

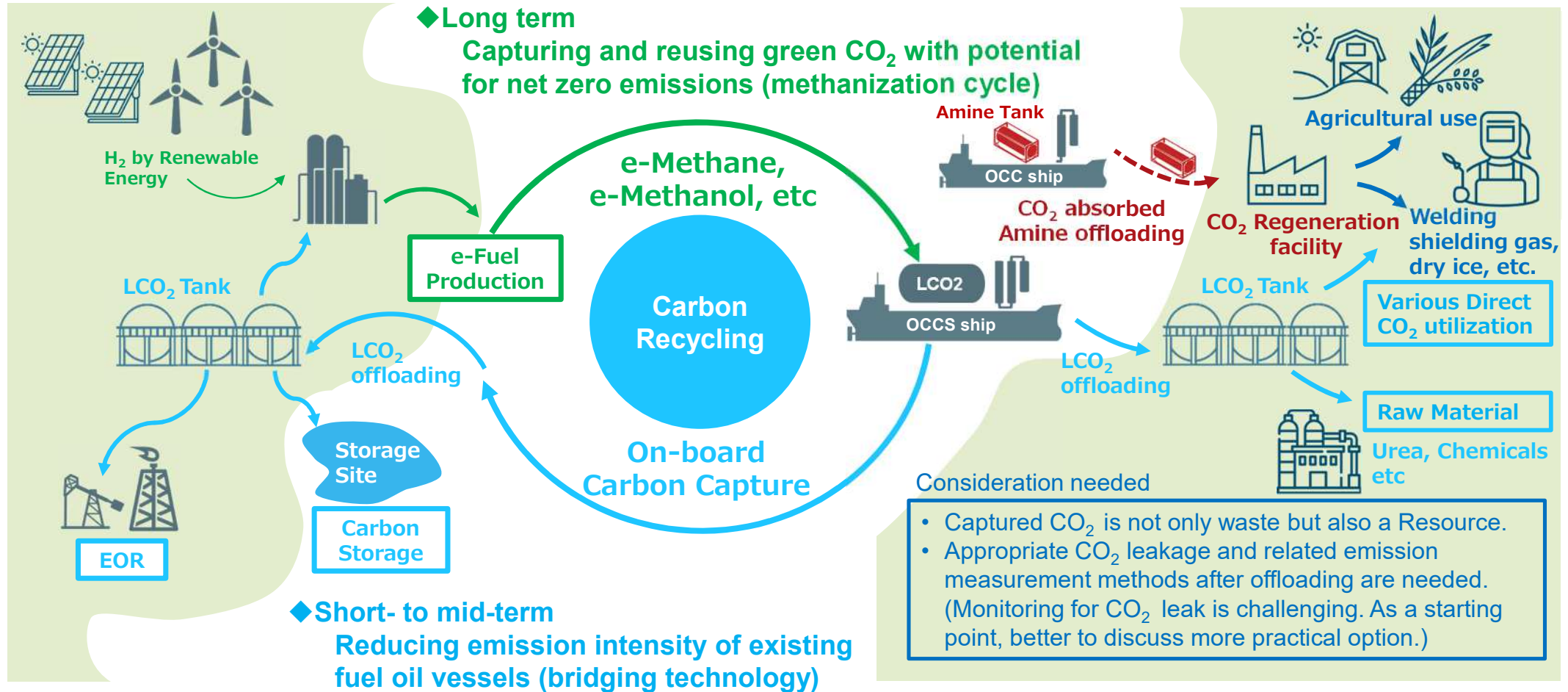
Onboard carbon capture - key considerations and challenges

**Technical Seminar on Onboard Carbon Capture and Storage (OCCS) Systems,
11 September 2025**

Mitsubishi Shipbuilding Co., Ltd.

Why OCCS : OCCS has Short- and Long-term roles

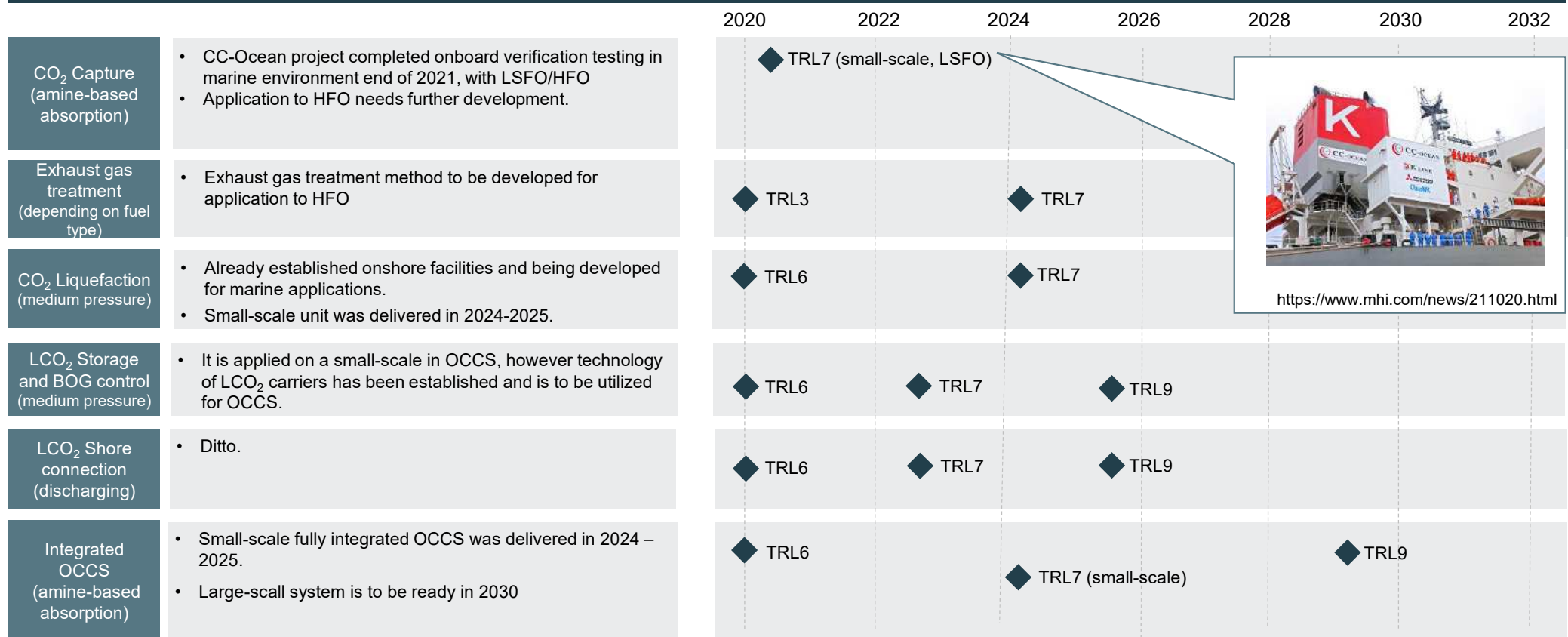
- Decarbonization through OCCS and CO₂ Value Chain has both short- and long-term roles .



Why OCCS : Practical implementation is getting closer.

■ Generally, related technologies are reaching high TRL.

Technology Readiness¹ (from the perspective of marine applications)



¹ Technology readiness levels (TRL) as defined by EU Horizon 2020 Program

Why OCCS : Some advantages of OCCS.

■ OCCS has advantages in ship's perspective.

Use of Conventional Fuel

Utilization of conventional fuel supply chains and infrastructure.
Utilization of conventional engine plants.

General Crew Operation

Operation can be carried out by general crew, no special technician to be assigned.

Future potential

Utilizing with any carbon-containing fuel with lower carbon intensity, such as methane, methanol, biofuels or e-fuels.

Onboard carbon capture plant was operated by general crew members, at the 1st onboard carbon capture demonstration of “CC-Ocean” project (2021)



OCCS Technologies : CO₂ Capturing Methods

- The chemical absorption method is suitable for OCCS relatively.

High TRL

Reliable technology that has already been used in many onshore commercial CO₂ production plants for a considerable duration.

Selective capturing of CO₂

Capturing from low-pressure and low CO₂ concentration exhaust gas that contains various impurities and has a low concentration of CO₂.

Space and Energy Requirement

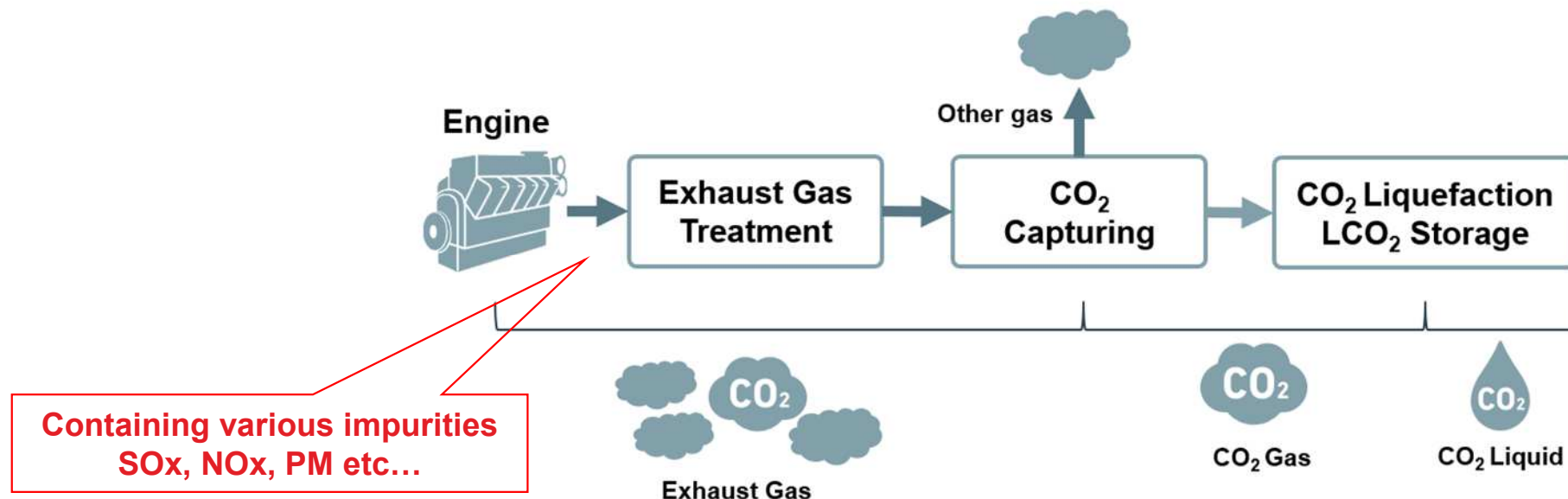
Relatively suitable for onboard limitation regarding both space and energy.

Method	Explanation	Evaluation
Chemical Absorption	<ul style="list-style-type: none"> Using an amine-based solvent, CO₂ is chemically absorbed into the liquid phase and separated from the flue gas. 	<ul style="list-style-type: none"> Well-suited for exhaust gas which is characterized by low pressure and low CO₂ concentration Already been commercialized and is currently used in onshore plants to recover CO₂ from large volumes of exhaust gas.
Solid Absorption	<ul style="list-style-type: none"> CO₂ is adsorbed onto the surface and micropores of a solid adsorbent, and subsequently released through thermal or pressure swing desorption. 	<ul style="list-style-type: none"> CO₂ desorption requires energy input for pressure reduction. For large-scale applications, a significant number of adsorption columns are needed.
Membrane Separation	<ul style="list-style-type: none"> Membrane separation is achieved by establishing a pressure differential across a CO₂ selective membrane, enabling preferential permeation of carbon dioxide. 	<ul style="list-style-type: none"> Significant energy is required to create a vacuum or reduced pressure on the permeate side of the membrane to allow CO₂ to pass through. Scaling up the system is challenging, since the gas permeation rate per unit membrane area is limited.

OCCS Technologies : Exhaust Gas Treatment

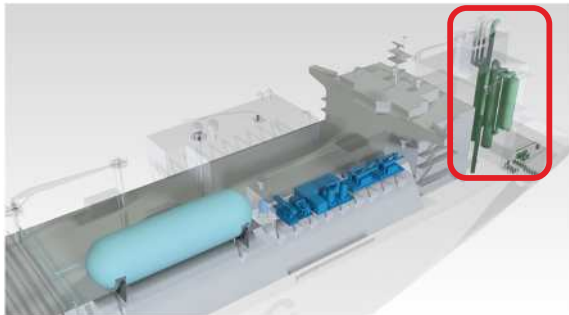
■ Treatment of exhaust gas is essential before CO₂ capturing.

- Exhaust gas from engine contains various impurities such as NO_x, SO_x, PM etc. (Especially, heavy fuel oil contains many unknown impurities, as it is a residual oil.)
- Such impurities affect failure of the CO₂ capturing system, reduction of CO₂ capturing system efficiency, and carrying over the impurities to the CO₂ (or LCO₂). Primary treatment before CO₂ capture is necessary.

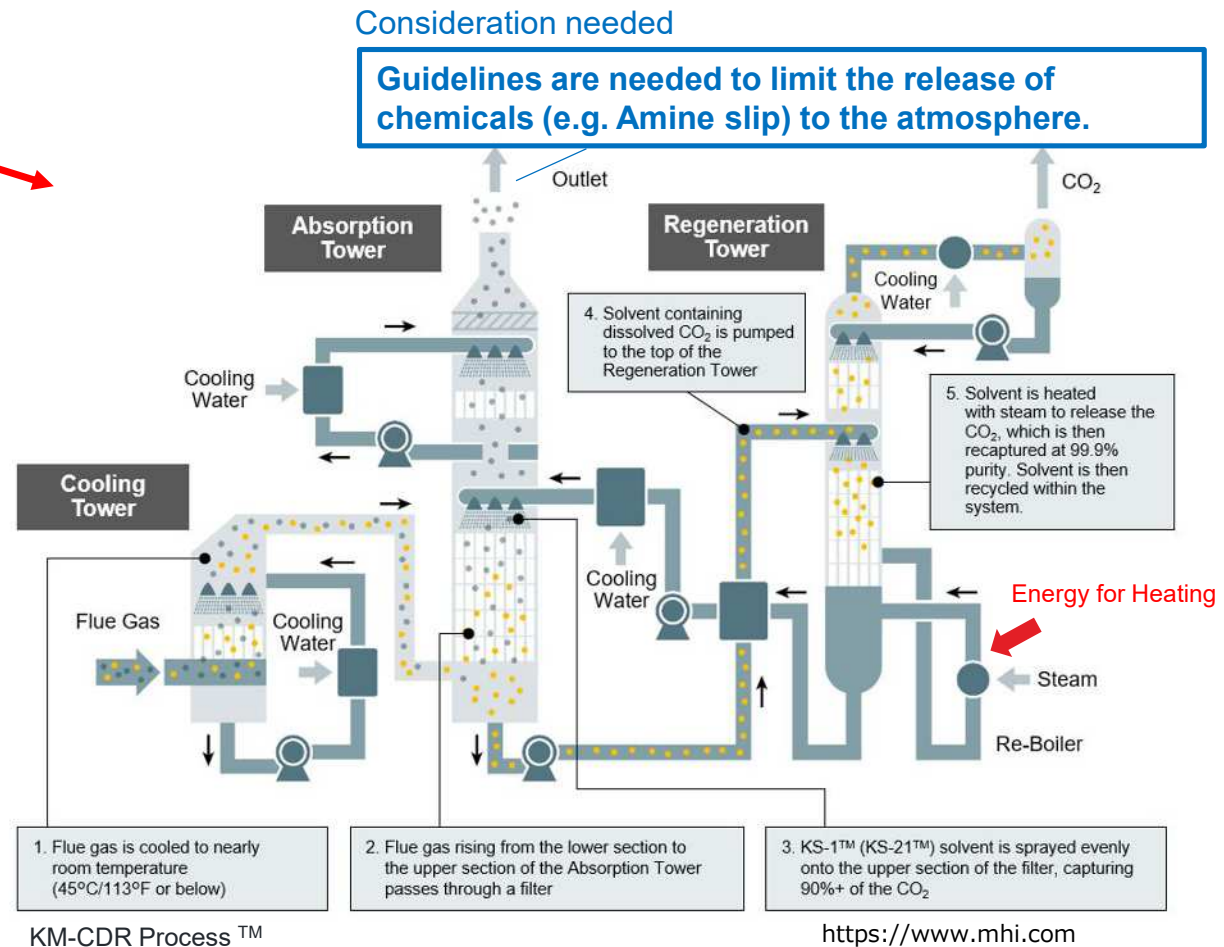


OCCS Technologies : CO₂ Capture

- Chemical absorption process is driven by a special amine solution.

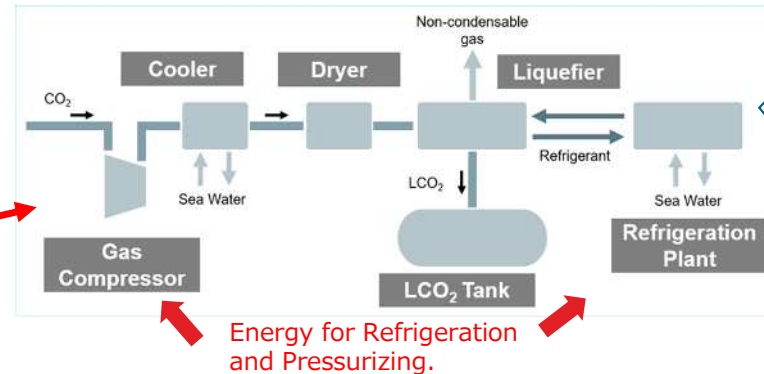
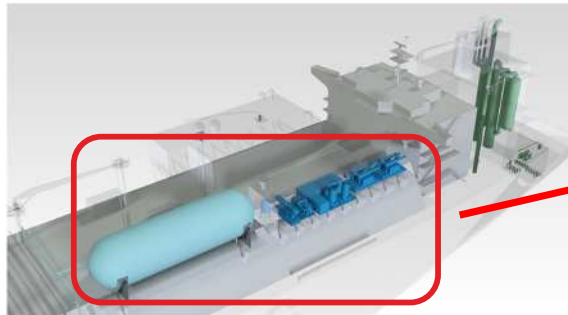


- **Key features of Amine (KS-1™)**
 - Better CO₂ loading.
 - Lower energy for regeneration.
 - Reduced deterioration.
 - Less corrosiveness.
 - Long term commercial operation of onshore plants.

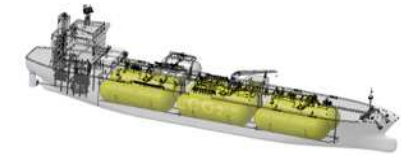


OCCS Technologies : CO₂ Liquefaction and LCO₂ Storage

- For onboard storage, CO₂ volume is reduced through liquefaction. (abt.1/500 of gas volume)

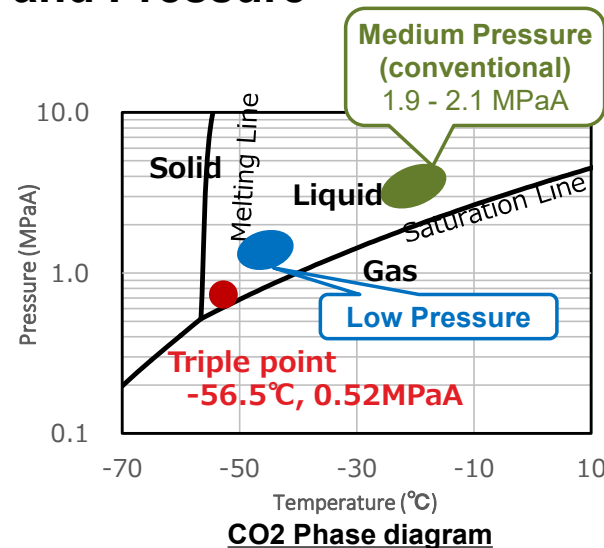


Mitsubishi shipbuilding is developing a LCO₂ handling system and utilizing its expertise in this process.



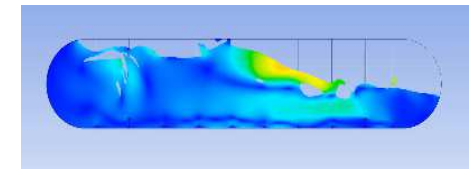
■ LCO₂ Temperature and Pressure

- Maintaining the liquid state requires appropriate control of both temperature and pressure.
- Low pressure is challenge because less margin from triple point.



■ LCO₂ Tank

- Consideration of the weight of LCO₂, holding pressure, holding temperature, and forces due to sloshing are required

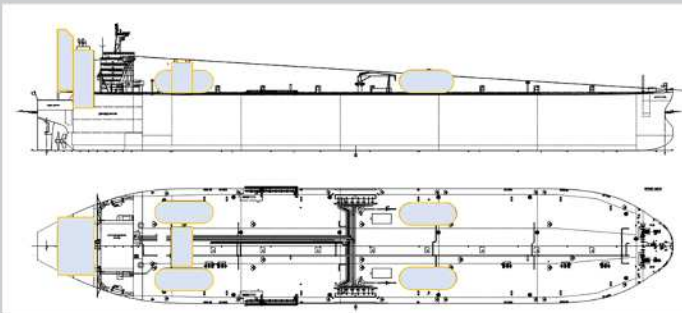
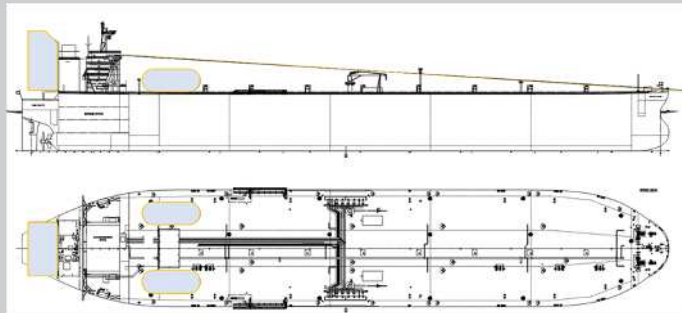


Consideration needed

Technical guidelines for safety may be needed regarding the release of CO₂ in emergencies or from the safety valves and etc.

OCCS Benefit : Case Study for VLCC (1 / 2)

■ Typical case studies ; New Building and Retrofitting application.

	Case	New Building	Retrofitting
Ship and OCCS cond.	Arrange		
	Engine Outputs	17,120 kW	17,120 kW
	OCCS size	260 ton/day (Tank 2,700 m3 x 4)	130 ton/day (Tank 2,700 m3 x 2)
Simulated one round trip*	CO ₂ Capture Ratio**	abt. 66%	abt. 39%
	CO ₂ Emission Reduction Ratio**	abt. 53%	abt. 27%
	Extra Energy (compared with non OCCS)	abt. +40%	abt. +20%

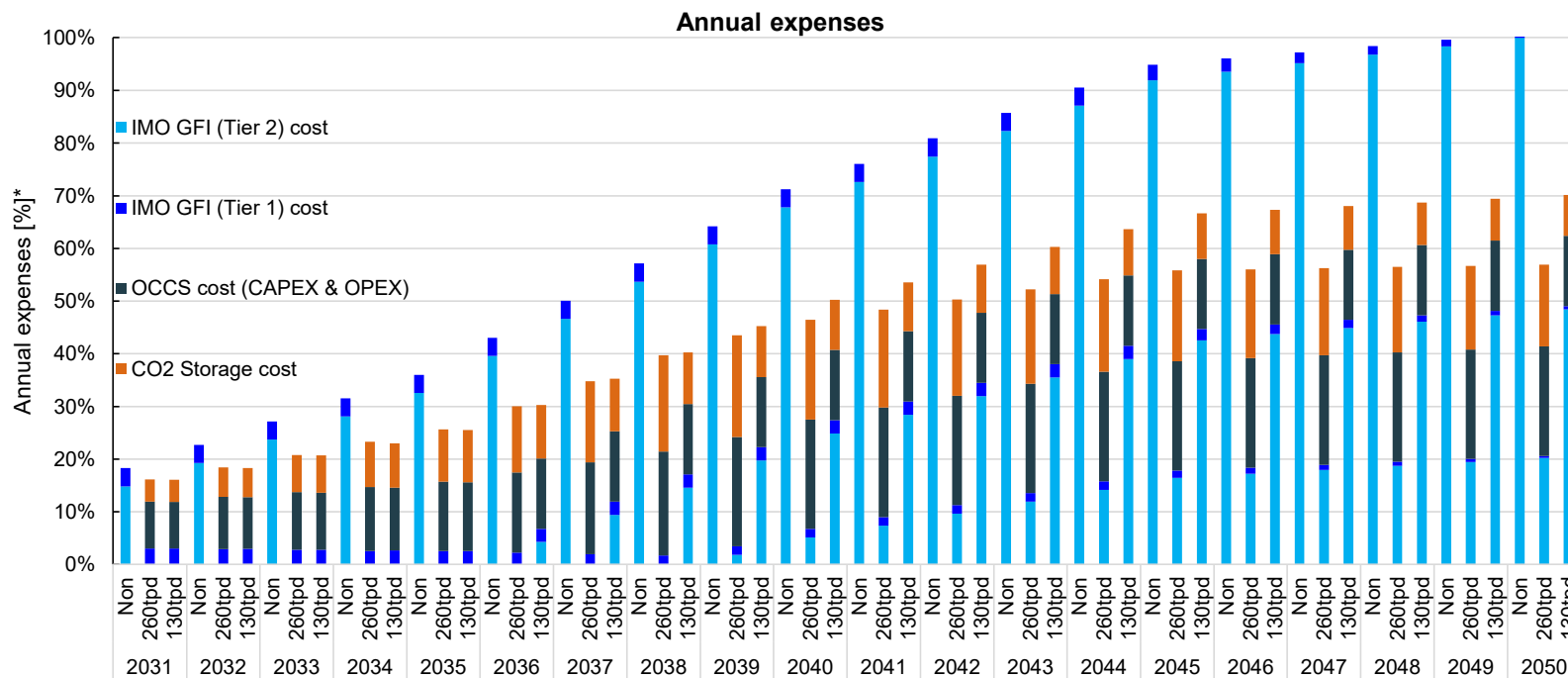
* OCCS is used only while at sea, but it is stopped during unloading, loading, and bunkering.

** Increase of the CO₂ emission due to the use of OCCS is included.

OCCS Benefit : Case Study for VLCC (2 / 2)

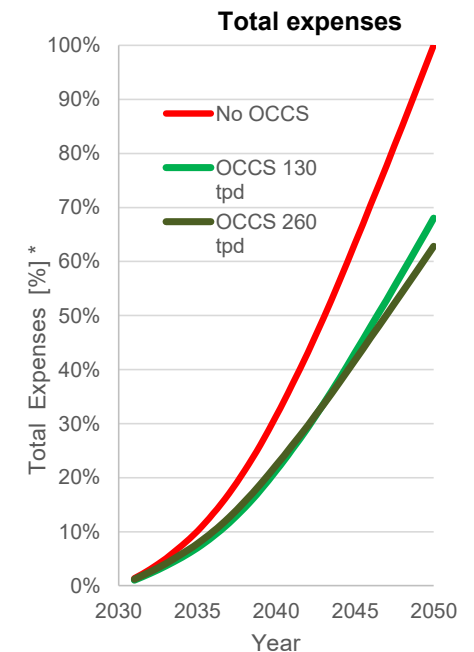
■ OCCS cases have advantages over the non OCCS case.

- The benefit of using OCCS becomes clear, due to the cost differences associated with IMO GFI cost.



Note) OCCS cost includes OPEX and CAPEX. (CAPEX distributed equally)

* : The costs for each case are expressed relatively, with the final cost of the 'non-OCCS' case set at 100%.



- **The CO₂ specifications are set (or will be set) by the CCUS industries.**
- **In order to handover the captured CO₂ to the CCUS industries, OCCS is requested to process the captured CO₂ to meet the specifications.**
- **Even though exhaust gas from engine contains unknown impurities, it is necessary to identify possible impurities and prepare provisions for their treatment.**

[illegible]

INTERNATIONAL
STANDARDS

ISO
16175:2008

Welding consumables — Gases and
gas mixtures for fusion welding and
after processes

ISO

Reference number
16175-01-01
2008-05-01

11

OCCS Challenges : Improvement and suitable application

■ Ship system

➤ Optimum design ;

Evaluate its decarbonization benefits and various impacts (such as cargo capacity, weight and stability, structural strength, visibility, etc) to achieve a balanced design of the ship.

To mitigate the impacts of OCCS installation, it is also important to reduce the amount of CO₂ emitted from the ship to minimize the size of the OCCS. For this purpose, the utilization of energy-saving devices and improvements in operational efficiency should also be considered.

➤ Find energy for OCCS ;

Find and utilize efficient methods to supply the energy required for the OCCS. (Waste heat recovery etc)

■ OCCS

➤ Energy efficiency ;

Improve the efficiency of amine solutions and related devices. Additionally, search for refrigeration gases and refrigeration devices suitable for CO₂ liquefaction pressure and temperature.

➤ Physical constraints ;

Improve space efficiency of the equipment in the OCCS.

Summary

- OCCS has Short- and Long-term roles towards GHG net-zero emissions.
- OCCS technologies are almost ready for practical implementation.
- Economically, the significance of utilizing OCCS is also recognized due to the IMO GFI reduction requirement.
- OCCS is viable option for the decarbonization, however still faces challenges regarding compliance with CO₂ specifications and achieving more efficient utilization.

MISSION NET ZERO

Through our group products, technologies, and services that help reduce CO₂ emissions, as well as new solutions and innovations to be developed with partners around the world, Mitsubishi Heavy Industries Group will contribute to realizing net zero emissions for the world as a whole.

To this end, each and every one of our employees is embracing and internalizing "MISSION NET ZERO" and will act to implement a net zero future.



Mitsubishi Shipbuilding will be working on the development and realization of OCCS, as well as energy transitions, contributing to the further development of shipping and the reduction of environmental impact on a global scale.

THANK YOU



Mitsubishi Shipbuilding Co., Ltd.

MOVE THE WORLD FORWARD

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