

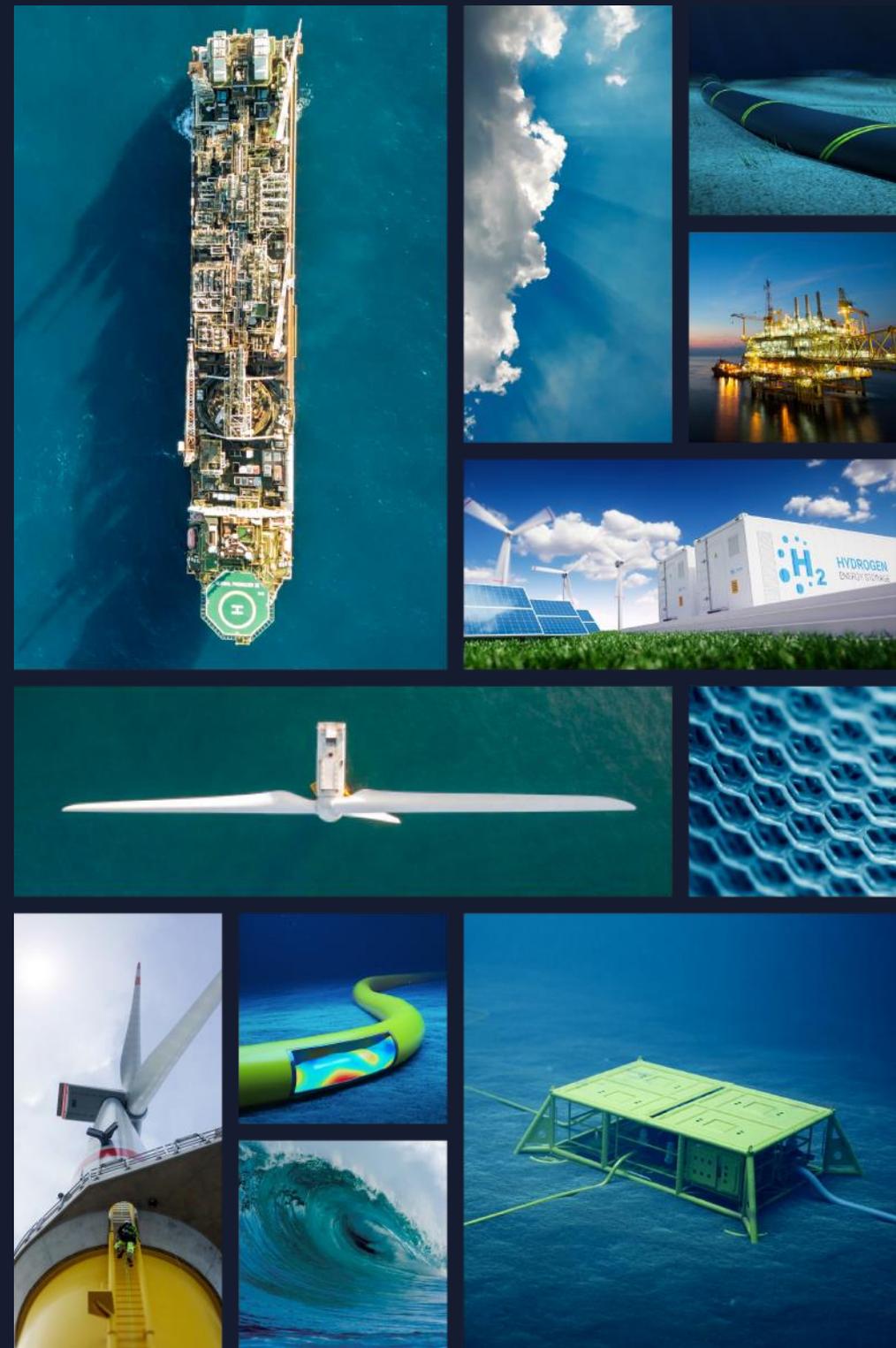


# Final Report - Public

Dutch Ministry of Economic Affairs  
and Climate Policy

L-400699-S00-Y-REPT-001

[WWW.XODUSGROUP.COM](http://WWW.XODUSGROUP.COM)





# Final Report

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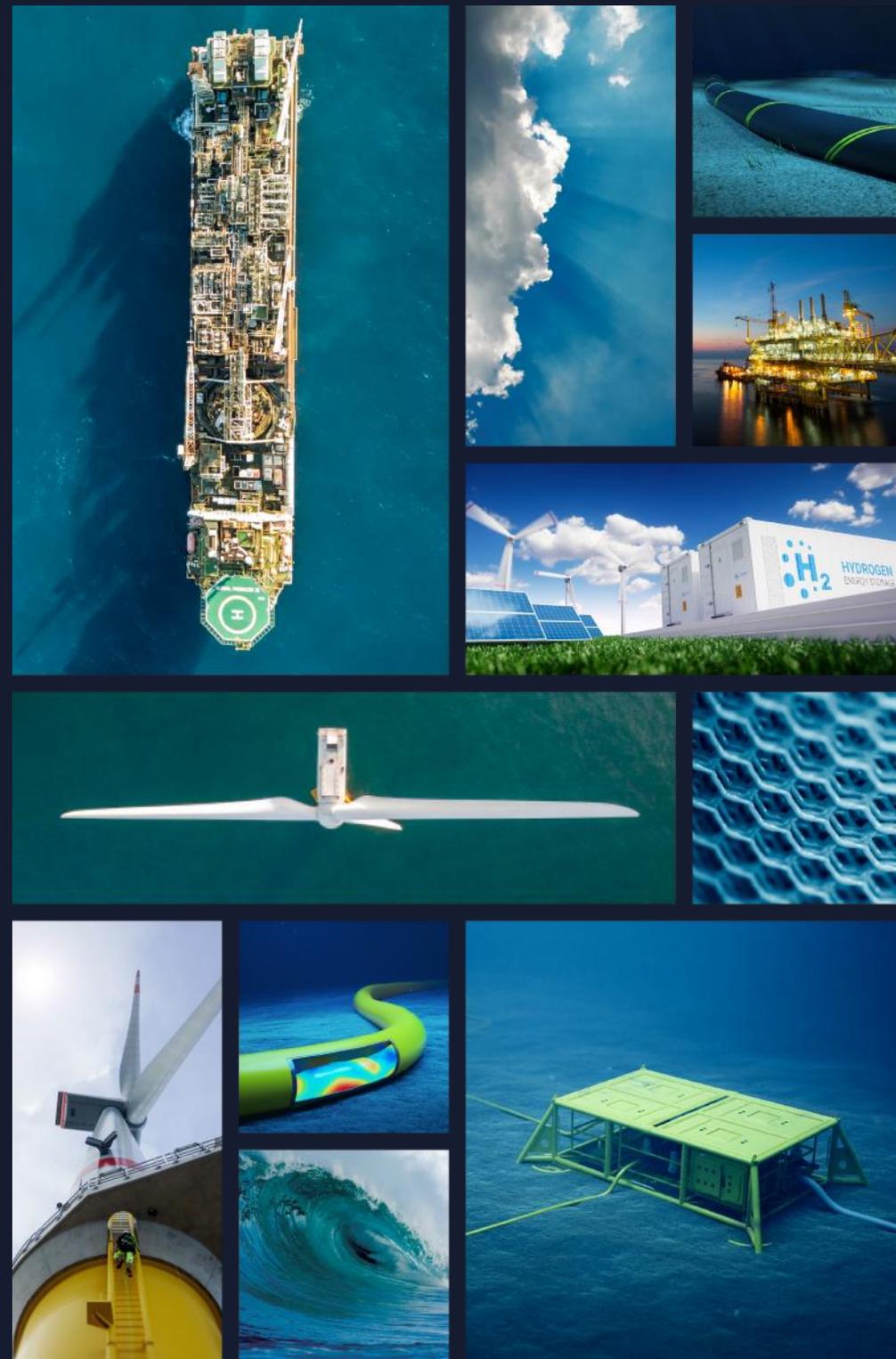
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# Executive Summary



# Executive Summary - Overall

Xodus has reviewed the Aramis project concept, cost estimates and the Aramis economic models.

The scope of Xodus’ assessment pertained only to the Porthos onshore gas pipeline, compressor station, trunkline and 2 x storage sites. Due to competition laws, the assessment of the two stores operated by Shell and TotalEnergies has been done independently and shared on an individual basis.

Xodus has not evaluated the shipping or terminal components of the Aramis value chain; it was not part of the Xodus workscope. Xodus engaged Porthos separately to obtain an indicative onshore pipeline tariff for Aramis customers.

The main purpose of the study was to:

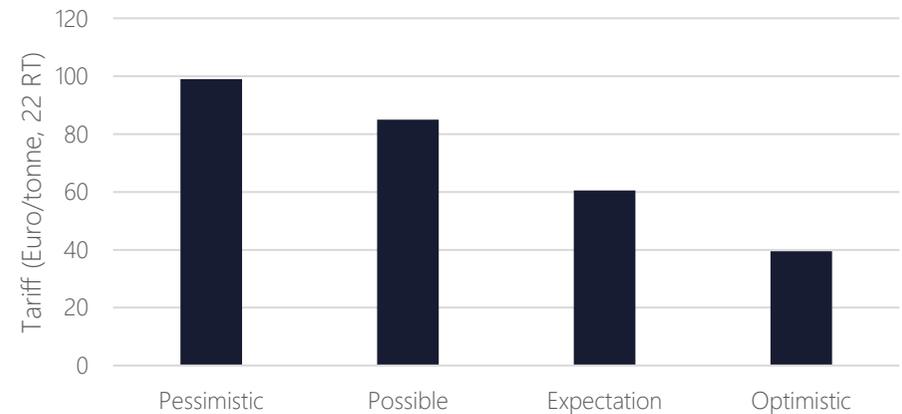
- Understand the reasonableness of the Aramis calculated Transport and Storage (T&S) tariff.
- Assess the cost and benefit of integration with the Porthos onshore system
- Assess the cost and benefit of the open access concept that Aramis intends to use.
- Provide an update of CCS projects that have emerged since the Porthos assessment of Xodus in 2020 and the impact on Aramis.

For the tariff assessment, the Aramis JV presented 4 scenarios, based on a range of cost outcomes and whether CEF grant funding can be secured from the European Union.

To evaluate the reasonableness of the Aramis estimated tariff, Xodus carried out the assessment in two ways:

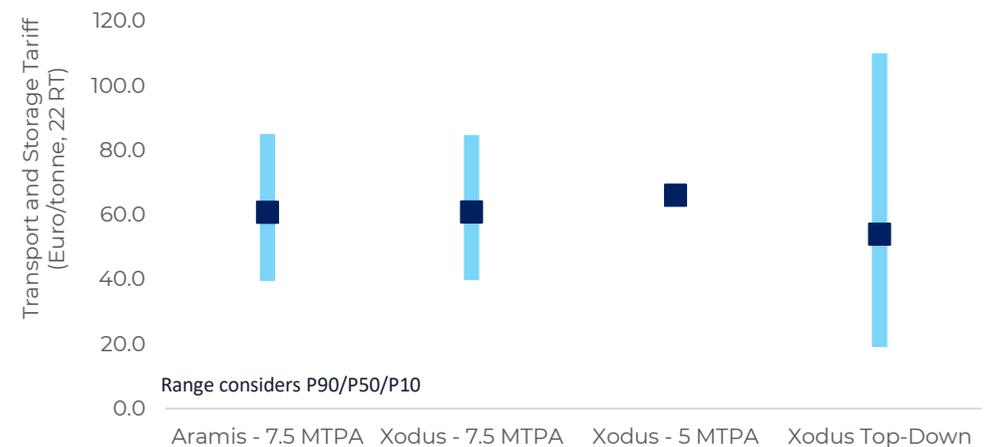
- Approach 1 – a ‘top-down’ benchmarking analysis where the Aramis project was compared to other planned CCS projects globally, building on the previous assessment carried out for Porthos in 2020.
- Approach 2 – a ‘bottom-up’ analysis whereby Xodus recreated the Aramis design in our cost estimating software and database to arrive at an independent tariff estimate and range.

Aramis Proposed Gas Tariff (7.5 MTPA)



\*excludes Porthos onshore pipeline tariff

Aramis Tariff Comparison



\*Excludes shipping, terminal costs and Porthos onshore pipeline tariff. Xodus storage cost for representation is as per Aramis, due to confidentiality reasons.



# Proposed Tariff

The scope of the proposed tariff includes the Porthos onshore pipeline, compressor station, offshore trunkline and CO2 stores. Costs associated with shipping and the CO2 terminal have not been included in this assessment.

Based on guidance from the Ministry of Economic Affairs regarding input assumptions, the Base Case tariff is estimated to be EUR 71.8/tonne (22,RT).

## Conclusions:

- Xodus considers the cost estimates and tariffs provided by Aramis to be reasonable. Xodus bottom up and top-down tariff analysis is comparable with what was presented by the Aramis project team.
- The Aramis project is still in an early stage of development, with current high volatility in the market, and therefore there are uncertainties in the current cost estimates and associated tariff for a project that will not reach FID until 2025 and first injection by 2027.
- There are some differences compared to the proposed guidance of the Ministry of Economic Affairs, relating to:
  - Securing 40% CEF grant funding. The Ministry of Economic Affairs assumes no CEF grant funding is received, whereas Aramis assume this can be achieved. Securing CEF grant funding would reduce the tariff. Given Porthos successfully secured CEF funding, Xodus considers this a reasonable assumption by Aramis.
  - Assumed IRRs are higher in the Xodus / Aramis case compared to guidance proposed by the Ministry of Economic Affairs.
- The trunkline capacity is over-designed with a capacity of 22 MTPA in order to support build out of future CO2 stores. The current Launch Phase of the Aramis project is 5 MTPA, with a view that a further 2.5 MTPA can be secured by Final Investment Decision (FID), totalling 7.5 MTPA. There is potentially considerable residual value in the trunkline post SDE++ subsidy after 15 years, if further stores and emitters can be identified.

EUR/tonne (22 RT)	Base Case
Base Case	71.8
Xodus Bottom-Up	67.4
Aramis Expectation Case	67.0



# Introduction



# Introduction

The Aramis CCS project is a partnership between TotalEnergies, Shell, EBN and Gasunie to develop a backbone transport and storage system to bring captured CO<sub>2</sub> from emission sources to offshore storage sites.

The infrastructure will be over-sized for 22 MTPA capacity with a target initial injection rate of c. 5 MTPA. The oversizing will support future buildout and expansion of the CO<sub>2</sub> emitter network, leveraging the Porthos infrastructure, and also enable potential future import of CO<sub>2</sub> via ships. The design life of the transport infrastructure will be 30 years.

The project considers:

- Shipping that will collect liquified CO<sub>2</sub> from new export terminals located in the North Sea port area on both sides of the Westerschelde estuary, studied by Aramis
- A new receiving shipping terminal at Massvlakte, operated by CO<sub>2</sub>next
- Adding incremental compressor capacity at the existing Porthos compressor station which will collect gas from Rotterdam through the existing Porthos onshore pipeline.
- A trunkline that will export dense phase CO<sub>2</sub> to the offshore storage sites
- 2 x storage sites in the Launch Phase

The Launch Phase will focus on transport and injection of 5 MTPA into two storage sites, operated by Shell and TotalEnergies separately. During the Launch Phase the transport and storage capacity will be jointly marketed.

The project aims to achieve Final Investment Decision (FID) by 2025 with first injection occurring in 2027. The project is currently in concept select phase with this due to be complete this summer (2022).



# Scope of Work

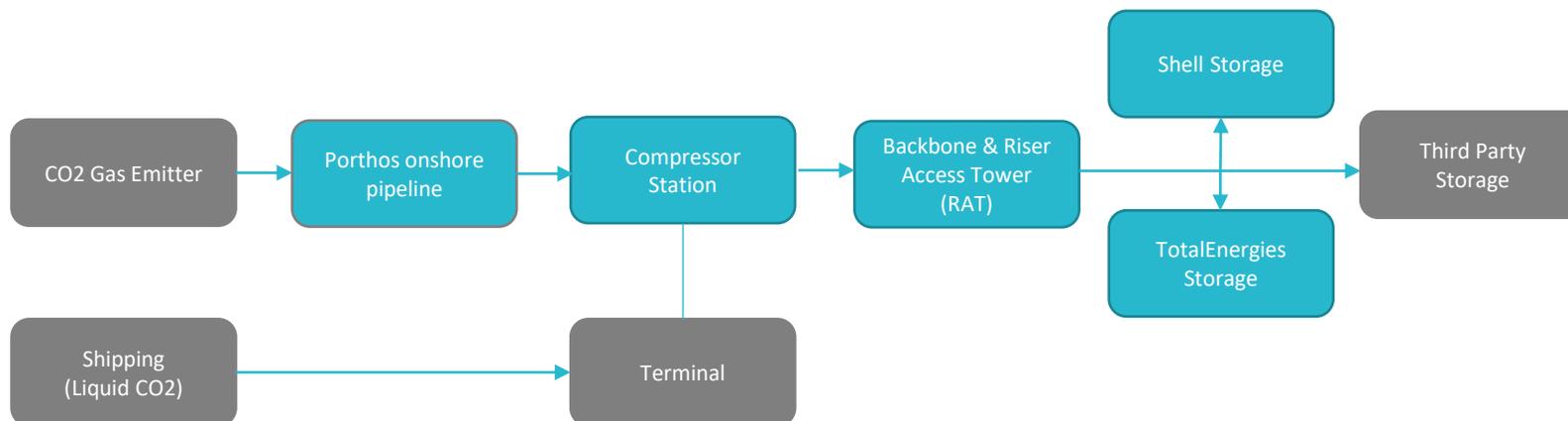
The Ministry of Economic Affairs and Climate Policy of the Government of the Netherlands has requested Xodus to carry out a review of the requested subsidy for the Aramis CCS project, building on the work carried out in 2020 by Xodus for the Porthos CCS project.

The scope of Xodus' assessment entails:

1. Verify and validate the transportation and storage fee as calculated with specific assessment of:
  1. Project return and return on equity of Aramis
  2. Residual value after 15 years (lead time SDE ++ subsidy)
  3. Risk premiums and insurances
  4. Significant cost components
  5. Cost and benefits of the infrastructure, which is partly shared with onshore Porthos backbone
  6. Cost and benefit of open access concept that Aramis intends to use. Aramis intends to enable additional CCS parties to connect and feed in on their infrastructure.
2. New CCS projects (that emerged after 2020), that have a significant impact on the results. Projects from which the parameters have significantly changed from the 2020 review should also be taken into consideration.

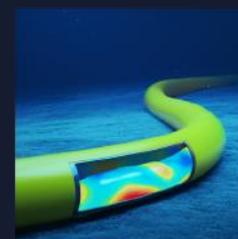
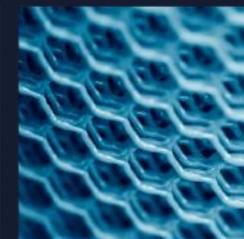
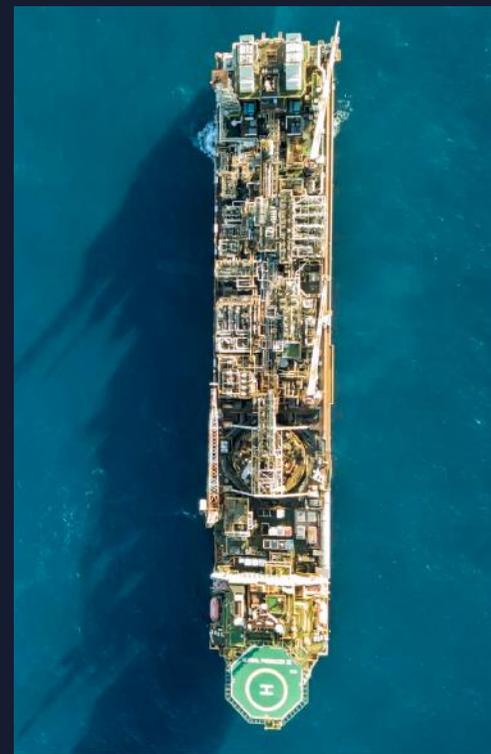
Technical expertise and insight into the construction, exploitation and maintenance of compressor stations and offshore pipelines is required.

A summary of Xodus' scope of assessment is outlined below, with items highlighted in grey excluded from the study.





# Project Aramis Overview





# Tariff Scenarios

Four tariff scenarios have been presented by Aramis to Xodus and shared with emitters. For the purposes of this representation, the storage component is an average of the Shell / TotalEnergies storage tariffs. The range of scenarios consider impact of P90/P10 cost outcomes as well as whether CEF funding can be secured for the Shipping / Transport component. If CEF funding could be secured for the stores, this would represent a further ~ EUR 10/tonne reduction from the Expectation Case.

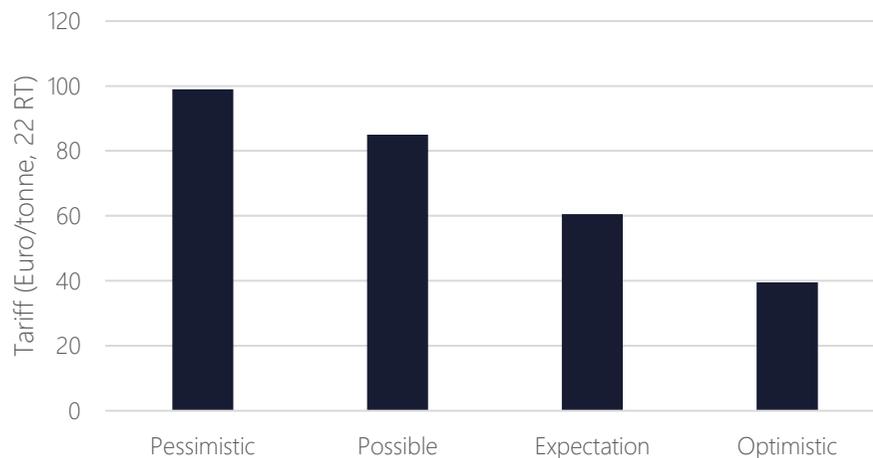
For gaseous emitters, which flow through the Porthos onshore backbone, these emitters will need to agree a tariff with Porthos to transport gaseous CO2 from the emitter to the compression terminal. This has not been included in the tariffs quoted below, but Xodus has engaged with Porthos to provide an indicative tariff.

Scenario	Description
Pessimistic	High Cost & Zero CEF
Possible	High CAPEX & OPEX, transport CEF only
Expectation	Base Case, P50 Costs, CEF funding
Optimistic	Low Cost + CEF stores

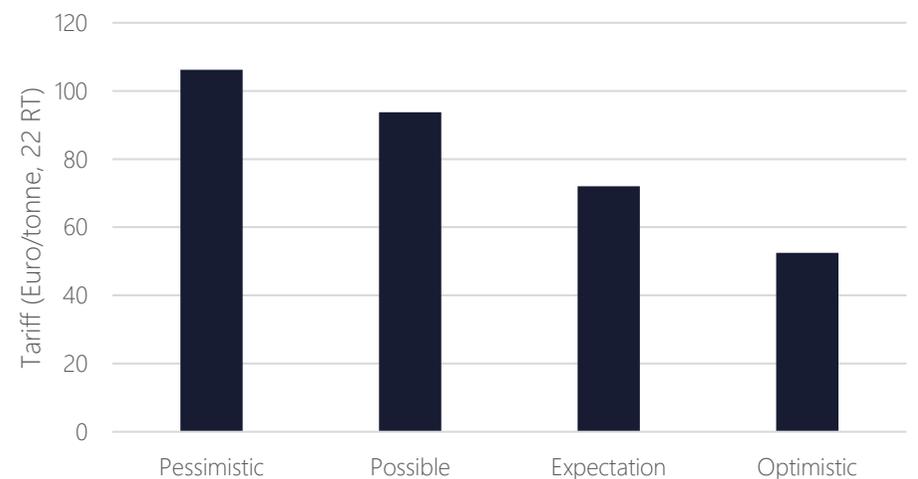
Tariff scope of assessment:

- In the Aramis Gas Tariff, Xodus has assessed 100% of the tariff contemplated by Aramis. Gaseous CO2 emitters will need to negotiate a separate tariff for transport of gaseous CO2 to the compression station via the Porthos pipeline.
- In the Aramis Liquid Tariff cases, Xodus has not reviewed the Shipping and Terminal tariff costs.

### Aramis Gas Tariff (7.5 MTPA)



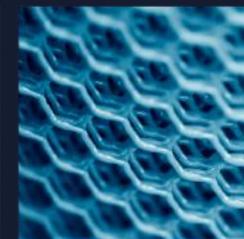
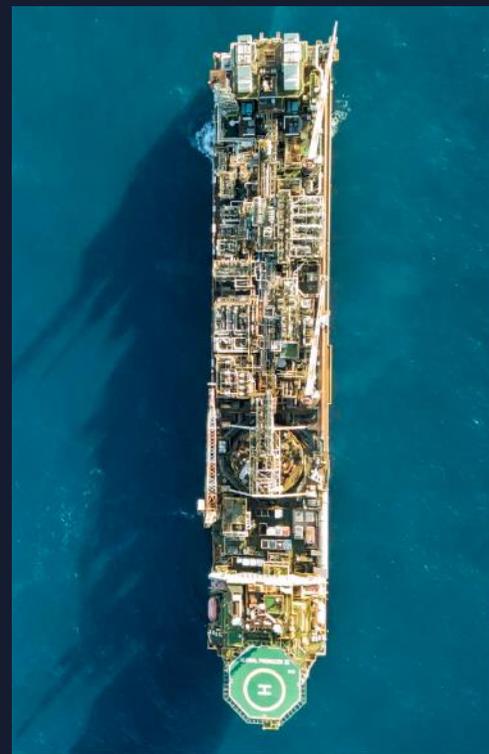
### Aramis Liquid Tariff



\*excludes Porthos onshore pipeline tariff



# CCS Project Update and Comparison



# Top Down Assessment

In 2020 as part of the Porthos subsidy review, Xodus carried out a top down benchmarking exercise to assess Porthos against other Transport and Storage (T&S) projects either planned or in operation.

The assessment focused on projects that were a) multi-party “industrial backbone” type developments and b) have accessible reports detailing project specifications, plans and estimated costs.

High level information was gathered on costs and injection volumes to assess what a pseudo T&S tariff would be for these projects.

In 2020 there were no operational CCS projects with multiple suppliers and a shared backbone. Currently there still no operational projects, with the planned projects currently targeting operation by mid 2020's. Since 2020, there have been a number of new projects announced with funding mechanisms provided by Governments including the Netherlands, UK, Norway and Denmark.

For the updated assessment, Xodus has carried out the following:

- High level review of regional CCS related policies
- Projects update since 2020 that have been announced post the issue of Xodus report
- An update of pseudo tariff for CCS industrial backbone projects, discounting a number of projects that were assessed previously, but have been cancelled.

What is clear from the assessment is that the progression of industrial hub based CCS projects has accelerated in the North Sea with a number of projects being progressed. Each project has its nuances which may consider

- Re-use of existing infrastructure (HyNet, Acorn)
- New infrastructure with injection into saline aquifer (East Coast Cluster / Northern Endurance Project)
- Combination of shipping and trunkline (Project Longship / Northern Lights)
- Integration with the production of blue hydrogen (Hynet, Acorn, East Coast Cluster)

Projects such as Acorn and Hynet will benefit from utilising existing infrastructure, such as the trunkline to transport CO2 offshore, which will reduce the up-front CAPEX and associated tariff. Projects with new infrastructure, such as East Coast cluster and Project Longship, will require higher CAPEX and in the latter case added complexity with a shipping solution. This element is comparable to Aramis.

# European CCUS Update

Since Xodus' 2020 report on Porthos there have been several advancements in CCUS projects within Europe with activity across a number of countries and supporting mechanisms being put in place

## Netherlands

- Porthos project and emitters successfully received SDE++ in 2020 with a grant of EUR 2.213 billion granted over a 15 year period to enable storage of 2.34 MTPA (source GCCSA)
- Porthos project secured CEF grant funding to support the capital investment
- FID is scheduled for 2022.
- Aramis project in concept select with aim for FID in 2025 and first injection by 2027

## United Kingdom

- Government stated aim to have 2 x CCUS projects operational in mid-2020s and 4 x CCUS projects by 2030 injecting 10 MTPA
- Track 1 Clusters have been announced as the East Coast Cluster and Hynet with the Scottish Cluster in reserve. Track 1 Clusters are comparable in concept to Porthos / Aramis with a cluster approach from an industrial hub.
- £1 billion infrastructure fund allocated to support these projects
- CCUS Business models have been established for capture and transport/storage components. These will be operated under a Regulated Asset Base Model, with utility style returns..
- Launched CO2 storage licencing round in June 2022.

## Norway

- Project Longship has been launched which includes the Northern Lights CCUS project.
- FID was approved by the Norwegian government in Dec 2020
- The Norwegian government has provided \$1.9 billion of the total \$2.8 billion cost (CAPEX + OPEX) over 25 years.
- Considers initial phase of capturing CO2 from plants within Norway for future expansion to support third party CO2
- The Norwegian Ministry of Petroleum and Energy has since awarded carbon capture and storage licenses to a consortium comprising Equinor, Horisont Energi, and Vår Energi. These licences are located in in the North Sea and Barents Sea.

## Denmark

- Danish Government in 2021 committed EUR 2.2 billion to support development of CCUS projects
- Two projects have received \$41 million to support their development. These are the Greensand (INEOS) and Bifrost (TotalEnergies)
- Projects will consider repurposing of existing infrastructure to support CCUS

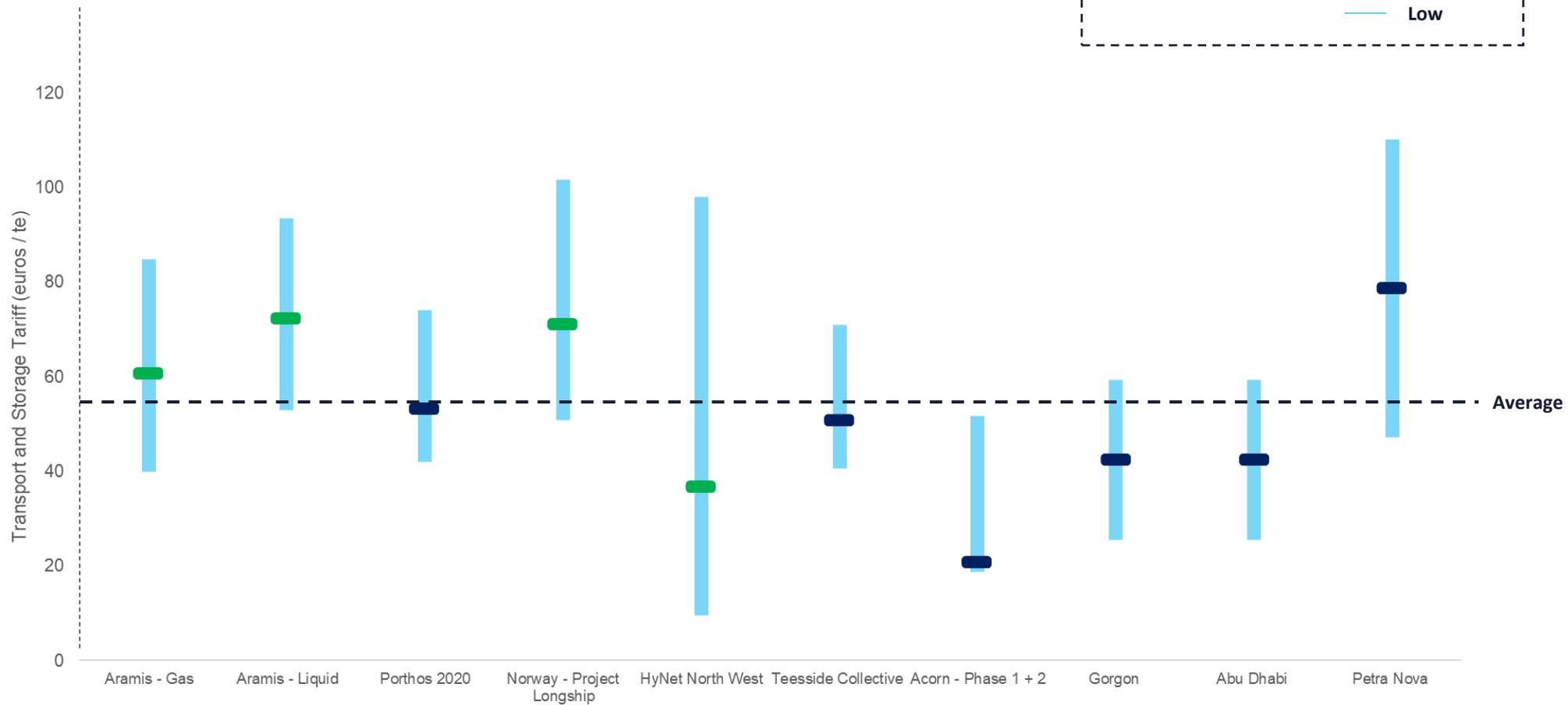
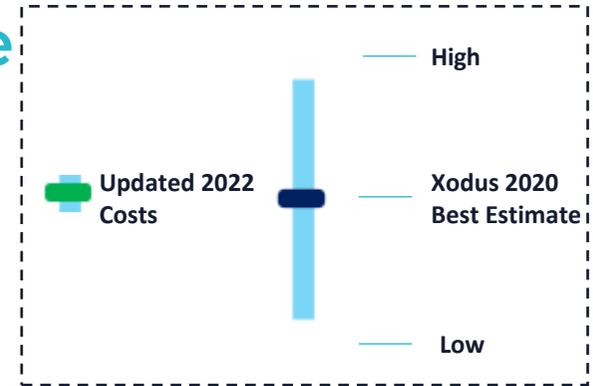
# Projects Update (1)

Project	Considered in 2020	Location	Capacity	Consortium	FID	First Injection	Commentary
<b>Porthos</b>	Yes	Netherlands	2.5 MTPA	EBN, Gasunie and Port of Rotterdam Authority	H2 2022	2024/25	Porthos is currently focusing on three main issues. These issues must be concluded so that a final investment decision (FID) can be taken in the second half of 2022: <ol style="list-style-type: none"> <li>1. Technical development of the transport and storage infrastructure</li> <li>2. Environmental Impact Assessment and permits</li> <li>3. Agreements with companies to supply CO2 and with the Dutch government to enable CCUS</li> </ol>
<b>Aramis</b>	No	Netherlands	Phase 1 – 5/7.5 MTPA Total - 22 MTPA	Shell, TotalEnergies	2025	2027	The infrastructure will be over sized to handle up to 22 MTPA and will consider an open access system. The Launch Phase targets CO <sub>2</sub> injection rate of 5 MTPA in dense phase with a target to secure a further 2.5 MTPA before FID. The project will consider combination of CO2 emitters from onshore and ships.
<b>Longship / Northern Lights</b>	No	Norway	Phase 1 1.5 MTPA, increasing to 5 MTPA	Shell, TotalEnergies, Equinor	Approved Dec 2020	Mid 2024	Northern Lights, which is responsible for the transport and storage part of Longship, plans to increase storage capacity to 5 million tonnes per year through an additional development phase (Phase 2) and an increasing customer base.
<b>Greensand</b>	No	Denmark	8 MTPA	INEOS	H2 2023	2025	1 <sup>st</sup> phase injecting 0.5-1 MTPA from 2025, increasing to 4-8 MTPA by 2030
<b>Bifrost</b>	No	Denmark	3 MTPA	Noreco Orsted DTU	Unknown	Unknown	The project study is a fairly recent announcement from Sept 2021. The study is due to begin in 2022, and is early in development stage.
<b>East Coast Cluster (Net Zero Teesside + Humber Zero)</b>	Yes (but as Teesside collective)	UK	Phase 1, 4 MTPA, Phase 2 10 MTPA, with up to 27 MTPA total capacity	BP, Eni, Equinor, Shell, TotalEnergies	2023	2026	Track 1 Cluster project that combines decarbonisation of two of UK's largest two industrial clusters Zero Carbon Humber and Net Zero Teesside. CO2 will be captured and stored offshore in a saline aquifer at Northern Endurance. The project will require new offshore infrastructure.

# Projects Update (2)

Project	Considered in 2020	Location	Capacity	Consortium	FID	First Injection	Commentary
<b>HyNet</b>	Yes	UK	1.2 initially, increasing to 10 MTPA	Progressive Energy / ENI	2024	2026	Track 1 Cluster project that focuses on producing blue hydrogen in the North West of England. CCUS infrastructure will be developed using largely re-purposed oil and gas assets, to capture, transport and store CO2 from industrial anchor sources. Pipeline infrastructure will be sized up to 10 MTPA to accommodate future phases of system growth. Initial injection is in gaseous phase into a depleted gas field, changing to dense phase in later life.
<b>Scottish Cluster</b>	Yes (as Acorn)	UK	Phase 1 0.3 MTPA 5.5 MTPA by 2028 7 MTPA by 2030	Storegga, Shell, Harbour Energy, INEOS	2022	2025	Acorn project will initially capture CO2 from St Fergus terminal and re-use existing infrastructure to inject CO2 offshore. The project will build out to capture CO2 sources from Scotland, such as Grangemouth as part of the Scottish Cluster. will be developed in phases. Blue Hydrogen will also be planned. The Scottish Cluster did not receive Track 1 funding from the UK Government, but is considered a Reserve Project. Financial backing of up to £80 million is being offered to help the Scottish Cluster carbon capture project accelerate its effort to help Scotland's just transition to net zero.
<b>V Net Zero</b>	No	UK	11 MTPA by 2029 12 MTPA by 2034	Harbour Energy, Humber Zero, EP UK Investments and Prax Lindsey Oil Refinery	2024	2027	The V Net Zero Humber Cluster has the potential to capture, safely transport and securely store >50% of the existing industrial emissions (19.8MTPA) in the Humber region.

# Project Comparison – Transport & Storage



\*Aramis assumes 40% CEF Funding and excludes Porthos onshore pipeline tariff

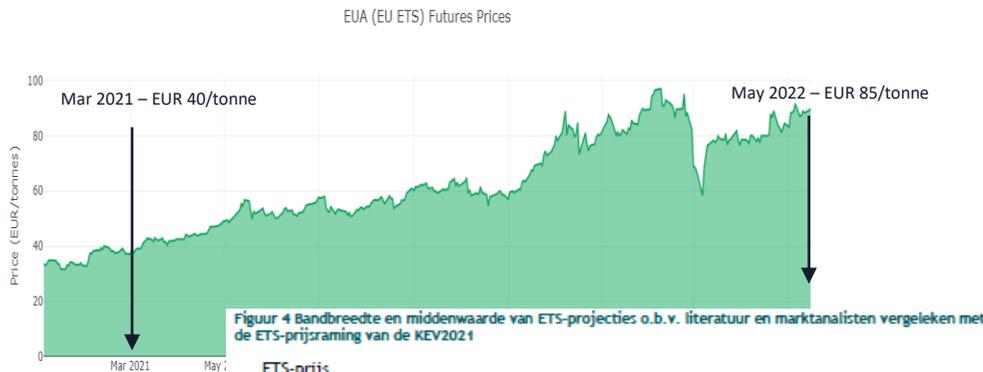
# Market conditions since 2020

Since 2020, the market conditions have materially changed. CO2 ETS price has increased, but electricity and steel prices have also risen as economies exit COVID and there are effects of Ukraine's invasion. It is expected that electricity / steel prices may drop by Aramis first injection, but there remains uncertainty in the costs.

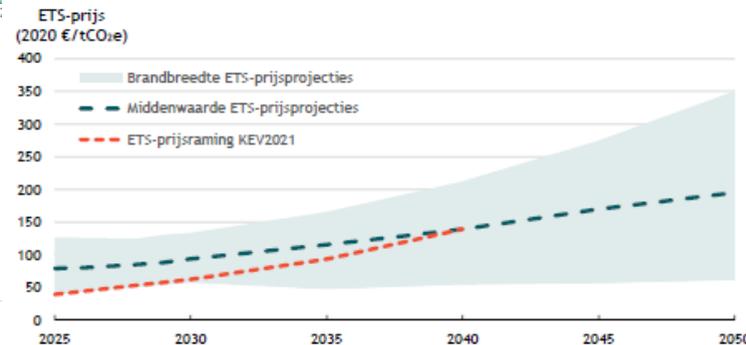
## CO2 price

Since 2020, the EU ETS price has increased materially from ~EUR 30/tonne to ~EUR 85/tonne in May 2022.

It is expected that the EU ETS price will continue to increase through 2020s, which requires industry to reduce their carbon exposure through initiatives such as CCUS. The Ministry of Economic affairs recently published an updated outlook for the price of CO2 which is shown below.



Source: Ember Climate

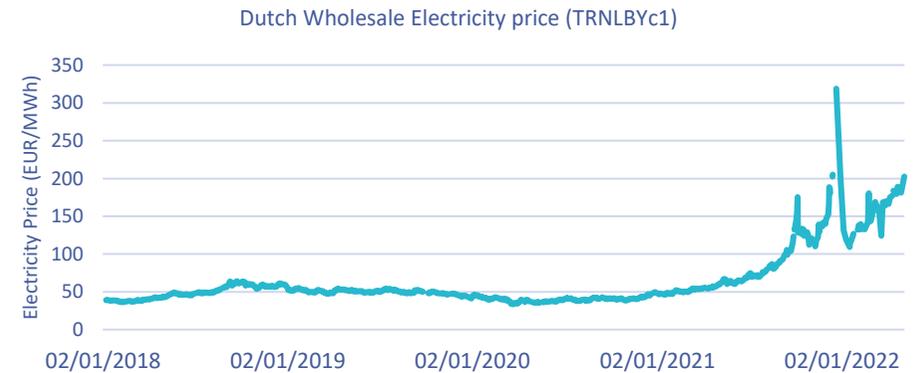


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Source: Ministry of Economic Affairs, <https://www.rijksoverheid.nl/documenten/rapporten/2022/02/25/second-opinion-ets-prijs--eindrapport>

## Electricity price

Dutch wholesale electricity prices have increased from ~ EUR 50/MWh in 2020 to EUR 200/MWh in 2022 due to Ukraine invasion.



Source: Refinitiv

## Steel price

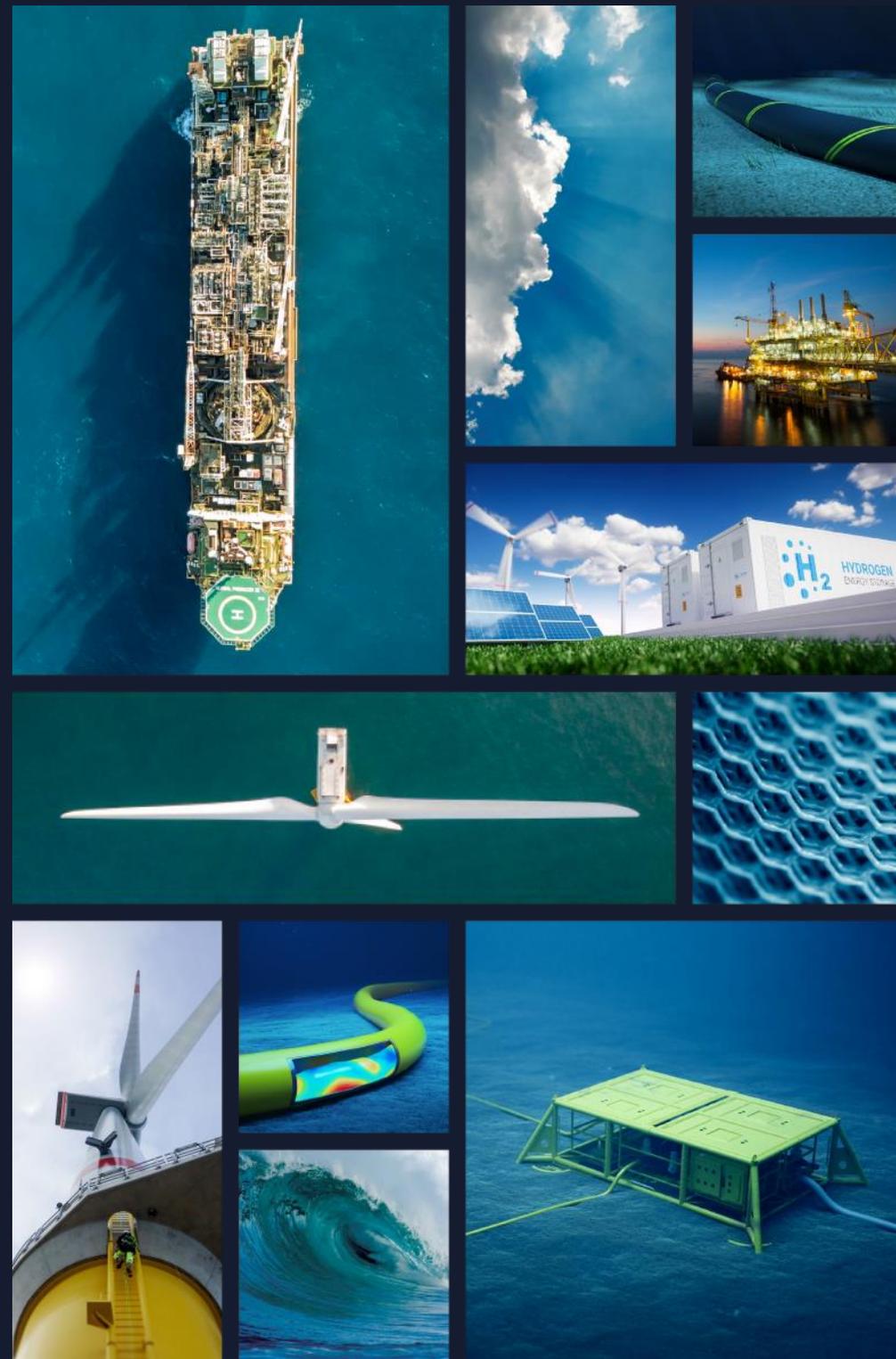


Source: Refinitiv

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# Abbreviations





# Acronyms and Abbreviations

Acronym	Description
CAPEX	Capital Expenditure
CCUS	Carbon Capture Utilisation and Storage
CEF	Connecting Europe facility
CO2	Carbon Dioxide
EUR	Euros
EU ETS	European Union Emissions Trading Scheme
FID	Final Investment Decision
FOB	Free on Board
JV	Joint Venture
Mt	Million Tonnes
MTPA	Million Tonnes per Annum
MWh	Mega Watt hours
OPEX	Operating Expenditure
RT	Real Terms
T&S	Transport and Storage