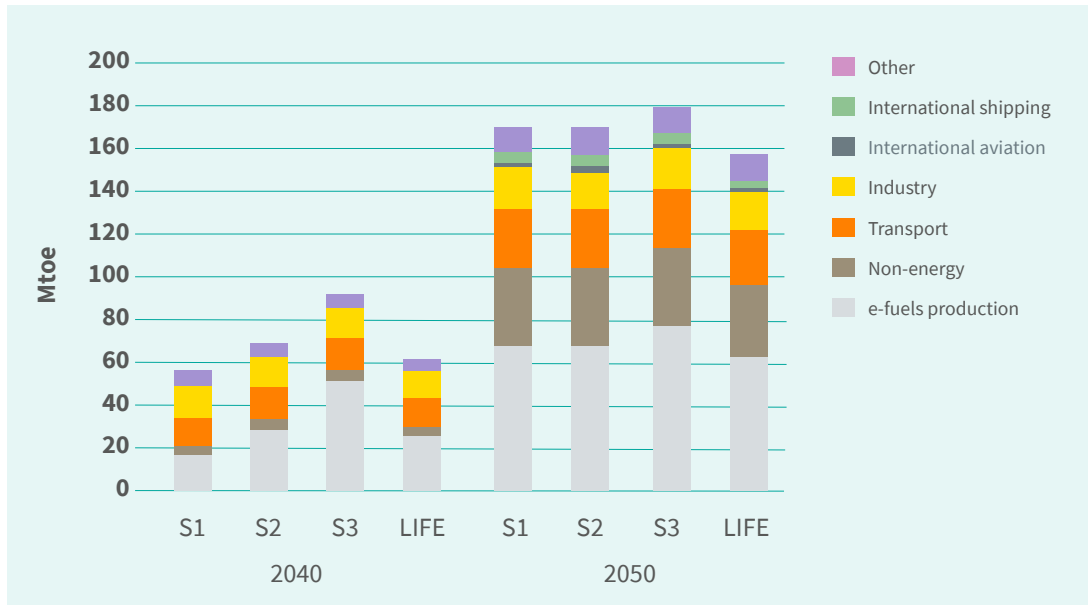
Future EU demand for GH_2 and its derivatives is uncertain given that it depends on EU and global commitment to decarbonisation, and the extent to which the production costs of GH_2 and its derivatives fall to enable them to become competitive with fossil fuel and low-carbon alternatives. One example of how the future demand for GH_2 and its derivatives may evolve is provided in the impact assessment of the 2040 EU GHG emissions targets that underpin the proposed amendment to the EU Climate Law announced on the 2nd of July 2025 (European Commission, 2024b; European Commission, 2025). The report highlights that the importance of H_2 as an energy carrier is expected to increase by 2050 (Figure 7), and indicates that the transport and industry sectors are expected to be the major users of H_2 (Figure 8).

Figure 7 Final energy consumption by fuel in the EU, 2015-2050



Source: (European Commission, 2024)

Figure 8 Consumption of H₂ in the EU, 2040 and 2050

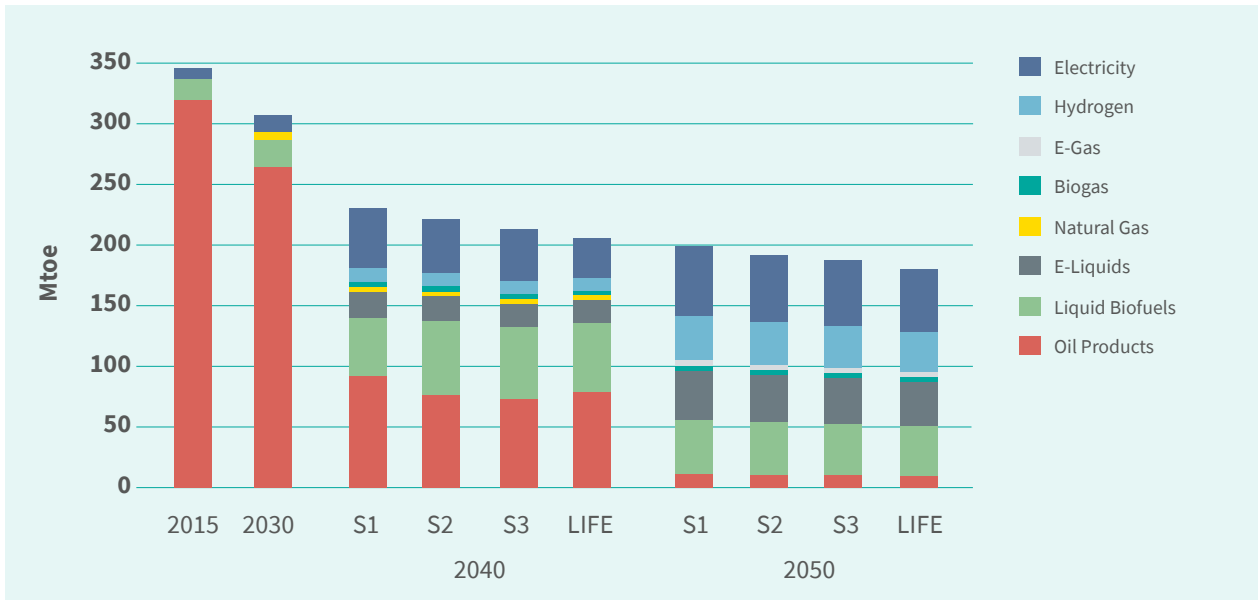


Note: e-Fuels include green ammonia, green methanol and other fuels derived from RE.

Source: (European Commission, 2024)

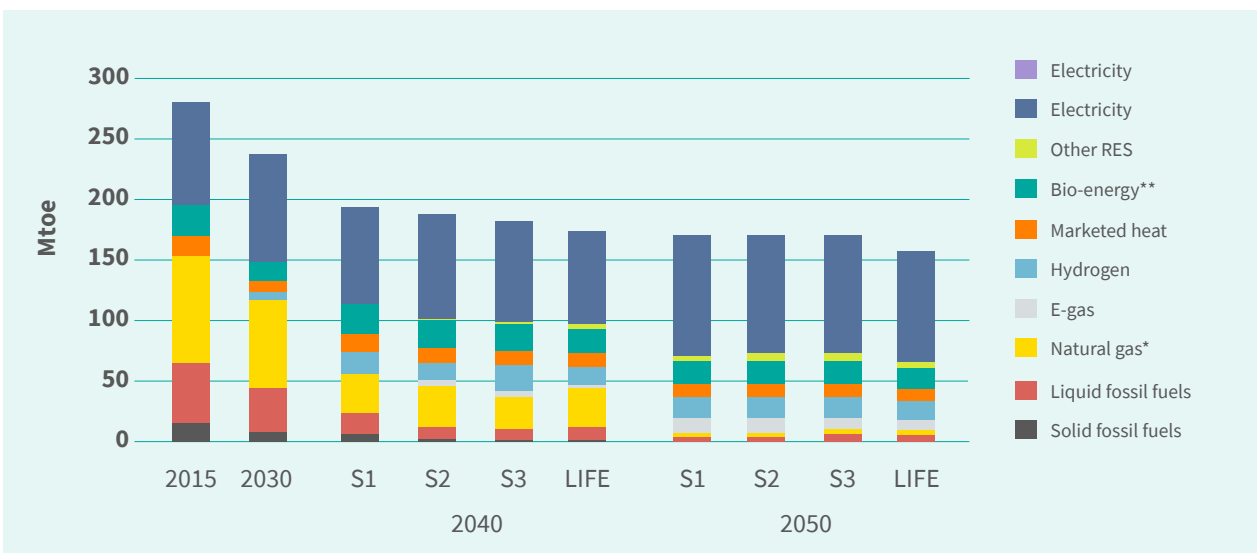
Figure 9 shows that the importance of H₂ as a transport fuel is expected to increase significantly within the EU by 2050. Lastly, Figure 10 and Figure 11 highlight that H₂ and its derivatives are expected to become increasingly important as both an industrial energy carrier and industrial input within the EU.

Figure 9 Energy consumption in the EU transport sector by fuel/energy carrier



Note: Energy consumption includes international aviation and maritime demand. E-liquids include green ammonia and green methanol
 Source: (European Commission, 2024)

Figure 10 Final energy consumption in EU industry by fuel, 2015-2050



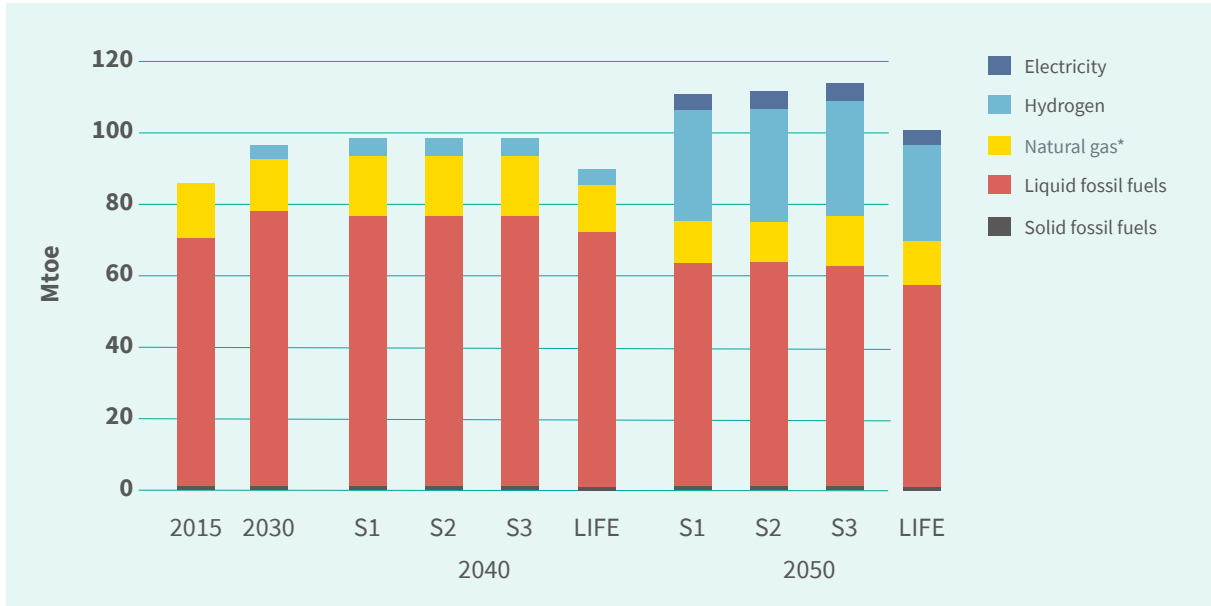
Note: E-liquids include green ammonia and green methanol. The energy consumption includes the final energy consumption plus the consumption in refineries.

*Natural gas including manufactured gas (coke-oven gas, blast furnace gas & gasworks gas), but not e-gas.

**Bioenergy including bio-solids, biofuels, biogas (including waste gas and biomethane) and solid waste.

Source: (European Commission, 2024)

Figure 11 Final non-energy consumption in EU industry by fuel, 2015-2050



Note: *including manufactured gas (coke-oven gas, blast furnace gas & fasworks gas), nut not e-gas.

Source: (European Commission, 2024)

3

Potential impact of CBAM on the choice of GH₂ export carrier

The potential impact of the CBAM on imports of PtX products from South Africa to the EU mainly depends on whether the CBAM covers the PtX product in question, the emissions scope (e.g. if indirect emissions are covered or not) and the GHG emissions embedded in the relevant PtX products. Differential CBAM coverage, scope, and embedded GHG values could lead to incurring differential CBAM costs when entering the EU, which could potentially affect the choice of PtX product to export. These issues are considered below.

3.1 CBAM coverage

The CBAM currently only covers CO₂ emissions embedded in imported H₂ (Combined Nomenclature (CN) code 2804 10 000) and ammonia (CN code 2814) (Commission Implementing Regulation (EU) 2023/1773, 2023) during production. H₂ is also defined as a precursor product to ammonia, and emissions embedded in H₂ thus need to be included in the embedded emissions of ammonia. Other derivatives of H₂, including methanol and LOHCs (organic chemicals) and synthetic hydrocarbon fuels like Sustainable Aviation Fuel (kerosene) (which share CN codes with refinery products) are not currently within the scope of CBAM. Furthermore, as highlighted in Commission Services (2022), there is the additional complexity of distinguishing LOHCs from other complex organic chemicals (or potentially even the same chemicals) used for purposes other than transporting H₂. The view that derivatives other than ammonia are not included in the CBAM is confirmed by legal opinion and a study commissioned by the Dutch parliament (Clifford Chance, 2023; Trinomics, 2022).

Future CBAM reviews will consider whether it is feasible to extend the CBAM to include organic chemicals (and thus potentially LOHCs) and refinery products.

The CBAM applies to both direct and indirect emissions embedded in ammonia during the definitive period, but only to direct emissions embedded in H₂ production. Future CBAM reviews will also consider including indirect emissions for hydrogen and other goods in the CBAM scope. The chemical sector currently benefits from state aid linked to indirect ETS costs passed on through electricity prices in some EU jurisdictions (Ferrara & Giua, 2022). Given that the CBAM was created to ensure a level playing field between domestic producers and importers, this complicates the expansion of CBAM coverage to indirect emissions embedded in imported H₂ in the near term (Regulation (EU) 2023/956, 2023).

CBAM and blue hydrogen

In a context of technological uncertainty, different hydrogen production pathways will compete for market share in the EU market. Despite regulatory incentives in the EU mainly supporting GH₂ (RFNBOs)⁴, GH₂ is not yet cost competitive with grey, black and blue hydrogen in most of geographies⁵. South Africa currently produces approximately 2% of global hydrogen output, most of it being produced with natural gas (grey hydrogen) and coal (black hydrogen)⁶. Box 3 intends to briefly explore the influence of CBAM on hydrogen imports into the EU from South Africa produced through different production pathways, with an special focus in the comparison between blue hydrogen (produced with natural gas and CCS) and GH₂ (produced with 100% renewable electricity in accordance with EU requirements).

Blue hydrogen is manufactured from natural gas, but with greenhouse gas emissions captured and stored. The cost of blue hydrogen currently sits between grey and green hydrogen in most of jurisdictions⁷. Allowing emissions sequestered via Carbon Capture and Storage (CCS) during the production of blue hydrogen to be exempted from CBAM costs ((Commission implementing regulation (EU) 2023/1773, 2023b) and (Commission implementing regulation (EU) 2025/2547)) reduces the ability of carbon costs to accelerate the move towards GH₂ cost parity with fossil fuel-derived hydrogen, providing CCS meets the legal requirements as set out in Commission implementing regulation (EU) 2025/2547. This will affect the cost competitiveness between green and blue hydrogen , since a carbon price is one of the main drivers expected to move GH₂ to cost parity with fossil-fuel-based hydrogen⁸. If the CBAM carbon price signal does not apply to emissions that are captured and stored, it may take GH₂ much longer to reach cost parity with fossil-fuel-based blue hydrogen. It should be mentioned that competitiveness of blue hydrogen vs green hydrogen is not just dependent on the carbon price component but also on other components such as the price of natural gas vs the price of renewable electricity, the price and scalability of the CCS technology including availability of suitable storage sites, capture rates etc⁹. Moreover, as a significant portion of the lifecycle emissions associated with blue hydrogen production occur upstream, specifically those linked to fugitive methane emissions during natural gas extraction and transportation. Given that these emissions are not under CBAM scope (scope 3 upstream emissions), they are not accounted for in the calculation of blue hydrogen's carbon footprint under CBAM. Crediting blue hydrogen production emissions captured by CCS in the CBAM cost calculation, without including the full value of upstream emissions, may artificially inflate the competitiveness of blue hydrogen relative to GH₂ in a CBAM context.

For imported grey or black hydrogen (hydrogen produced with natural gas or coal) the case is more straightforward as exposure to the carbon price will not be cushioned by emissions being captured and stored and therefore much higher. Considering regulatory incentives for green hydrogen in the EU market and the high exposure of carbon emissions embedded in imported grey hydrogen to the CBAM carbon price signal, it is highly unlikely that the EU will import grey hydrogen from South Africa.

-
- 4 Inter alia, RFNBO mandates in the Renewable Energy Directive (RED) III, support of the hydrogen bank through a green premium for RFNBOs, SAF quotas as part of the ReFuelEU Aviation, extension of the EU-ETS scope so that producers of RFNBOs are eligible for free allowances (historically only grey hydrogen producers were eligible for free allowances) etc.
- 5 International Energy Agency (2025) Global Hydrogen Review, cost comparison of different production routes.
- 6 Department of Science and Innovation, Hydrogen society roadmap for South Africa (2021)
- 7 International Energy Agency (2025) Global Hydrogen Review, cost comparison of different production routes.
- 8 Other mechanisms, like the requirements for assessing whether RH₂ qualifies as a Renewable Fuels of Non-Biological Origin (RFNBO) under the Renewable Energy Directive (RED) II and III regulatory framework discussed in the next section, also increase the demand for RH₂.
- 9 ERCST (2023), The inclusion of hydrogen in the EU CBAM

However, from a South African perspective, combining hydrogen production with CCS is also not currently attractive in South Africa. South Africa currently produces black hydrogen primarily from coal due to a lack of a reliable, long-term natural gas supply. Hydrogen produced from coal is more expensive than grey hydrogen produced from natural gas, and generates significantly larger volumes of GHG emissions that need to be captured, transported and stored. South African hydrogen produced from coal is therefore unlikely to be competitive in international markets where grey hydrogen dominates. Furthermore, after an initial policy focus and more than two decades of endeavours to study the feasibility of CCS for different applications in South Africa, interest in CCS in South Africa has waned in recent years (Vourliotakis et al., 2024). The first Carbon Capture, Utilisation and Storage (CCUS) research site was established in South Africa in 2024, but this site is located in the Mpumalanga province, far from the coast where export-focused PtX projects are likely to be based (Campbell, 2024; Clean Energy Ministerial, 2025).

Thus, even though CBAM may increase the attractiveness of blue hydrogen relative to green hydrogen (since sequestered emissions are not subject to the CBAM if in compliance with the CBAM requirements for CCS), South African conditions mean that this will not affect the choice of hydrogen produced and carrier chosen.

3.2 Rules for defining GH₂ and PtX in EU market

Several schemes, policy and regulatory incentives are being implemented to generate a premium for GH₂ and its derivatives in the EU and its Member States. These include, for example, the EU hydrogen bank green premium, the RFNBO mandates as part of the Renewable Energy Directive, the H₂Global mechanism or the use of lead markets in the EU's Clean Industrial Deal (CID). South African producers of GH₂ and PtX must adhere to the criteria used to define GH₂ in the EU to benefit from these market development initiatives and incentives. This is another factor, in addition to the CBAM rules, that will determine the production processes and inputs used by South African exporters of PtX to the EU. These requirements are discussed below.

The EU has established requirements for assessing whether GH₂ qualifies as a Renewable Fuels of Non-Biological Origin (RFNBO) under the Renewable Energy Directive (RED) II and III regulatory framework. The EU Renewable Energy Directive (RED) is the legal framework for promoting the deployment of renewable energy sources (RES) across all sectors of the EU economy. The first RED (RED I) was adopted by the EU in 2009. RED I was replaced by a revision (RED II), which was adopted in 2018. A new revision of RED was adopted in 2023. RED III includes an updated definition of renewable hydrogen (RFNBOs or Renewable Fuels of Non-Biological Origin). This definition has been completed and complemented by two delegated acts, legally anchored in RED II. RED III defines renewable hydrogen as hydrogen which is produced from renewable energy sources and achieves at least 70% greenhouse gas emissions savings vs a fossil fuel comparator. The two delegated acts adopted by the European Commission in June 2023 define the criteria for electricity for the production of renewable hydrogen to be considered truly renewable (first delegated act)¹⁰ and the GHG emissions methodology to verify that emissions remain below the 70% emissions threshold (second delegated act)¹¹. The two delegated acts apply to both domestic producers and international producers exporting renewable hydrogen to the EU. For a comprehensive explanation of the delegated acts please refer to: [EU requirements for renewable hydrogen and its derivatives by the PtX Hub](#).

Given the nature of South Africa's current RE infrastructure and its outlook, the requirements of additionality, temporal and geographical correlation can readily be met. MRV against these principles are not likely to represent a significant barrier to the export of GH₂ or its derivatives to the EU given the evolution of electricity supply options in South Africa (see section 3.3).

10 Delegated Act (EU) 2023/1184 on a methodology for renewable fuels of non-biological origin

11 Delegated Act (EU) 2023/1185 a minimum threshold for GHG emissions savings of recycled carbon fuels

In order to harmonise and provide consistency between the rules defining RFNBOs and the emissions accounting methodology under the CBAM transitional period, Commission Implementing Regulation (EU) 2023/1773 (2023) specifies that if the hydrogen has been certified as an RFNBO, an emission factor of zero can be used for the indirect emissions.

3.3 The impact of CBAM on the choice of GH₂ export carrier to the EU

3.3.1 Products covered by CBAM

The proportion of RE used in the production of hydrogen and its derivatives is an important determinant of exposure to CBAM costs. Green ammonia, green methanol, or synthetic hydrocarbon fuels produced using 100% renewable energy and sustainable carbon in accordance with EU regulatory requirements will generate zero or close to zero direct or indirect GHG emissions during their production – and will most likely not include any embedded emissions under CBAM GHG accounting rules¹². In this case, it is irrelevant whether CBAM covers an export carrier or not. A carrier produced with 100% renewable energy that falls within the scope of the CBAM will generally have zero or close to zero embedded emissions and therefore will not incur any additional cost relative to one that the CBAM does not cover. If low-carbon hydrogen rather than GH₂ with renewable energy is produced, the resultant carriers will contain embedded emissions which are subject to CBAM costs. In the latter case, export carriers not covered by the CBAM will have a cost advantage relative to those covered by the CBAM (e.g. low-carbon hydrogen-based methanol vs low-carbon hydrogen-based ammonia). Even if the ammonia is produced with fully renewable hydrogen (RFNBO), therefore qualifying for the EU regulatory incentives for RFNBOs, this does not mean that under CBAM the ammonia will have 0 embedded emissions. In this case, emissions attributed to hydrogen will be 0, however other direct or indirect emissions could be added to the process of ammonia production if not used energy is not 100% renewable. In this case (where the PtX product is produced with RFNBO certified hydrogen but other emissions direct or indirect are added to the process), CBAM could also represent a cost advantage to those carriers not covered by CBAM.

Roos and Wright (2021) outline several reasons why hydrogen and its derivatives produced for export in South Africa are expected to be powered exclusively (100%) via renewable energy (i.e. be exclusively GH₂) in compliance with RFNBO regulatory requirements:

- **Compliance.** The South African grid is very carbon-intensive, and while it is expected to decarbonise relatively quickly, it will not reach zero emissions for many decades. To qualify for market development incentives in the European ([see section 3.2](#)) and Japanese (post-2040) renewable hydrogen markets, hydrogen needs to be produced exclusively from renewables, and low-carbon hydrogen or its carriers are therefore not eligible. Low-carbon hydrogen will, however, be eligible for incentives and regulatory compliance in the European market¹³, though to a lesser extent if its emissions are at least 70% lower than those of fossil fuels, irrespective of how it was produced, [see section 3.2](#). It is difficult to guarantee any set level when relying on a grid with significant fossil fuel capacity (like in South Africa). Temporary factors or outages could lead to the grid emissions factor varying and breaching 'low carbon' requirements. Furthermore, using grid electricity also introduces the risk that the carbon intensity saving thresholds that define 'low carbon' in the EU and other export markets may increase faster over time than the South African grid decarbonises. National energy policy thus becomes an additional risk factor to consider when developing low-carbon hydrogen and derivative export projects. Having RE, in compliance with EU regulatory requirements, contractually linked to PtX supply removes this uncertainty and makes compliance easier to track.

12 As part of a comprehensive CBAM review, several aspects related to the calculation of embedded direct and indirect emissions as well as the role of different PPAs are being reviewed.

13 The threshold applies to all types of recycled carbon fuels used in any type of transport (Piria et al, 2023).

- **Cost.** RE is already cheaper than grid power in South Africa, and it also provides cost certainty over time since the price increase in power purchase contracts are fixed up front. These increases are typically in line with inflation. In contrast, the cost of grid power in South Africa is expected to increase above inflation for the foreseeable future while the country recovers from an electricity supply crisis. Fixed cost increases are desirable since they allow costs to be matched with revenues defined in offtake agreements. Furthermore, while oversizing RE capacity to increase electrolyser utilisation rates is a cost-effective approach in South Africa, new innovations and trading platforms in the local electricity market are reducing the amount of oversizing (and thus capital investment) required, which is further increasing the cost advantage of dedicated RE over grid electricity (Discovery, 2025; Sasol, 2025). The Discovery Green platform, for example, is providing industrial users with RE to cover up to 90% of their electricity needs by combining supply from solar and wind power generators (Creamer Media Reporter, 2025).
- **License to operate.** The electricity supply crisis in South Africa has raised concerns that PtX production will divert electricity from domestic users for the benefit of international consumers of PtX. Avoiding the perception that the PtX industry will negatively impact domestic electricity availability is therefore key to ensuring political and public support for the PtX industry. 100% dedicated RE supply to PtX plants in compliance with the additionality requirement under EU legislation will help in achieving this. Furthermore, wheeling RE power to PtX plants also provides income for transmission and distribution network owners. It therefore helps to increase the sustainability of the electricity sector as a whole, which engenders social and political support.

Given the reasons outlined above, South Africa is expected to produce green export carriers (e.g. green ammonia or green methanol) from 100% RE in accordance with EU regulatory requirements, potentially through a direct connection between the renewable electricity generation source and the electrolyser. **These carriers or products will therefore have zero or close to zero embedded emissions to which CBAM costs could be applied, and the CBAM will not influence the choice of carriers used for the export of GH₂ from South Africa to the EU.** While some compliance costs will have to be incurred for products like ammonia that are within the scope of the CBAM, these costs will be relatively low compared to the value of green hydrogen export projects (which are typically very large (Young & McGregor, 2024)) and are unlikely to affect the choice of GH₂ carrier for export.

3.3.2 Products not currently covered by CBAM

Should the CBAM be extended to include organic chemicals in future, the emissions embedded in LOHC may then be subjected to CBAM costs. However, the embedded carbon content of LOHC produced with sustainable carbon and GH₂ is expected to be low (Cho, Strezov and Evans, 2024). Furthermore, Chilunda et al. (2025) suggest that the carbon footprint of hydrogenation and rehydrogenation during LOHC transport can be significantly reduced by using RE, reducing embedded emissions even further. Finally, the same LOHC molecules can be used hundreds or even thousands of times to transport GH₂ (Distel, et al., 2025) and, in line with standard life cycle accounting practices, the impact of producing the LOHC would be spread across the multiple uses, leading the emissions per tonne of GH₂ transported, and thus CBAM costs, to become insignificant.

Given LOHC's low level of technical readiness (see section 2.1.4), the fact that LOHCs are not currently covered by the CBAM, and that the carbon embedded in LOHCs are not expected to lead to significant CBAM costs even if they are included in future, the **CBAM is not expected to have a significant impact on the decision to deploy LOHCs as a GH₂ carrier between South Africa and the EU.**

Looking towards Sustainable Aviation Fuel, the EU-ETS, which informs the CBAM, only covers domestic aviation, i.e. flights between the European Economic Area (EEA) (the EU plus Iceland, Liechtenstein and Norway). From 2027, flights starting or terminating outside of the EEA will be covered by the International Civil Aviation Organisation's Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)¹⁴. There should thus be significant demand for Sustainable Aviation Fuel outside the EEA – not driven by CBAM – which will consume the bulk of Sustainable Aviation Fuels that can be produced given that there is limited sustainable carbon available in domestic markets. The impact of CBAM on imports of aviation fuel to the EU is unlikely to alter demand dynamics in the sustainable aviation market significantly. **In summary, it does not make sense to export Sustainable Aviation Fuel to the EU as a carrier of GH₂ to avoid CBAM since SAF will be a scarce and valuable commodity elsewhere.**

In terms of maritime fuel, the EU-ETS requires EU allowances to be surrendered for 100% of the emissions from maritime transport activities within the European Economic Area member states, and 50% of emissions from voyages that originate or terminate within member states. Voyages are measured between ports where ships load or unload cargo only, and exclude stops where ships refuel, for example. Since 2024, the requirements apply to large cargo and passenger ships (with a gross tonnage of more than 5,000), with large offshore ships being covered from 2027. Smaller ships have to report their emissions and may be included in the EU-ETS in the future (European Commission, Undated a). This creates a demand for PtX in the maritime sector outside of the EU to reduce the EU-ETS costs of voyages that either originate or terminate in EU (IEA, 2024). The FuelEU Maritime regulations (European Commission, Undated c) also already impose declining maximum limits on the average yearly GHG emissions intensity of the energy used by ships above 5,000 gross tonnage calling at European ports, irrespective of where they are registered. As in the case of Sustainable Aviation Fuel, **the impact of a possible extension of the CBAM to maritime fuels is thus reduced since significant demand for PtX already exists in this market.**

14 European Commission, Climate Action, Reducing emissions from aviation.

4 Conclusion

This study investigated whether the European Union's Carbon Border Adjustment Mechanism (CBAM) will influence the choice of emerging GH₂ carriers, or Power-to-X (PtX) products, as exports to the EU from South Africa.

Given South Africa's abundant renewable energy resources and existing industrial experience, especially in ammonia production, the country is potentially well-positioned to become a competitive exporter of green hydrogen derivatives to Europe. Among the leading hydrogen carriers currently under consideration globally (i.e. green ammonia, green methanol, synthetic hydrocarbons, and Liquid Organic Hydrogen Carriers (LOHCs)), green ammonia stands out as the most promising option for long-distance export. This is due to its higher hydrogen density, established global trade infrastructure, and South Africa's technological readiness. Green methanol and synthetic fuels face challenges related to sourcing sustainable carbon feedstocks, have lower hydrogen content, and possess less developed local production capabilities, while LOHCs are still in the early stages of development. Additionally, LOHCs incur significant energy penalties during loading and unloading, and the necessity for return shipments increases logistics costs.

The CBAM's current scope includes hydrogen and ammonia but excludes methanol, LOHCs, synthetic hydrocarbon fuels and other derivatives. At present, only direct emissions from H₂ production are covered by the CBAM, while both direct and indirect emissions from ammonia production incur CBAM costs. The CBAM rewards the use of Carbon Capture and Storage (CCS) technologies (as discussed in Box 1) to produce blue hydrogen and derivatives if in compliance with the CBAM regulatory requirements for CCS, but the use of CCS to produce low-carbon hydrogen is not currently being explored in South Africa.

South Africa's fast-evolving renewable energy market presents opportunities to procure the long-term supply of dedicated and increasingly cheap zero-carbon electricity. This enhances the price competitiveness of local GH₂, mitigates input cost inflation risks, simplifies regulatory compliance, and removes the risk of high grid carbon intensity hindering access to lucrative EU GH₂ market development mechanisms.

Local market conditions favour the production of GH₂ (RFNBOs) and its derivatives using 100% renewable energy in accordance with EU regulatory requirements, and locally produced PtX products will thus generate zero or close to zero GHG emissions, either direct or indirect. GH₂ carriers or PtX products have zero or close to zero embedded emissions to which CBAM costs could be applied, and, irrespective of the fact that some GH₂ carriers are included in the CBAM scope and others are not, the CBAM will not influence the choice of carriers used for the export of GH₂ from South Africa to the EU.

The CBAM could influence the choice of H₂ derivative if these are not produced with 100% renewable energy and therefore embed some emissions (low-carbon ammonia vs low-carbon methanol). CBAM could also influence the choice of derivative even if ammonia is produced with 100% renewable hydrogen as there may be other direct or indirect emissions embedded in the final product (ammonia) and therefore will bear some carbon costs at the border, vs other derivatives not covered by CBAM such as e-methanol. However, the carbon component is just one element of the competitiveness of the final products and therefore a more comprehensive analysis taking into account additional elements should take place.

CBAM is at the beginning of its definitive phase, and therefore changes in its implementation and scope are to be expected. It is therefore premature to consider the full policy implications at this stage. It is, however, important to note that an expansion of the CBAM scope to include more H₂ carriers and indirect emissions for H₂ could help to increase the cost competitiveness of PtX exports from South Africa to the EU market.

5 References

- Borsboom-Hanson, T. et al. (2022) Point-to-point transportation: The economics of hydrogen export, GCGW-21 - Global Warming Reduction by Hydrogen, 47(74), pp. 31541–31550. Available at: <https://doi.org/10.1016/j.ijhydene.2022.07.093>
- Burgess, J. (2025) Interactive: Ammonia price chart, S&P Global Commodity Insights. Available at: <https://www.spglobal.com/commodity-insights/en/news-research/latest-news/energy-transition/051023-interactive-ammonia-price-chart-natural-gas-feedstock-europe-usgc-black-sea>
- Business Analytiq (2025) Ammonia price index, <https://businessanalytiq.com/>. Available at: <https://businessanalytiq.com/procurementanalytics/index/ammonia-price-index/>
- Campbell, R. (2024) South Africa's pilot carbon capture scheme officially inaugurated, Engineering News. 2 September 2024. Available at: <https://www.engineeringnews.co.za/article/south-africas-pilot-carbon-capture-scheme-officially-inaugurated-2024-09-02> (Accessed: 3 July 2025)
- Chatterjee, S., Parsapur, R.K. and Huang, K.-W. (2021) Limitations of Ammonia as a Hydrogen Energy Carrier for the Transportation Sector, ACS Energy Letters, 6(12), pp. 4390–4394. Available at: <https://doi.org/10.1021/acsenergylett.1c02189>
- Chen, P.S.-L., Fan, H. and Abdussamie, N. (2025) Evaluation of hydrogen shipping cost for potential trade routes, WMU Journal of Maritime Affairs, 24(2), pp. 315–338. Available at: <https://doi.org/10.1007/s13437-025-00365-w>
- Chilunda, M.D. et al. (2025) Electrochemical Cycling of Liquid Organic Hydrogen Carriers as a Sustainable Approach for Hydrogen Storage and Transportation, ACS Sustainable Chemistry & Engineering, 13(3), pp. 1174–1195. Available at: <https://doi.org/10.1021/acssuschemeng.4c05784>
- Cho, H.H., Strezov, V. and Evans, T.J. (2024) Life cycle assessment of renewable hydrogen transport by liquid organic hydrogen carriers, Journal of Cleaner Production, 469, p. 143130. Available at: <https://doi.org/10.1016/j.jclepro.2024.143130>
- Clean Energy Ministerial (2025) Global Developments with Carbon Capture, Use and Storage Deployment Programmes, Carbon Capture, Utilization, and Storage (CCUS) A Proposed Initiative of the Clean Energy Ministerial. Available at: <https://www.cleanenergyministerial.org/content/uploads/2025/02/january-2025-global-overview-of-ccus-policies-and-programmes.pdf> (Accessed: 3 July 2025)
- Clifford Chance, 2023. 10 Questions on the EU Carbon Border Adjustment mechanism. s.l.:Clifford Chance.
- Cohen, B., Cloete, B. and Uhorakeye, T. (2023) PtX Competitiveness Analysis. H2.SA Report. Bonn, Germany: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. Available at: <https://greenhydrogensummit.org.za/wp-content/uploads/2025/04/GH2-PtX-Competitiveness-analysis.pdf>
- Commission Delegated Regulation (EU) 2023/1884 (2023) Commission Delegated Regulation (EU) 2023/1184 of 10 February 2023 supplementing Directive (EU) 2018/2001 of the European Parliament and of the Council by establishing a Union methodology setting out detailed rules for the production of renewable fuels of non-biological origin. OJ L 157 20.6.2023 / 02023R1184 — EN — 10.06.2024 — 001.001. Brussels, Belgium: European Commission. Available at: https://eur-lex.europa.eu/eli/reg_del/2023/1184
- Commission Implementing Regulation (EU) 2018/2066, 2018. Commission Implementing Regulation (EU) 2018/2066 of 19 December 2018 on the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council and amending Commission Regulation (EU) No 601, s.l.: European Union.

- Commission Implementing Regulation (EU) 2023/1773 (2023) Commission Implementing Regulation (EU) 2023/1773 of 17 August 2023 laying down the rules for the application of Regulation (EU) 2023/956 of the European Parliament and of the Council as regards reporting obligations for the purposes of the carbon border adjustment mechanism during the transitional period. OJ L 228 15.9.2023. Brussels, Belgium: European Commission. Available at: http://data.europa.eu/eli/reg_impl/2023/1773/2024-10-31
- Commission implementing regulation (EU) 2023/1773, 2023b. Commission implementing regulation (EU) 2023/1773 of 17 August 2023 laying down the rules for the application of Regulation (EU) 2023/956 of the European Parliament and of the Council, Brussels: European Commission.
- Commission Services, 2022. CBAM: Draft Commission Services analysis, Brussels: Council of the European Union.
- Creamer Media Reporter (2025) Discovery Green ushers in a renewable-energy future for S African mining, Mining Weekly. Available at: <https://www.miningweekly.com/article/discovery-green-ushers-in-a-renewable-energy-future-for-s-african-mining-2025-02-10>
- Directive (EU) 2003/87/EC, 2003. Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC, s.l.: European Union.
- Discovery (2025) Discovery Green concludes its first renewable energy project agreement with Red Rocket, Mynewsdesk. Available at: <https://www.mynewsdesk.com/za/discovery-holdings-ltd/pressreleases/discovery-green-concludes-its-first-renewable-energy-project-agreement-with-red-rocket-3389382>
- Distel, M. et al., 2025. Large-Scale H2 Storage and Transport with Liquid Organic Hydrogen Carrier Technology: Insights into Current Project Developments and the Future Outlook. Energy Technologies, 13(2), p. 2301042.
- EPO and IEA (2023) Hydrogen patents for a clean energy future: A global trend analysis of innovation along hydrogen value chains. Munich: European Patent office and OECD/IEA. Available at: <https://iea.blob.core.windows.net/assets/1b7ab289-ecbc-4ec2-a238-f7d4f022d60f/Hydrogenpatentsforacleanenergyfuture.pdf>
- European Commission (2024) Part 3 - Accompanying the document “Securing our future - Europe’s 2040 climate target and path to climate neutrality by 2050: Building a sustainable, just and prosperous society”. Commission Staff Working Document Impact Assessment Report {COM(2024) 63 final}-{SEC(2024) 64 final}-{SWD(2024) 64 final}: Part 3/5. Brussels, Belgium: European Commission. Available at: https://eur-lex.europa.eu/resource.html?uri=cellar:6c154426-c5a6-11ee-95d9-01aa75ed71a1.0001.02/DOC_3&format=PDF
- European Commission (2025) Proposal for a Regulation of the European Parliament and of the Council amending Regulation (EU) 2023/956 as regards simplifying and strengthening the carbon border adjustment mechanism. Ordinary legislative procedure 2025/0039 (COD) Brussels, 26.2.2025 COM(2025) 87 final. Brussels, Belgium: European Commission. Available at: https://commission.europa.eu/document/download/606b4811-9842-40be-993e-179fc8ea657c_en?filename=COM_2025_87_1_EN_ACT_part1_v5.pdf
- European Commission (Undateda) FAQ – Maritime transport in EU Emissions Trading System (ETS), <https://climate.ec.europa.eu/>. Available at: https://climate.ec.europa.eu/eu-action/transport-decarbonisation/reducing-emissions-shipping-sector/faq-maritime-transport-eu-emissions-trading-system-ets_en
- European Commission (Undatedb) Reducing emissions from aviation, <https://climate.ec.europa.eu/>. Available at: https://climate.ec.europa.eu/eu-action/transport-decarbonisation/reducing-emissions-aviation_en
- European Commission Joint Research Centre (2021) Policy Brief: Assessment of Hydrogen Delivery Options. European Union. Available at: https://joint-research-centre.ec.europa.eu/document/download/5cddb6f7-7ab4-447b-be0a-dde0a25198ab_en

- European Commission, 2024b. Part 3—Accompanying the document Communication From the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions Securing our future—Europe’s 2040 climate target and path to climate ne, Brussels: European Commission.
- European Commission, 2025. EU’s Climate Law presents a new way to get to 2040. Available at: https://ec.europa.eu/commission/presscorner/detail/en/ip_25_1687
- European Commission, Undatedc. Decarbonising maritime transport – FuelEU Maritime. Available at: https://transport.ec.europa.eu/transport-modes/maritime/decarbonising-maritime-transport-fueleu-maritime_en
- Ferrara, A. R. & Giua, L., 2022. Indirect cost compensation under the EU ETS: A firm-level analysis. Energy Policy, p. (165) 112989.
- Ferrara, A.R. and Giua, L. (2022) Indirect cost compensation under the EU ETS: A firm-level analysis, Energy Policy, 165, p. 112989. Available at: <https://doi.org/10.1016/j.enpol.2022.112989>
- Heinrichs, B., Ohle, L. and Langenhorst, T. (2024) International-PtX-Hub_202402_Legal-considerations-of-global-trade-in-green-hydrogen-and-PtX. International PtX Hub Report. Bonn, Germany: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. Available at: https://ptx-hub.org/wp-content/uploads/2024/02/International-PtX-Hub_202402_Legal-considerations-of-global-trade-in-green-hydrogen-and-PtX.pdf
- IEA (2023) Global Hydrogen Review 2023. Report. Paris, France: International Energy Agency. Available at: <https://iea.blob.core.windows.net/assets/cb9d5903-0df2-4c6c-afa1-4012f9ed45d2/GlobalHydrogenReview2023.pdf>
- IEA (2024) Global Hydrogen Review 2024. Paris, France: International Energy Agency. Available at: <https://www.iea.org/reports/global-hydrogen-review-2024>
- IEA (2025) End-Use Prices Data Explorer. Available at: <https://www.iea.org/data-and-statistics/data-tools/end-use-prices-data-explorer?tab=Overview>
- ITC (Undated) Trade Map. Online database on international trade statistics. International Trade Centre. Available at: <https://www.intracen.org/resources/tools/trade-map>
- Methanol Institute (2023) Methanol price and supply/demand. Methanol Institute. Available at: <https://www.methanol.org/methanol-price-supply-demand/>
- Methanol Institute (2025) Methanol Price and Supply/Demand, <https://www.methanol.org/>. Available at: <https://www.methanol.org/methanol-price-supply-demand/>
- Ocko, I. and Hamburg, S. (2022) For hydrogen to be a climate solution, leaks must be tackled | EDF, <https://www.edf.org/>. Available at: <https://www.edf.org/article/hydrogen-be-climate-solution-leaks-must-be-tackled>
- Piria, R. et al. (2023) EU Requirements for Renewable Hydrogen and its Derivatives: Analysis of the two delegated acts adopted by the European Commission in February 2023 specifying the conditions under which electricity used to produce renewable fuels of non-biological origin (RFNBO) may be counted as fully renewable & the methodology to assess the greenhouse gas emissions savings from RFNBO. International PtX Hub Report September 2023. Berlin, Germany: Internationale Zusammenarbeit (GIZ) GmbH. Available at: https://ptx-hub.org/wp-content/uploads/2023/04/International-PtX-Hub_EU-Requirements-for-green-hydrogen-and-PtX.pdf
- Regulation (EU) 2023/956 (2023) Regulation (EU) 2023/956 of the European Parliament and of the Council of 10 May 2023 establishing a carbon border adjustment mechanism. REGULATION (EU) OJ L 130/52. Brussels, Belgium: European Commission. Available at: <https://eur-lex.europa.eu/eli/reg/2023/956>

- Roos, T. and Wright, J. (2021) Powerfuels and Green Hydrogen (public version). EU-South Africa (EU-SA) Partners for Growth Project Report funded by the European Union. Brussels, Belgium: European Commission. Available at: https://www.euchamber.co.za/wp-content/uploads/2021/02/Powerfuels-Final-Report-South-Africa-EU-SA_Partners-for-Growth-Final-28-Jan-2021.pdf
- Sasol (2025) Discovery Green and Sasol launch Ampli Energy to unlock renewable energy access for all South African businesses |, Discovery Green and Sasol launch Ampli Energy to unlock renewable energy access for all South African businesses. Available at: <https://www.sasol.com/media-centre/media-releases/discovery-green-and-sasol-launch-ampli-energy-unlock-renewable-energy-access-all-south-african>
- Sollai, S. et al. (2023) Renewable methanol production from green hydrogen and captured CO₂: A techno-economic assessment, Journal of CO₂ Utilization, 68, p. 102345. Available at: <https://doi.org/10.1016/j.jcou.2022.102345>
- Trinomics, 2022. Study on the inclusion of the chemical sector in CBAM, The Hague: Dutch Parliament - the House of Representatives (Tweede Kamer). Available at: <https://www.tweedekamer.nl/downloads/document?id=2022D52573>
- Uhorakeye, T., Kopp-Moini, A. and Cohen, B. (2023) PtX Business Opportunities in South Africa. Report. South Africa: PtX Hub South Africa. Available at: https://ptx-hub.org/wp-content/uploads/2024/05/Green-Hydrogen-South-Africa_2311_Business-Opportunities-South-Africa-GH2.pdf
- Vourliotakis, G. et al. (2024) CARBON CAPTURE IN SOUTH AFRICA: An overview on Carbon Capture and Storage or Utilisation in South Africa. Report prepared for International PtX Hub by EXERGIA Climate Change Consultants. Bonn, Germany: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. Available at: https://ptx-hub.org/wp-content/uploads/2024/03/International-PtX-Hub_202403_Carbon-Capturing-South-Africa.pdf
- Ward, J. (2023) Carbon Border Adjustment Mechanisms and Implications for South Africa. A PRESIDENTIAL CLIMATE COMMISSION WORKING PAPER. Pretoria, South Africa: Presidential Climate Commission. Available at: <https://pcccommissionflo.imgix.net/uploads/images/PCC-Working-Paper-CBAM.pdf>
- Young, B. & McGregor, C., 2024. South Africa's green hydrogen hub: EU grants not nearly enough to get industry going. [Online] Available at: <https://theconversation.com/south-africas-green-hydrogen-hub-eu-grants-not-nearly-enough-to-get-industry-going-238706>