Kgs. Lyngby, Denmark
1st October 2024

CarbonCuts A/S- Slutrapportering 1. oktober 2024 til Den Danske Maritime Fond.

Projekt reference: Den Danske Maritime Fond

CarbonCuts, Undersøgelse af muligheden for at anvende en mobil, flydende lægter til import og mellemlager af CO2

År: 2023 – Projekt: 2. Maritim erhvervsudvikling – Udgivet den 6. oktober 2023.

CarbonCuts A/S conclusive report.

Background:

CarbonCuts is working to establish the "Ruby Project", which is a land-based underground CO2 storage in Rødby on Lolland. The storage must be established in one of the geological structures that the Danish Energy Agency has designated as suitable for CO2 storage. The structure in Rødby consists of an underground salt water reservoir, which forms a 10 x 20 km area at Rødby and Rødbyhavn. The location is particularly well placed to receive and store CO2 both from Danish and other emitters in the Baltic Sea region. CarbonCuts estimates that the Ruby Project can annually store around 1,5 million tonnes of captured CO2 in the project's first phase.

Press release: CarbonCuts awarded exploration licence on Lolland for onshore CO_2 storage Project 'Ruby'

"Kgs. Lyngby, June 20, 2024 – The Danish authorities have awarded CarbonCuts a licence to explore the possibility of a future onshore CO_2 storage facility on the island of Lolland. CarbonCuts expects to begin storage in 2030 or earlier following a successful exploration plan. The project, located near the town of Rødby, has been named ´Ruby´".

In addition to the underground storage itself, the Ruby Project must also establish other necessary sub-elements in the infrastructure which is part of the CCS value chain and which makes it possible to receive and store CO2, whether the CO2 is transported to the storage via train, pipeline or ship. Including facilities that can receive and store the imported CO2 temporarily (interim storage). After staying in the intermediate storage, the liquid CO2 will either be sent to permanent storage in the underground storage or included in the production of green fuels (PtX). CarbonCuts plans to investigate whether it is possible to establish a floating tank-based intermediate storage at sea.

Project:

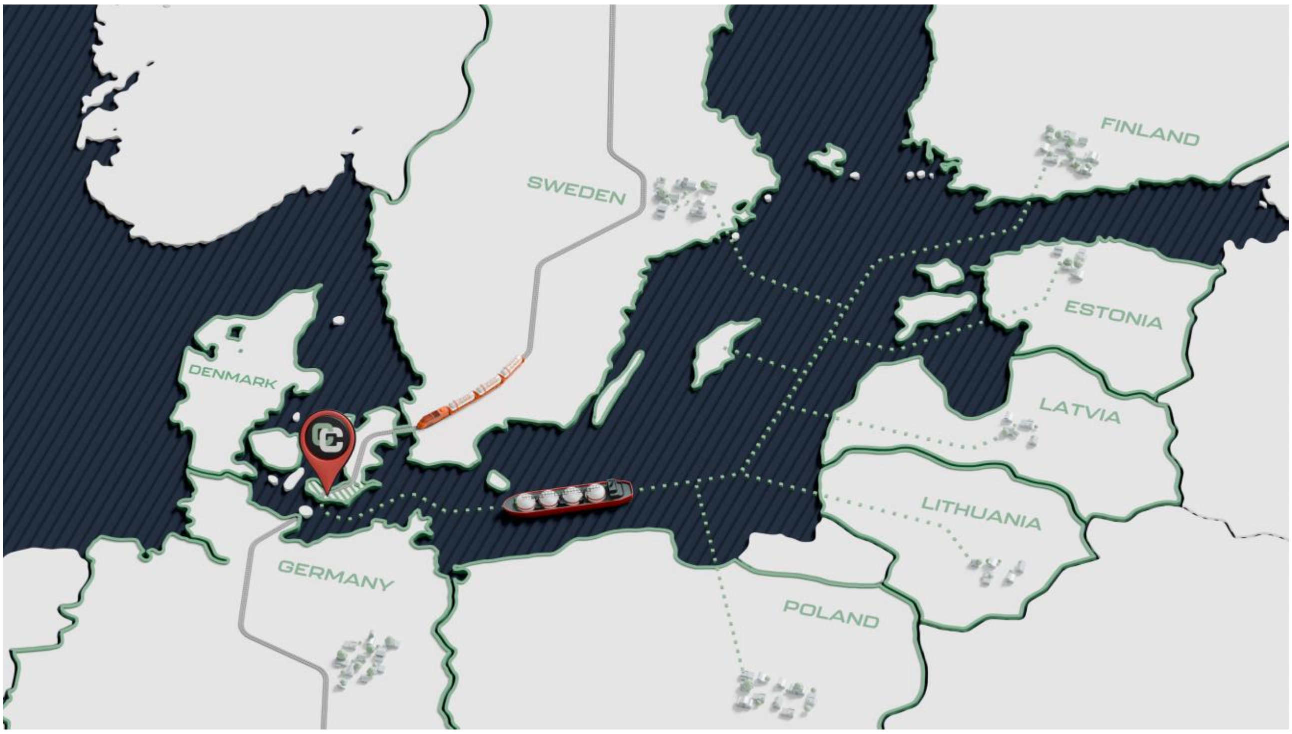
Regardless of which way the CO2 arrives at Rødby, it is necessary to establish import and intermediate storage facilities in order to receive CO2 in liquid form. To be able to receive CO2 via ship, CarbonCuts has investigated whether, as an alternative to a traditional land-based import/interim storage at the port, it is possible to build a storage barge. A storage barge is a flexible floating intermediate storage consisting of CO2 tanks on a flat-bottomed barge, which is placed either in the harbor or at seaside.

The barge solution offers several advantages compared to the land-based solution:

- more flexible, because the barge is floating and movable,
- easier to expand the storage size in terms of area,
- can be constructed via modules on shipyards and hence less local impact during construction
- is further away from public traffic.

Results

A so-called FEED "Front End Engineering Design" study of the Barge design has been carried out and provided a good certainty for feasibility, understanding practical and physical limitations, estimations of costs, and further needs for the project development. In addition, the study has provided an understanding of the barge design and solution relative cost-efficiency compared to a traditional land based solution.



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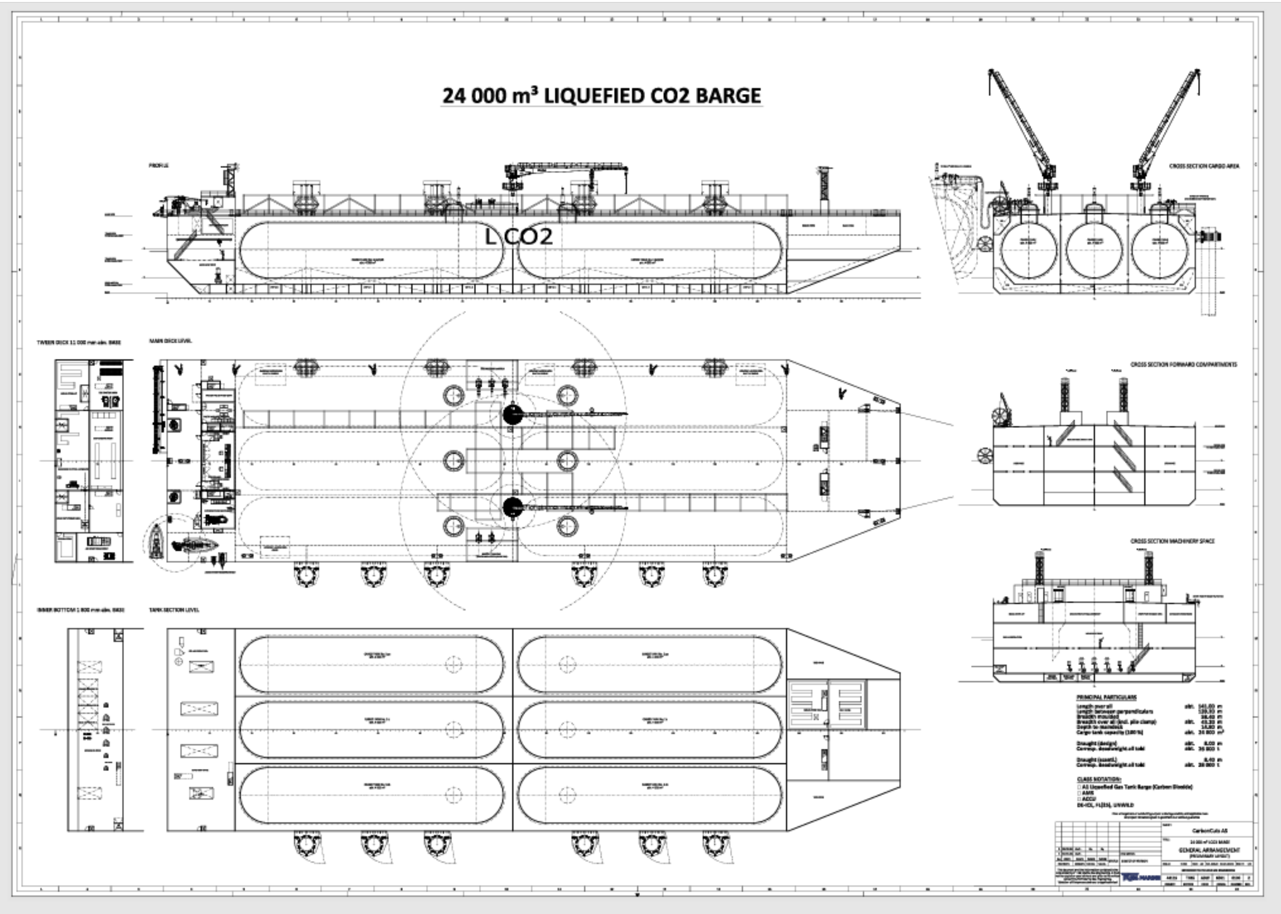
The FEED Study

The FEED "Front End Engineering Design" study of the Barge design and concept has been carried by CarbonCuts A/S, TGE-Marine and American Bureau of Shipping, ABS.

Following outcome and deliverables has been developed:

The General Arrangement, GA:



The Outline Specification (partial):

General outline of the barge

The vessel shall be designed, constructed, built and delivered as a floating barge for temporary storage and send-out of liquefied carbon dioxide (LCO_2) to shore in Denmark, Lolland in the area of Rødby. The vessel will fulfilling the applicable rules and regulations of the International

Maritime Organization (IMO), the classification society, and the relevant requirements of the flag authorities.

The barge is part of the import facility of the Floating Storage and Offloading facility project for the receipt, storage and transmission of CO_2 for permanent underground storage below Lolland in Denmark.

The LCO_2 barge will be located outside along the existing breakwater, facing with starboard side to the breakwater and portside to the open Baltic Sea, from which the frequently calling LCO_2shuttle carrier will approach and be moored to the barge.

The general intention is to keep the barge permanently onsite for continuous operational/send-out reasons in moderate water/environmental conditions by a pile mooring system, able to withstand environmental loads.

The mooring system shall allow free floating conditions for the barge and suitable to compensate the expected tide levels and/or the frequent draught variations during operation.

In case of more severe environmental conditions which will exceed the overall design conditions for the mooring system, and or an emergency event, the barge will need to be relocated to a safe area in advance by tugboats.

The clamps shall be hydraulically operated, allowing a quick release of the barge from the piles by hydraulic open/close devices. The time frame for releasing the barge from the piles shall be as quick as possible.

The barge will be non-propelled and designed to stay onsite without the need for dry docking for an operational lifetime of 25 years.

During normal operation onsite, the barge will be electrically powered from shore by suitable plug-in cable connection to shore.

The operational control philosophy onboard shall be based on a permanently manned barge during all normal LCO_2 send-out operation onsite including frequent cargo transfer operations from LCO_2 shuttle carrier and during transport/waiting periods in case of barge relocation caused by emergencies.

The vessel will be operated in general from the control and monitoring room on main deck. All major operation and safety systems for the barge and the cargo system shall be centralized within this compartment.

A selection of operational information shall be transferred to shore by suitable interface connection for monitoring purposes.

The LCO_2 will be stored onboard the barge in 6 cylindrically shaped IMO type C tanks, arranged as shown in the general arrangement plan and further described in the separate specification for the cargo handling system.

The LCO_2 cargo containment system of the barge will follow the philosophy of a 'pressure built up' conception without cargo boil-off gas (BOG) reliquefication.
The barge is designed to receive liquefied CO2 from either Low pressure (about -45 deg c and 7.5 bars pressure) or Medium pressure (about -30 deg C and 18 bars pressure) import vessels. The barge's storage tanks are of MP design so a cargo heater is included in the design to heat the CO2 from Low Pressure vessels.
When pumping ashore the barge will use cargo heater and booster pumps to raise temperature to about -20 degc and about 15 bars pressure. Ashore a heater and booster station will raise temperature and pressure to injection requirements - ca. +10 deg C and 65 bars.
As the discharge ashore will be continuous at low-rate half of the barge's deep well cargo pumps will be designed with variable frequency drive to enable energy efficient pumping at low rate – anticipated to be in the range of about 150-250 mts/hour.

Principal particulars

Length over all	Abt.	142.00 m
Length between perpendiculars (hull)		139.2 m
Breadth moulded		38.4 m
Depth moulded		14.80 m
Design draught moulded abt.	Abt.	8.00 m
Scantling draught moulded		8.40 m
Displacement estimation abt.	Abt.	40400 t
Light ship weight estimation	Abt.	12800 t

The handling of CO2.

The CO2 Operation

CarbonCuts and Synergy Ships & Vedam

A study was undertaken by Synergy and Vedam on behalf of CarbonCuts to ascertain mooring of import tankers alongside including the approach, required dredging, transfer equipment, mooring equipment and the walkway and piping on top of the breakwater.

This ascertained the feasibility of the intended operations and that standard equipment for ship-to-ship transfer in the gas carrier industry could be used. It further provided the design of the walkway and estimate of the associated costs.

Dredging of an area of 80.000 square meters to a water depth of 11 meters will be required. Ref below "Mooring study" figure.

<u>The Approval in Principle, AiP by ABS</u>

ABS has carried out an appraisal of the entire document suite from the FEED Study and issued AiP:

Electronically published by ABS London.
Reference T2519875, dated 19-MAR-2024.

ABS

APPROVAL IN PRINCIPLE

as requested by:

CARBONCUTS A/S

Date of Issuance: 19 March 2024

Certificate Number: T2519875

ABS has reviewed the documentation as specified in the ABS letter dated 19 March 2024 (Task No. T2519875) and considers that the conceptual engineering as proposed is feasible for the intended application, and the facility as presented is, in principle, in compliance with the applicable requirements of the following:

- ABS Rules for Alternative Arrangements, Novel Concepts and New Technologies, Part 1D, 2024
- ABS Rules for Building and Classing Steel Barges 2024
- ABS Requirements for Liquefied Carbon Dioxide Carriers 2024
- ABS Rules for Building and Classing Marine Vessels 2024
- ABS Requirements for Onboard Carbon Capture and Storage 2023
- IGC Code

FACILITY: Liquefied CO_2 Barge

DESCRIPTION: Approval in Principle for Liquefied CO_2 Barge

To achieve final class approval of the subject design, the conditions and requirements as specified in the ABS letter must be satisfied.

Steve Brincat
Engineering Manager, ABS

Note: This certificate evidences compliance with one or more of the Rules, Guides, standards or other criteria of American Bureau of Shipping or a statutory, industrial or manufacturer's standards and is issued solely for the use of the Bureau, its committees, its clients or other authorized entities. Any significant changes to the aforementioned product without ABS approval will result in this certificate becoming void. This certificate is governed by the terms and conditions in the ABS Rules.

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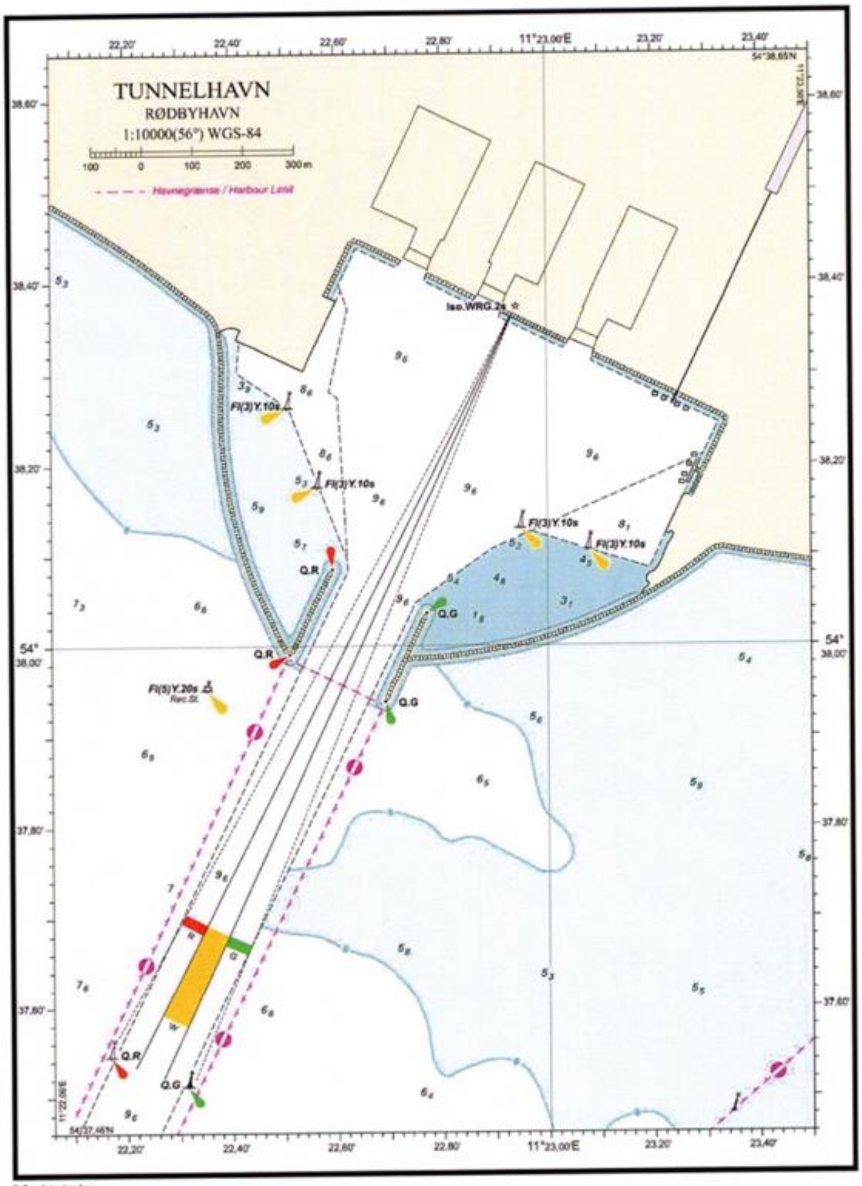
The site facility – existing Work Harbour

Map of site in Rødby:



© Geodatastyrelsen

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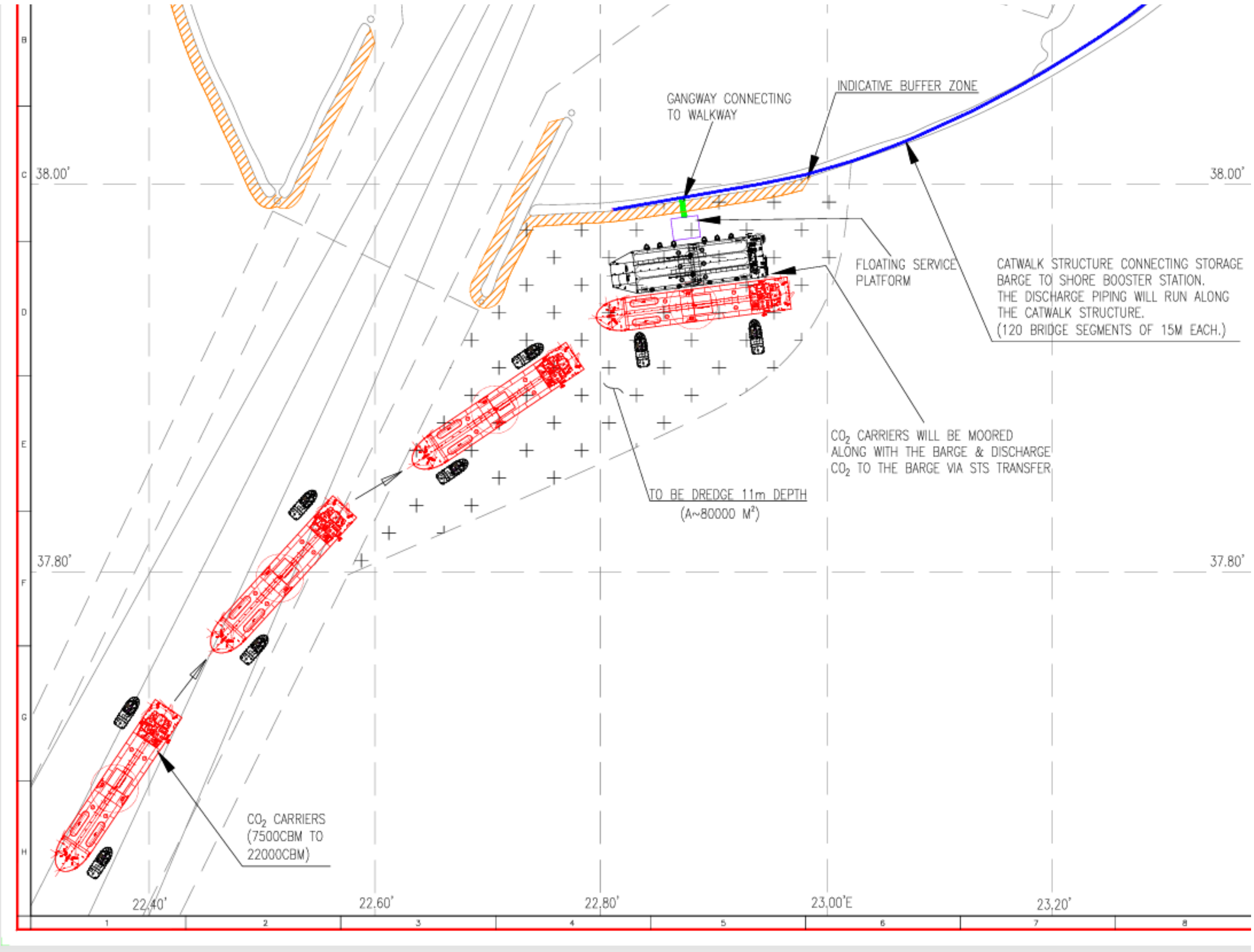
1st October 2024

The mooring Study

CarbonCuts and Synergy Ships & Vedam has carried out a report describing how CO2 supply tankers will approach the site in the Work Harbor and moor long side at the LCO2-Barge for offloading of LCO2.

From this report below illustration:



The Floating Service Platform – interface from LCO2-Barge to the Breakwater / Shore side.

The Floating Service Platform – ref below illustrations – has been designed in order to minimizes interfaces and approvals with existing infrastructure (such as harbor and breakwater), and will amongst other provide the following main interface functions and equipment:

<u>Allowance of vertical heights differences:</u>

Due to the altering loading conditions of the LCO2-Barge its deck-level will variate up to approximately 5,5 meters in comparison to the Floating Service Platforms deck-level.

Due to the altering sea-level (caused by high and low tide, current and wind pressure) the Floating Service Platform deck-level will variate up to approximately 2,5 meters in comparison to the top of the Breakwater.

All of the interface physical connections are designed to accommodate these vertical movements.

Safe access for personnel:

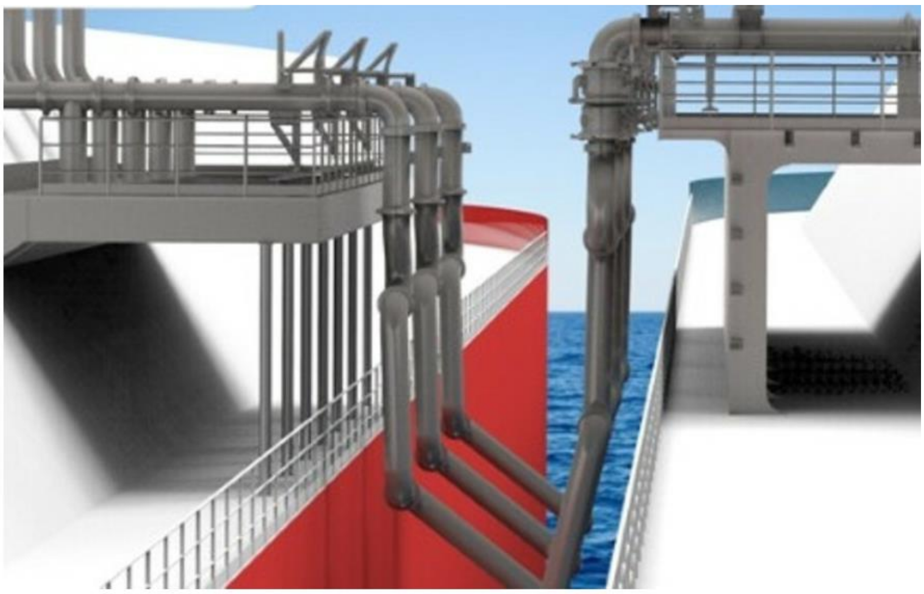
Traditional walkway connections are designed to carry personnel and a flexible hose for fresh water supply.

Electrical cables connections (Cold ironing / shore supply):

Separate flexible cable connections for the electrical supply will connect from shore to the Floating Service Platform – via a container with transformers, breakers and control units – to the LCO2-Barge.

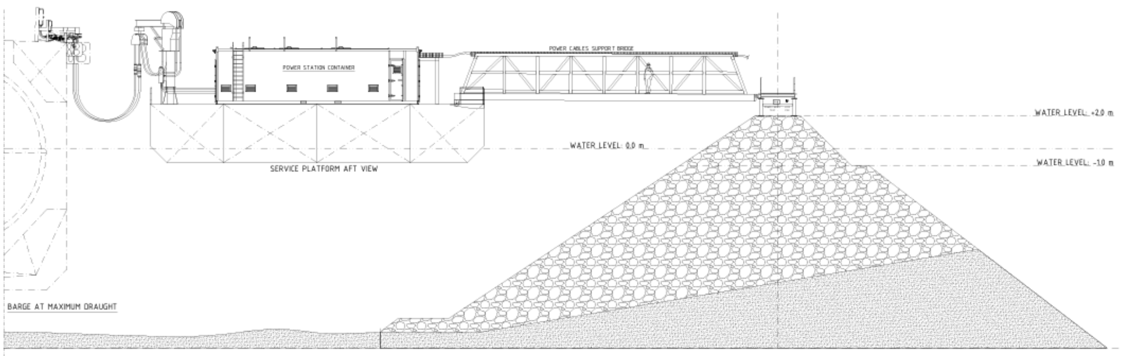
LCO2 connection:

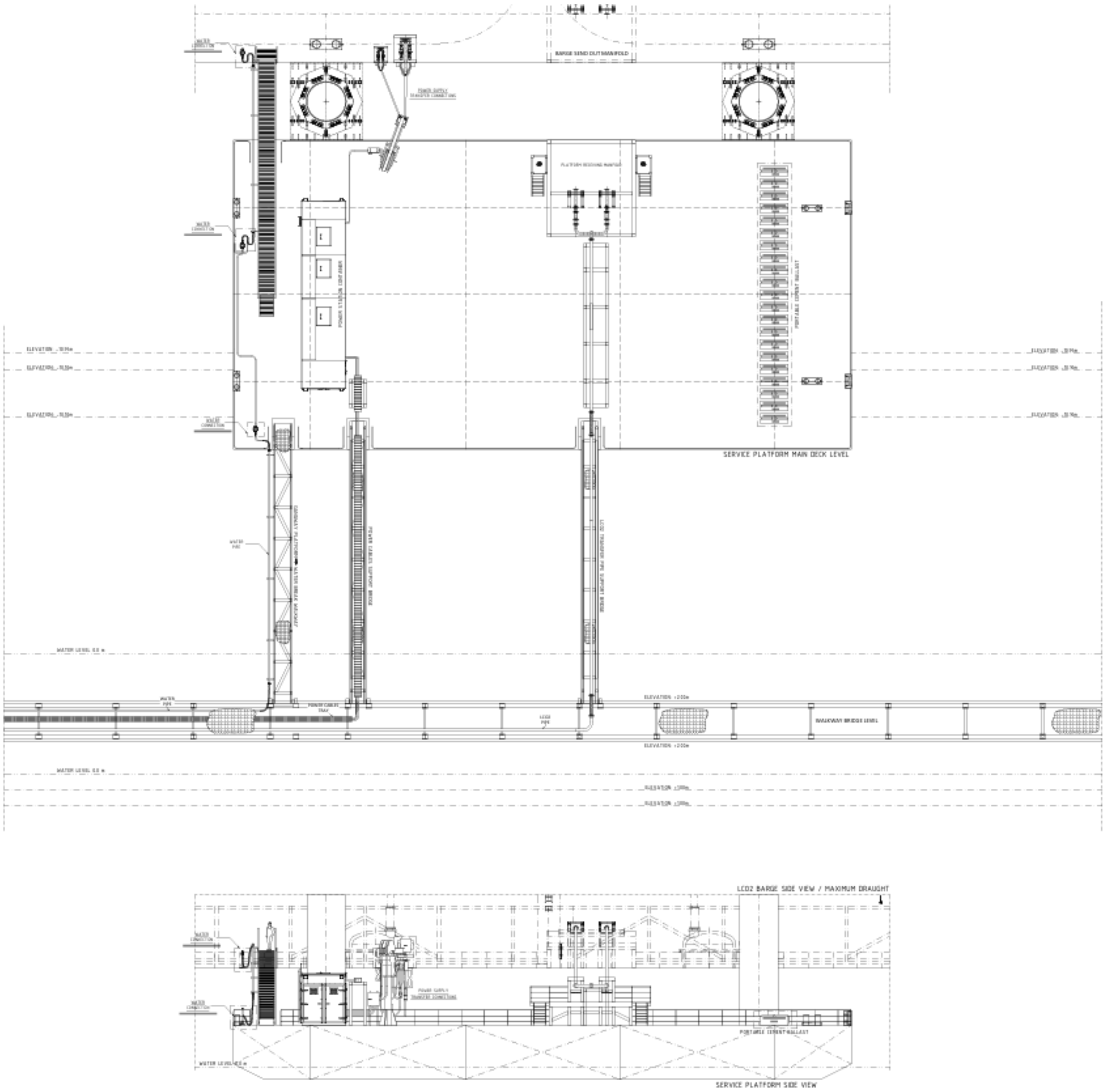
The CO2-connection between the LCO2-Barge and the Floating Service Platform is designed with the flexible ARCOS-system(ARCOS as a cheaper, more efficient equipment with less risk of motion sensitivity(accelerations):



Across the deck of the Floating Service Platform the CO2 will be transferred via a traditional pipeline, some flexible connections onto a separate connection like the walkway for personnel and ending up being connected to the fixed pipeline on top of the breakwater.

Floating Service Platform:





The safety aspects

<u>Liquid transfer safety features</u>

The proposed cargo transfer from import tanker to barge and from barge ashore is based on typical safety equipment used for Ship-to-Ship transfers in the gas tanker industry so it will feature

- hydraulically operated mooring hooks for quick release of mooring lines

- Dry breakers – in essence two ball valves that are hydraulically actuated in the event of activation of Emergency Shut Down – closing against each other and then disconnecting from each other creating a dry break
- Motion sensors detecting excessive movement between the two vessels, and in such case activating emergency shut down
- Interlink adopted from the gas tanker industry (Ship/Shore ESD interlink connection as approved by SIGTTO)
- All safety measures, check lists etc, testing protocols etc.

Barge emergency release of the LCO2-Barge:

The LCO2-Barge has been designed in such a way that it can be emergency released from the mooring rings on the monopiles holding it in its normal operation position.

In case of a CO2 leakage and/or more severe environmental conditions which will exceed the overall design conditions for the mooring system, and/or any emergency event (such as collision, fire etc.) the barge will need to be relocated to a safe area in advance by tugboats.

The mooring clamps will be hydraulically operated/released, allowing a quick release of the LCO2-Barge from the monopiles by the hydraulic open/close devices.

During such emergency events all transfer equipment connections (personnel, water, electrical power and CO2) will be quick released. By the disconnect Emergency Shut Down CO2-valves will secure minimum release of CO2 to the surrounding atmosphere in the event of both intended and unintended activation.

Risk assessment HAZID by CarbonCuts and ABS

Liquid CO2 Storage Barge Risk Assessment (HAZID-SWIFT) carried out by ABS and CarbonCuts.

OBJECTIVE AND SCOPE OF WORK:

The primary objective of the study was to identify and assess all probable risks arising from the LCO2 Barge operations that could affect the vessel, the crew, surrounding populations and the environment. The study only considers the barge whilst in operation and does not consider fabrication, transportation, commissioning, decommissioning etc at this stage. The scope of this assessment included the entire limits of the vessel but primarily focused on the LCO2 operations. The study boundary was from the Barge Loading manifold to the Onshore Station, which will be located in the port and will form the interface between Barge operations and the onshore transfer pipework to the injection site. Therefore, the study considered the following equipment:

1. LCO2 Tanks
2. LCO2 Pipework (e.g. loading and Send-out headers/manifolds, tank connections, etc.)
3. LCO2 handling equipment (e.g. compressors, heaters, pumps etc)
4. Safety Philosophy / Safety Systems (e.g. ESDs, PRVs etc)
5. C&I System
6. Vessel Utilities
7. Emergency Response Systems

From the Report: Samples of the HAZID process, tools and risk retirements outcome:

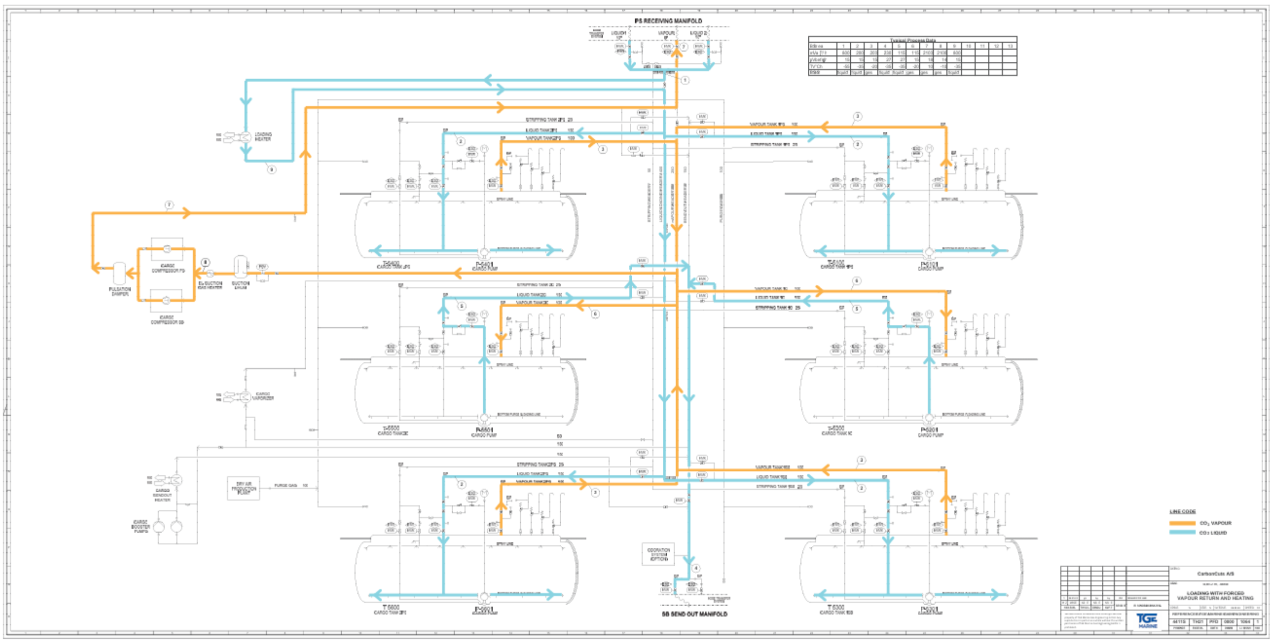
The workshop considered the LCO2 barge in a series of sections, or nodes, which were a combination of physical assets and modes of operation; these are listed in Table 2.

Table 2: Node List

Nodes	Description	Key Information Reference
1	LCO_2 Barge	1.1
2	Ventilation with Dry Air	3.4
3	Gassing Up	3.5
4	Tank Cooling with CO_2 from Shuttle Tanker	3.6
5	Loading with Free Flow Vapour Return	3.7
6	Loading with Forced Flow Vapour Return	3.8
7	Loading with Forced Flow Vapour Return and Heating	3.9
8	Send-out to Shore without Heating	3.10
9	Send-out to Shore with Heating	3.11
10	Warming up of Tanks using Cargo Compressors	3.12

Appendix A – Risk Matrix

Category			Consequence Severity					
Asset			No shutdown, costs less than €10,000 to repair	No shutdown, costs less than €100,000 to repair	Operations shutdown, loss of day rate for 1-14 days and/or repair costs of up to €1,000,000	Operations shutdown, loss of day rate for 15-29 days and/or repair costs of up to €2,500,000	Operations shutdown, loss of day rate for 30-45 days and/or repair costs of up to €5,000,000 Euro	Operations shutdown, loss of day rate for more than 45 days and/or repair more than €5,000,000 Euro
Environmental Effects			Localised and minor impact which is recoverable.	Localised significant impact which is recoverable.	Localised significant impact which is not immediately recoverable.	Impact is beyond "localised" but recoverable.	Significant impact beyond "localised" and is not immediately recoverable.	Irreversible damage to protected environment beyond the "local" area.
Injury and Disease			First aid only, or minor impact to health and manageable at work. No impact to public.	Requires medical intervention and short absence from work. No impact to public.	Lost time injury or extended absence form work with full recovery or minor injury to a member of the public.	Life changing injury / chronic illness which prevents work, or significant injury to member of the public.	Single fatality or terminal condition to a single employee, or life changing injury to a member of the public.	Multiple fatalities or terminal condition of multiple employees, or fatality/terminal condition for a single member of the public.
			Negligible	**Minor**	**Significant**	**Major**	**Critical**	**Catastrophic**
			1	**2**	**3**	**4**	**5**	**6**
Likelihood	A	**Frequent** Certain to occur on a regular basis. More than once per year (>1)	Undesirable	Intolerable	Intolerable	Intolerable	Intolerable	Intolerable
	B	**Probable** Likely to occur on a regular basis Every 1 to 10 years (1 to 10^{-1})	Undesirable	Undesirable	Intolerable	Intolerable	Intolerable	Intolerable
	C	**Occasional** Likely to occur on an infrequent basis Every to 10-100 years (10^{-1} to 10^{-2})	Tolerable	Undesirable	Undesirable	Intolerable	Intolerable	Intolerable
	D	**Unlikely** Unlikely to occur but could happen more than once. Every 100-1,000 years (10^{-2} to 10^{-3})	Tolerable	Tolerable	Undesirable	Undesirable	Intolerable	Intolerable
	E	**Remote** Unlikely, but could happen once. Every 1,000-10,000 years (10^{-3} to 10^{-4})	Broadly Acceptable	Tolerable	Tolerable	Undesirable	Undesirable	Intolerable
	F	**Improbable** Very unlikely to occur. Every 10,000-100,000 years (10^{-4} to 10^{-5})	Broadly Acceptable	Broadly Acceptable	Tolerable	Tolerable	Undesirable	Undesirable
	G	**Highly Improbable** Extremely unlikely to occur. Every 100,000-1,000,000 years (10^{-5} to 10^{-6})	Broadly Acceptable	Broadly Acceptable	Broadly Acceptable	Tolerable	Tolerable	Undesirable
	H	**Incredible** Extremely unlikley to occur and almost impossible. > 1,000,000 years (<10^{-6})	Broadly Acceptable	Broadly Acceptable	Broadly Acceptable	Broadly Acceptable	Tolerable	Tolerable
Action Key	Int.	Intolerable	The level of risk is intolerable and further controls are required.					
	Und.	Undesirable	Risk is undesirable and additional efforts are required to further understand and reduce the risk. Additional controls are likely to be required.					
	Tol.	Tolerable	Additional controls not required if ALARP position can be justified. Monitoring required to confirm no changes in the circumstances, and that controls are effective.					
	BA	Low	Broadly Acceptable - No action is required, unless change in circumstances					



Issue 1 Draft A

Node 1: LCO2 Barge

Hazard Category	Hazard Guideword	What-if?/Causes	Ref	Consequences	Cons Cat	Initial Risk			Planned Safeguards (P/M) (Prevention / Mitigation)	Current Risk			HAZID Recommendations	Remarks
						S	L	RR		S	L	RR		
Natural Hazards	Tides Currents Sediments and sanding (natural depositing in the dredged shallow waters) Wind Extremes of Temperature Degradation Mechanisms (Corrosion)	Could tides, currents or wind create a relative displacement concern for attached hoses between manifold and Shuttle Tanker?	1.1.1	Break of the hose between the Shuttle Tanker and Barge causing full bore loss of containment.	People	5	A	R	- Metocean report to be considered in the design (Optimoor analysis) - Weather windows for safe operation - Ship to Ship safety checklist (IMO requirement) - Quick release decoupling's (KLAW) linked to ESD - Emergency response procedures - Tankers to meet IGC code requirements and SIGTTO linked ESD recommendations. - PPE - EEBD mandatory on each vessel. - Odourised CO2 - ESD on manifolds limit inventory if KLAW system fails.	5	F	U	1. Consider remote surveillance (CCTV) of manifold area to see CO2 leaks 2. Consider CO2 detection in area of manifold (e.g. IR) 3. Consider Odourising on receipt of CO2 4. Provide portable O2 monitoring for personnel. 5. Terminal compatibility requirements for Shuttle Tankers	Number of fatalities in the industry is very low historically in NH3/LNG operations. These have been related to fire/explosion and toxicity.
					Assets	3	A	R		3	F	T		
					Env.	1	A	U		1	F	BA		
		What if Shuttle Tanker mooring fails due to natural hazards?	1.1.2	Collision of Shuttle tanker with barge is unlikely to lead to significant CO2 release, but maybe a hazard to people.	People	5	D	R	- Design of mooring lines. - Fenders. - Metocean report to be considered in the design (Optimoor analysis) - Weather windows for safe operation	5	F	U	6. Consider tension monitoring of mooring cables.	Very unlikely to lead to loss of CO2
					Assets	5	D	R		5	F	U		
					Env.	1	D	T		1	F	BA		
			1.1.3	Collision leading to flooding of the Hull space	People	4	F	T	- Hull design (subdivision) Damage stability requirement -Shallow water mooring -Anti-float supports on the CO2 tanks. -Insulation of the tanks provides time for emergency response.	4	G	T		
					Assets	4	F	T		4	G	T		
					Env.	2	F	BA		2	G	BA		
			1.1.4	Loss of cold ironing of power to Shuttle Tankers	People	1	C	T	-Tanker emergency power would be initiated.	1	F	BA	7. Emergency generator capacity to be considered in the detailed design.	
					Assets	1	C	T		1	F	BA		
					Env.	1	C	T		1	F	BA		
			1.1.5	Damage to walkway between the Shuttle Tanker and Barge causing a hazard for personnel.	People	4	E	U	- Procedural control of the use of the walkway (e.g. Permit to Work). - Access is monitored at all times.	4	H	BA		
					Assets	4	E	U		4	H	BA		
					Env.	1	E	BA		1	H	BA		
			1.1.6	Shuttle Tanker Soft Grounding and Blocking the channel.	People	2	D	T	-Harbour channel is dredged. -Tanker turning area is dredged. (Commercial issue) -No damage to Barge (damage associated with Shuttle Tanker)	2	F	BA		
					Assets	1	D	T		1	F	BA		
					Env.	3	D	U		3	F	T		
		Could sea intakes be affected by silt/mud/seaweed intake?	1.1.7	Blocked/reduced feed to fire pumps, heat exchangers	People	2	C	U	-Periodic back flush of strainers	2	F	BA		
					Assets	2	C	U		2	F	BA		
					Env.	1	C	T		1	F	BA		
		Marine growth in Heat Exchangers	1.1.8	Loss of cooling to Heat Ex	People	1	D	T		1	D	T	8.Consider Chemical injection but balanced against long term environmental impact. 9.Consider redundant Heat Exchanger to allow maintenance on one. (Duty and Standby)	
					Assets	3	D	U		3	D	U		
					Env.	1	D	T		1	D	T		
		Could tides, currents or wind create a relative displacement concern for attached hoses between Barge discharge manifold and Shore?	1.1.9	Hose break and full bore loss of containment	People	5	A	R	-Metocean report to be considered in the design (Optimoor analysis) -Weather windows for safe operation -Mooring limits lateral movement -PERC -Emergency response procedures -Tankers meet IGC code requirements and SIGTTO linked ESD recommendations. -PPE - EEBD mandatory -Odourised the CO2	5	F	U		
					Assets	3	A	R		3	F	T		
					Env.	1	A	U		1	F	BA		
		Loss of communications, electricity, DCS monitoring	1.1.10	Worst case would be hydraulically full tanks and pressure relief of LCO2	People	5	A	R	-Blackout would trip the ESD system. -UPS system for 30 minutes power -Emergency generator would be initiated. -Cargo tanks designed to contain the contents for 90 days without reaching limiting (MARVS) conditions.	5	G	T		
					Assets	3	A	R		3	G	BA		
					Env.	1	A	U		1	G	BA		

The report suggests that acceptable resolution of identified risks has been reached.

CO2 odorizer.

CO_2 is a fairly benign gas but is of course heavier than air and thus not easily dispersed in the event of a major leak and it is asphyxiating. It significantly mitigates the risk of exposure to the civil population to have the storage in the harbour on a barge which worst case can be towed away compared to shore-based storage tanks.

In order to ensure early detection of potential leaks or spills it was decided to install an odorization skid so the CO_2 is odorized with Methyl Mercaptan on arriving from the import tankers. This is a common approach with many natural gases in the transport industry. The product will give off the smell of rotten eggs in the event of a leak.

All people involved with the operation will be equipped with Emergency Escape Breathing Devices (EEBD) to ensure their safe escape from a spill of CO_2. Both the barge and the walkway will be properly equipped with means of escape in the event of a leak.

Kgs. Lyngby, Denmark
1st October 2024

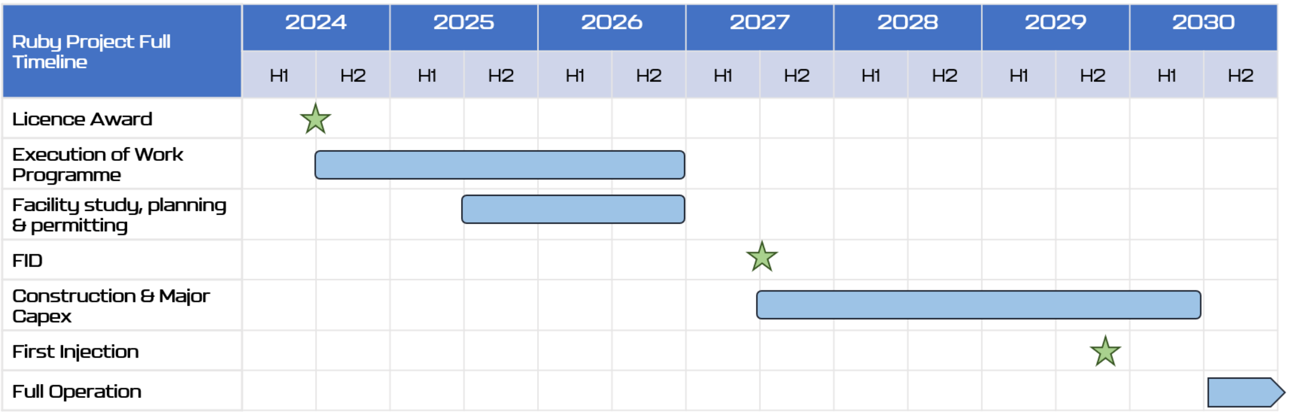
Cost estimation

A traditional shore based tank farm installation including a harbor terminal facility to receive LCO2 tanker vessels for CO2 supply has been used for comparison of cost estimate (Design, construction etc) at index 100.

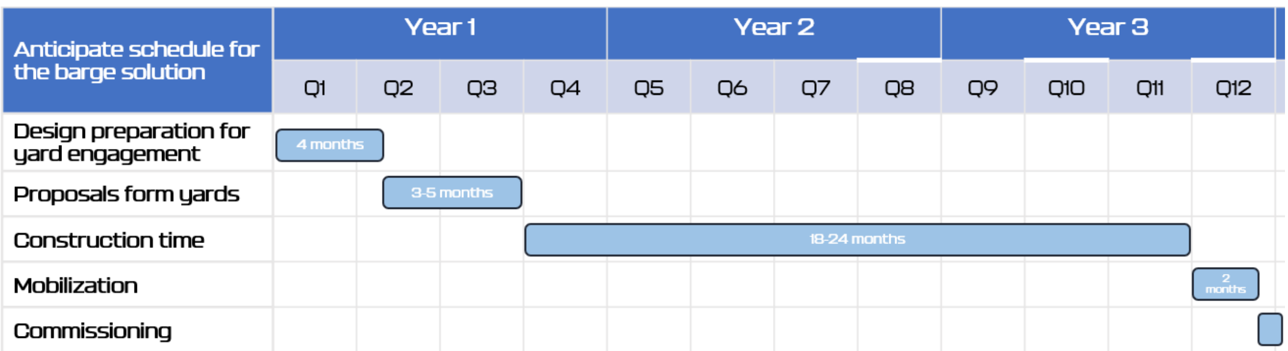
The LCO2-Barge storage including facility to receive LCO2 tanker vessels for CO2 supply and interface to shore (Design and construction) has been cost estimated at index 0,80 to 0,85.

Time Line

Ruby project timeline



Realistically we anticipate a schedule for the barge solution:



i.e. up to 36 months.

Kgs. Lyngby, Denmark
1st October 2024

CarbonCuts and outlook for the Ruby Project.

CarbonCuts will in the coming year advance other import options and CO_2 handling facilities cases as part of the Ruby Project. Thise cases will be assessed in a stage gate process alongside the Barge option described in the document. Among the parameters that will be applied to assess and compare the various types of cases are; cost, permitting, safety, timeline, local impacts, local CO_2 infrastructure synergies, CCS value chain compatibility and compatibility with geological exploration outcome.