Main Issues and Technical Measures on IMO Strategy for GHG Reduction

2022. 7. 21.

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KOREA RESEARCH INSTITUTE OF SHIPS & OCEAN ENGINEERING

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1. IMO GHG reduction measures and technologies

2. KRISO research projects on alternative fuels

3. KRISO research project for Onboard CCS

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1



IMO GHG Reduction Measures and Technologies

IMO GHG Reduction Measures

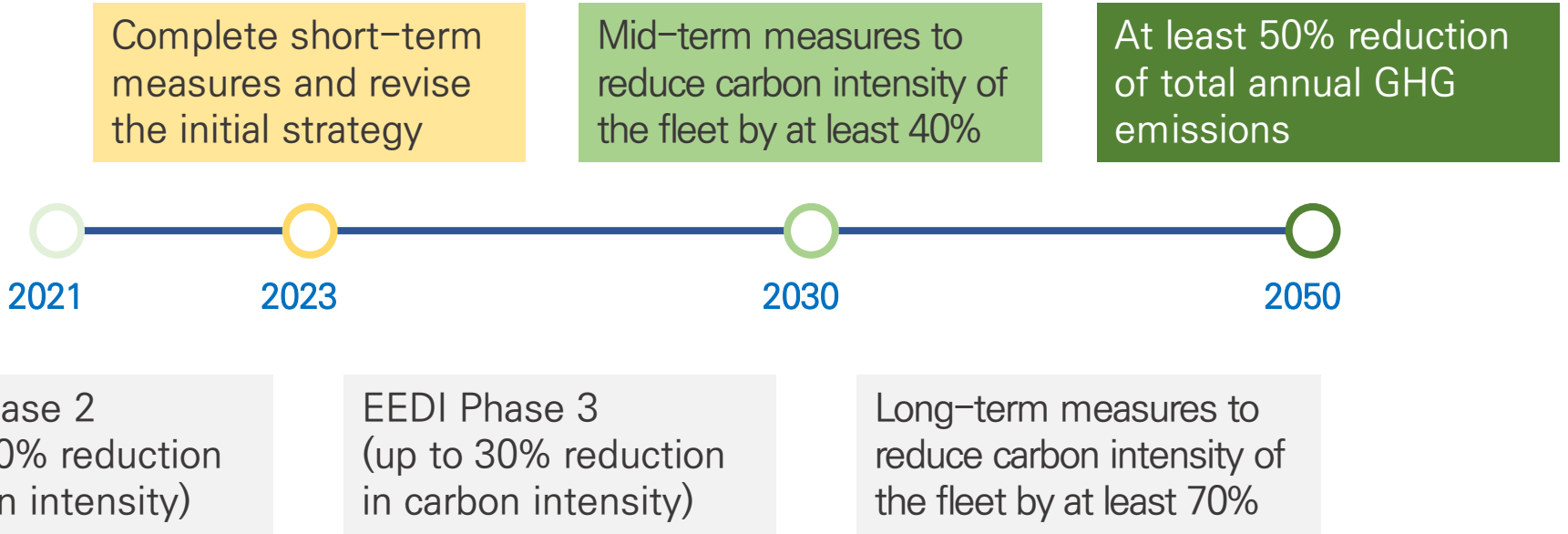
Year/Meeting		Discussion
2018	MEPC 72	Adoption of Initial IMO Strategy
2019	–	Step 1: Data Collection System (DCS)
2020	MEPC 75	Step 2: Data Analysis / Results of the 4th IMO GHG study
2021	MEPC 76	Establishment of new guidelines related to the regulation of existing ships Amendments to the convention for short-term measure Discussion of mid- & long-term action plan
	MEPC 77	Revision of initial IMO Strategy Discussion of mid- & long-term measures
2022	MEPC 78	
2023	–	Revision and adoption of “IMO GHG reduction strategy”

IMO GHG Reduction Measures

Initial IMO Strategy

Ambitious goals at MEPC 72 (compared to 2008 levels)

- Reduce carbon intensity by at least **40% by 2030**
- Reduce carbon intensity by at least **70% by 2050**
- Reduce GHG emissions by at least **50% by 2050**

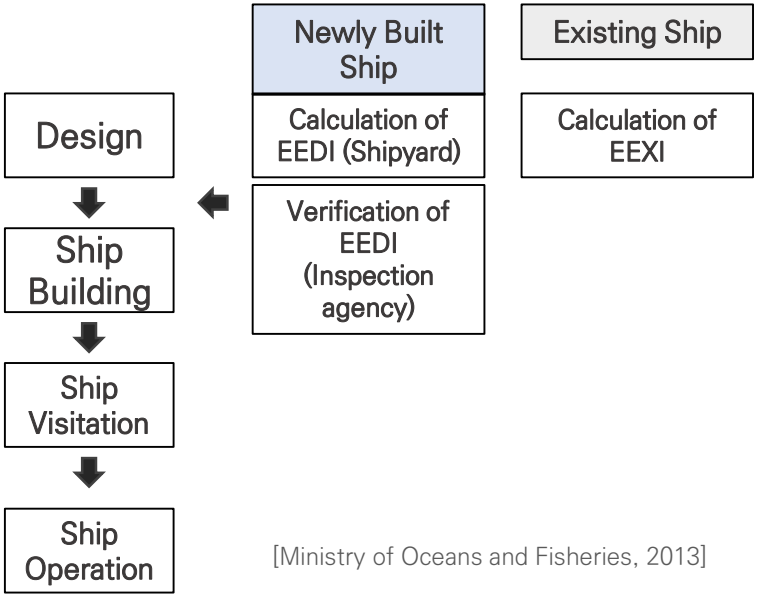


Energy Efficiency Design Index

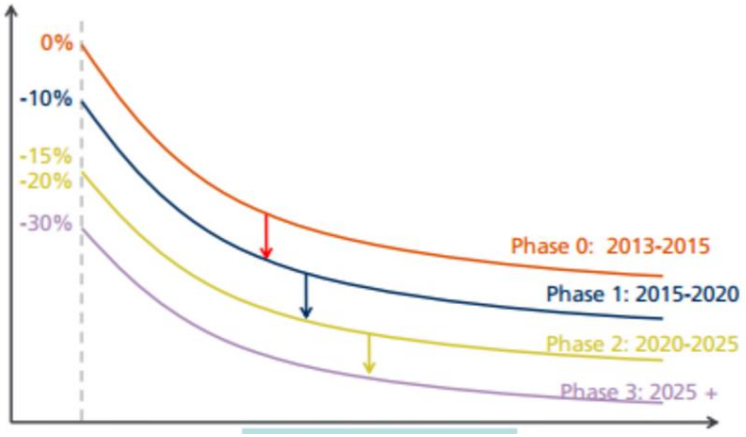
"The amount of CO_2 emitted when transporting 1 ton of cargo, 1 nautical mile"

$$EEDI\left(\frac{gCO_2}{ton \cdot nm}\right) = \frac{CO_2\ Factor \times FOC\left(\frac{g}{kW}.h\right) \times Engine\ output(kW)}{DWT(ton) \times Ship\ speed\ (mile/h)} = \left[\frac{(\frac{gCO_2}{gFuel}) \times (\frac{gFuel}{kW \cdot h}) \times (kW)}{(ton) \cdot (\frac{nm}{h})}\right]$$

※ Nautical mile :One nautical mile is approximately 1,852 m as a unit of sea distance.



[Ministry of Oceans and Fisheries, 2013]



〈 EEDI Baseline 〉

IMO GHG Reduction Measures

Short-term measures; EEXI, CII, SEEMP

Introduction of energy efficiency regulations for existing ships (MARPOL Annex VI)

- Adoption of amendments to the convention for the introduction and compulsory enforcement of energy efficiency regulations (EEXI·CII) for existing ships approved at the 75th MEPC
- MEPC 76 Adoption ('21.6.) → Acceptance ('22.4.) → Effective ('22.10.)

<table>
<tr><th>Sort</th><th>Applicable to</th><th>Before 2023</th><th>2023</th><th>2024</th><th>2025</th><th>Before 2026.1.1.</th></tr>
<tr><td>EEXI
(Technical measures)</td><td>International vessels with
〉400 gross tonnage</td><td colspan="2">EEXI is applied to the first inspection among annual/intermediate/regular inspections after the entry into force of the agreement;
IEEC certificate issuance when satisfied</td><td>–</td><td>–</td><td rowspan="4">Review of the provisions of the Convention
Review of the EEXI reduction rate and the need to introduce mandatory measures for low-grade ships</td></tr>
<tr><td rowspan="3">CII
(Operational measures)</td><td rowspan="3">International vessels with
〉5,000 gross tonnage</td><td>SEEMP Amendment</td><td>CII Grading①</td><td>CII Grading②</td><td>CII Grading③</td></tr>
<tr><td colspan="4">↓ ↓ ↓ ↓</td></tr>
<tr><td>Issuance of CoC</td><td colspan="3">(Class E for one year and Class D for 3 consecutive years)
SEEMP amendments including corrective action plans and approval by administrations</td></tr>
</table>

IMO GHG Reduction Measures

Mid-/long-term measures

GHG Levy

- ✓ A scheme in which contributions are paid **per ton of fuel oil based on fuel oil consumption** identified in the IMO DCS.
- ✓ Some countries claim **240-400 USD per ton of CO_2** emissions, but the specific levy per ton of CO_2 is not discussed.

※ International Maritime Research Council (IMRB)

Invest in the development of zero carbon fueled vessels
with a fee of 2 USD per ton of fuel oil for international shipping

GHG Fuel Standard

- ✓ A standard that restricts the **WtW GHG emission intensity (MJ/gCO2eq)** for each vessel and applies the gradually strengthened value
- ✓ Similar to MARPOL Annex VI, Regulation 14, Sulfur Cap

Emission Trading System

Allocating the total amount of emission permits (standard amount) to ships

- ✓ In case of exceeding the standard, **emission permits are purchased through an auction**
- ✓ Marketable if emissions are less than credits

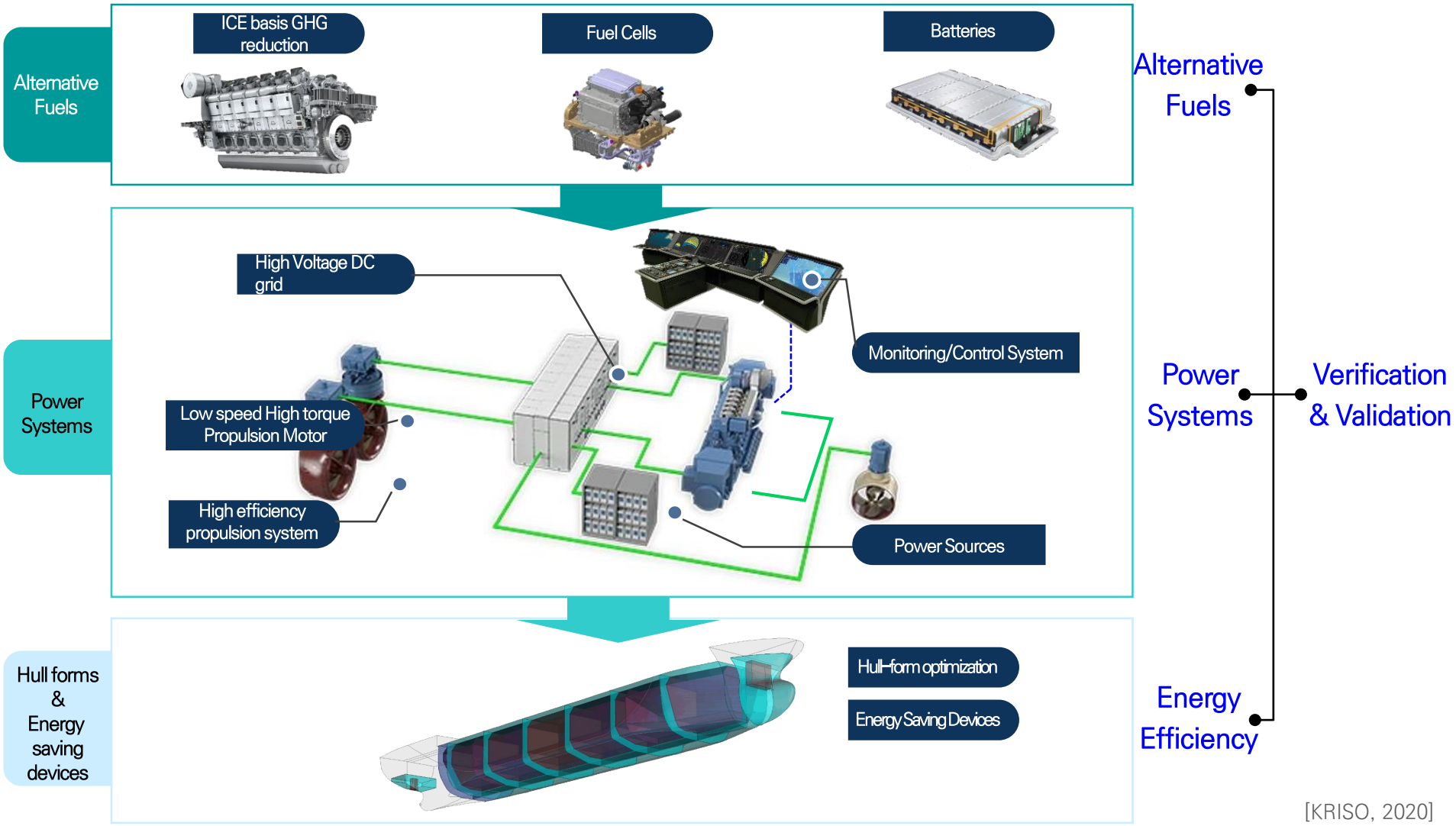
Basket of Measures

- ✓ GHG Fuel Standard + GHG Levy
- ✓ GHG Fuel Standard + Emissions Trading System

※ to compensate shortcomings of each measure

Source: KOMSA, 2021

Technology for GHG Reduction

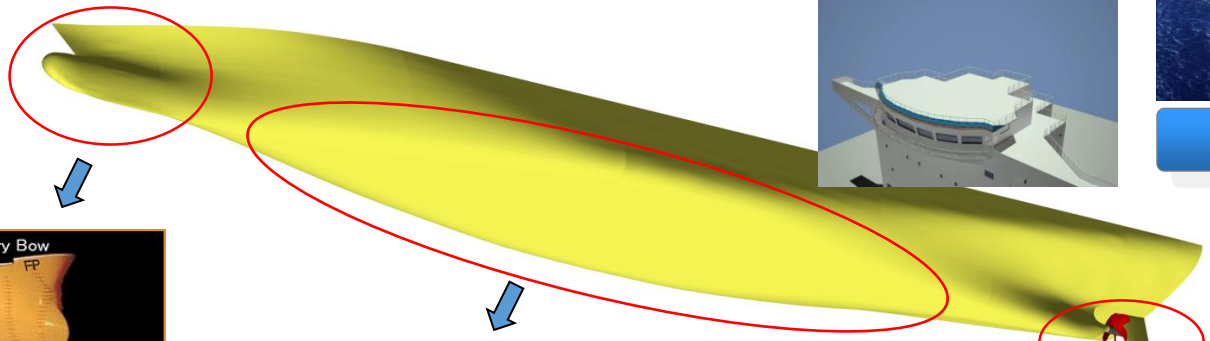


[KRISO, 2020]

Technology for GHG Reduction

Development of Hull Form and Energy Saving Devices (ESD)

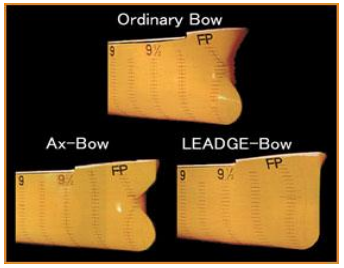




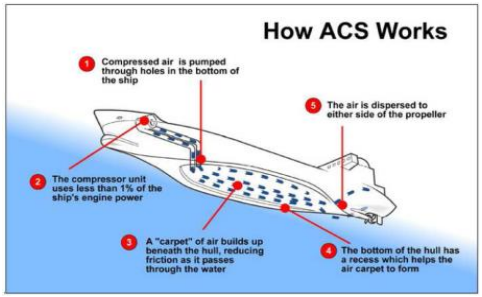
Air Drag Reduction



EEDI Evaluation



- Energy Saving Hull Forms
- Hull Optimization
- Added Resistance in Waves



Friction Drag Reduction
- Air layer
- Microbubble



Propulsion Efficiency
- ESD
- Hybrid POD



[KRISO, 2020]

Results of the 4th IMO GHG Study (MEPC 75/7/15)

IMO INTERNATIONAL MARITIME ORGANIZATION

E

MARINE ENVIRONMENT PROTECTION COMMITTEE
75th session
Agenda item 7

MEPC 75/7/15
29 July 2020
Original: ENGLISH
Pre-session public release: ☒

REDUCTION OF GHG EMISSIONS FROM SHIPS

Fourth IMO GHG Study 2020 – Final report

Note by the Secretariat

SUMMARY

Executive summary:	This document provides in the annex the Final report of the Fourth IMO GHG Study 2020, as well as the "Highlights" of the Study and the Executive Summary
Strategic direction, if applicable:	3
Output:	3.2
Action to be taken:	Paragraph 7
Related documents:	Resolution MEPC.304(72); MEPC 73/19/Add.1; MEPC 74/18, MEPC 74/WP.6; MEPC 75/7/3, MEPC 75/7/3/Add.1 and MEPC 75/7/3/Add.2

Background

1 In accordance with the *Initial IMO Strategy on reduction of GHG emissions from ships* (resolution MEPC.304(72)) and its programme of follow-up actions up to 2023 (MEPC 73/19/Add.1, annex 9), MEPC 74 agreed on the terms of reference of the Fourth IMO GHG Study and requested the Secretariat to initiate the Study with a view to consider its Final report during MEPC 76 initially planned for Autumn 2020.

2 Despite the COVID-19 pandemic and regardless of the postponement of MEPC 75, the Fourth IMO GHG Study has been progressed and finalized in line with the steps and timeline approved by MEPC 74 (document MEPC 74/WP.6, annex 2).

3 Documents MEPC 75/7/3, MEPC 75/7/3/Add.1 and MEPC 75/7/3/Add.2 provide detailed information on the steps of the development of the Study, including in particular its supervision by a Steering Committee of Member States.

I:\MEPC\75\MEPC 75-7-15 .doc

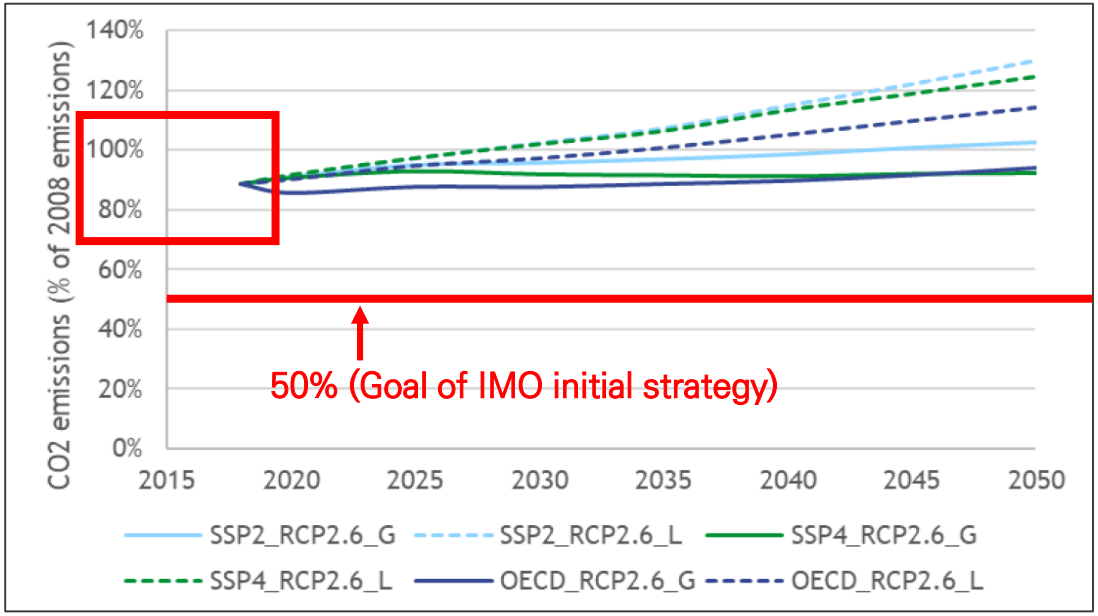
SUSTAINABLE SHIPPING FOR A SUSTAINABLE PLANET

- Emissions in '18 compared to '08 were 90%
- Expected to increase by 90 ~ 130% compared to '08 by '50

✓ Difficult to respond to the IMO GHG regulations with only the fossil fuel-based propulsion method due to the limitation of operation efficiency improvement

✓ Inevitable to introduce zero carbon fuels such as ammonia and hydrogen and eco-friendly systems (battery, fuel cell, etc.)

[MEPC 75/7/15, 2020]



Technology for GHG Reduction

Achieving the goals of the Initial IMO GHG Strategy will require a mix of technical, operational and innovative solutions applicable to ships. Some of them, along with indication on their approximate GHG reduction potential, are highlighted below.



5-50% Fleet management, logistics and incentives

1-10% Voyage optimization

2-50% Concept, speed and capability

up to **75%** Extensive speed optimization

5-15% Power and propulsion systems

50-90% Full electric

35% Bio-LNG/LPG

90% Biofuel 3rd generation

80-100% Hydrogen and other synthetic fuels

1-10% Energy management

2-20% Hull and superstructure

[Ref.] IMO Action to Reduce Greenhouse Gas Emissions from International Shipping (IMO, 2019)

2

KRISO Research Projects On Alternative Fuels

Major Technologies for Decarbonization

1 Eco-friendly future fuel



2 Onboard CCS



3 Digitization for decarbonization



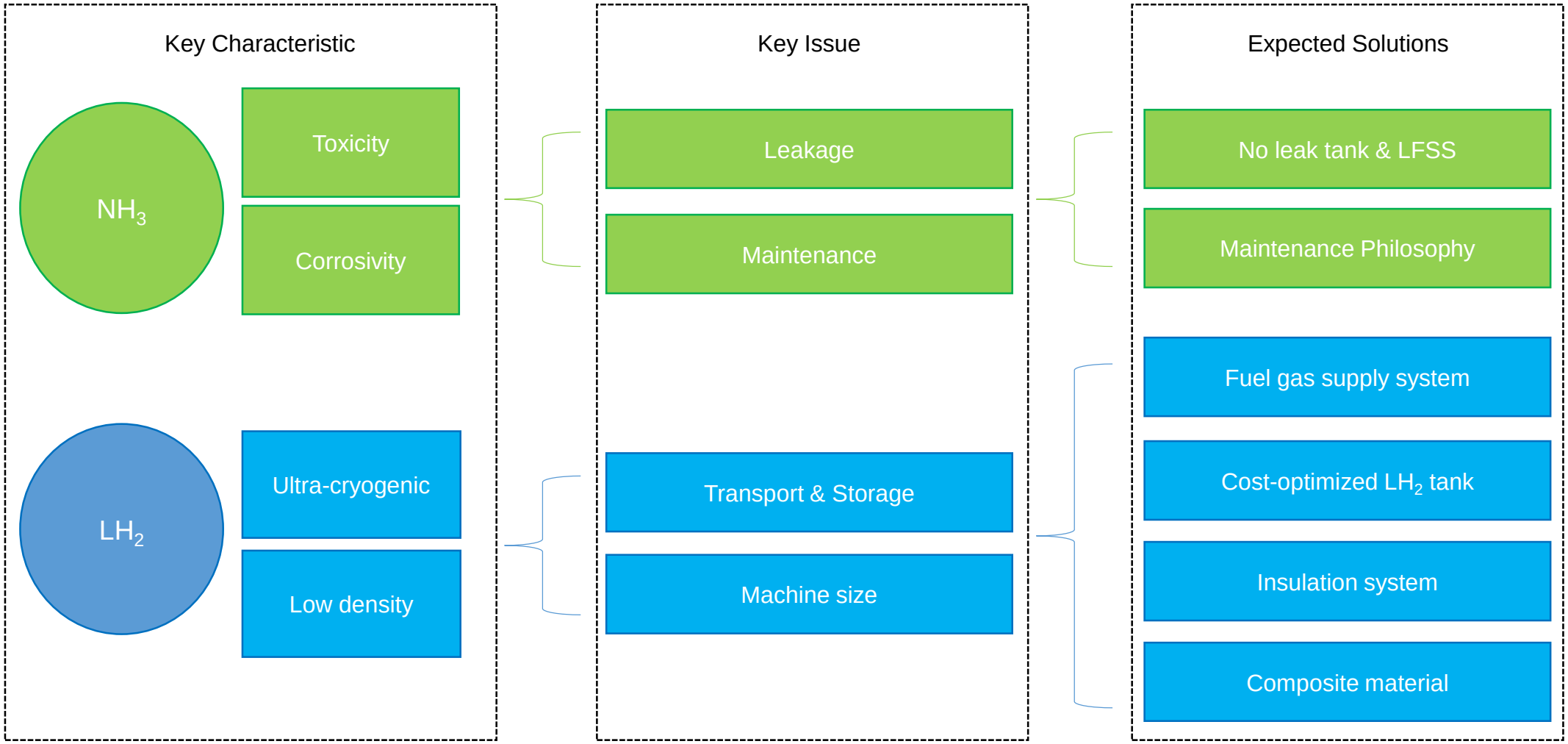
Evaluation of Eco-Friendly Alternative Fuels

〈 Advantages and Disadvantages of Eco-Friendly Alternative Fuels〉

Sort	MGO	LNG ★	Bio gas	Bio diesel	Methanol	Ammonia ★	Hydrogen ★
Type	Fossil Fuel		Carbon-Neutral Fuel/Non-Carbon Fuel				
Storage condition	Atmospheric & Ordinary	-163 ℃	-163 ℃	Atmospheric & Ordinary	Atmospheric & Ordinary	-34 ℃	-253 ℃
Fuel tank size	1 (Ref.)	2.3	2.3	1	2.3	4.1	7.6
Relative CAPEX	1 (Ref.)	~1.3	~1.3	1	~1.15	~1.2	Very Expensive
Fuel cost & Availability	Rich reserves in conventional and unconventional oil fields		Difficulty in mass production due to raw material supply problems	Supply and demand instability, food security issues	High carbon dioxide capture cost (airborne capture)	Relatively inexpensive among carbon-neutral fuels	Fuel production costs are reasonable, transportation and storage costs are high

Source: KR, 선박연료로써의 암모니아, 2021

Ammonia & Hydrogen Fuels



Alternative Fuels and Power System Research Division

- R&D according to the GHG reduction roadmap planned by 2050
- International joint research and data sharing centered on the research base in Mokpo
- Looking forward to cooperation with Europe for JIP and international standardization



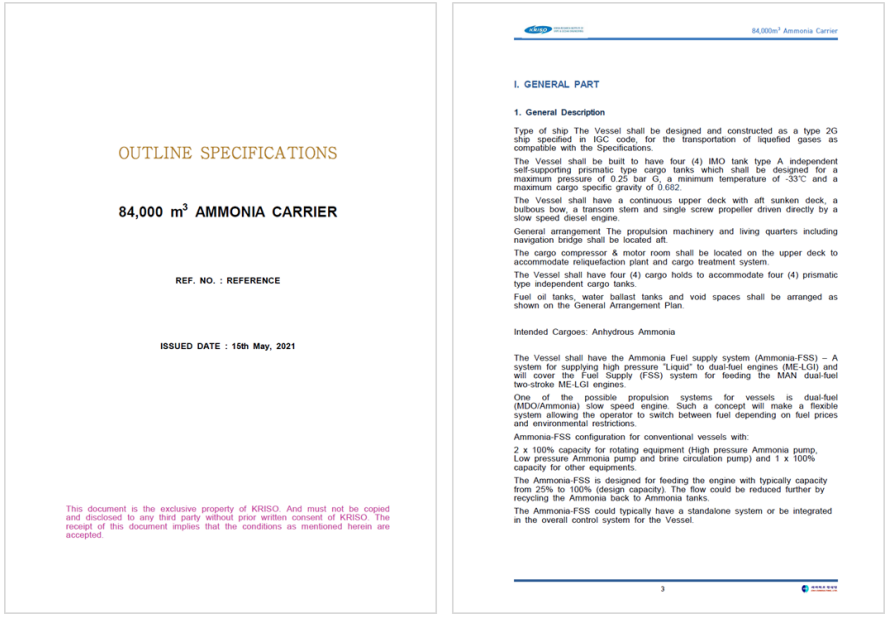


Researcher in charge: Dr. Kang, Hee Jin

Research Projects: Ammonia LFSS

Basic Design of LFSS for 84K Ammonia LFSS

- Ammonia Fuel Tank
- LP Pump, HP Pump
- Main Ammonia HE Configuration
- GW System
- Fuel Valve Train
- Return Line Configuration
- Oil Separator
- Disposal Method of Ammonia Vapor from K.O. Drum, etc.



OUTLINE SPECIFICATIONS

84,000 m³ AMMONIA CARRIER

REF. NO. : REFERENCE

ISSUED DATE : 16th May, 2021

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84,000m³ Ammonia Carrier

I. GENERAL PART

1. General Description

Type of ship The Vessel shall be designed and constructed as a type 2G ship specified in IGC code, for the transportation of liquefied gases as compatible with the Specifications.

The Vessel shall be built to have four (4) IMO tank type A independent self-supporting prismatic type cargo tanks which shall be designed for a maximum pressure of 0.25 bar G, a minimum temperature of -33℃ and a maximum cargo specific gravity of 0.682.

The Vessel shall have a continuous upper deck with aft sunken deck, a bulbous bow, a transom stern and single screw propeller driven directly by a slow speed diesel engine.

General arrangement The propulsion machinery and living quarters including navigation bridge shall be located aft.

The cargo compressor & motor room shall be located on the upper deck to accommodate reliquefaction plant and cargo treatment system.

The Vessel shall have four (4) cargo holds to accommodate four (4) prismatic type independent cargo tanks.

Fuel oil tanks, water ballast tanks and void spaces shall be arranged as shown on the General Arrangement Plan.

Intended Cargoes: Anhydrous Ammonia

The Vessel shall have the Ammonia Fuel supply system (Ammonia-FSS) – A system for supplying high pressure "Liquid" to dual-fuel engines (ME-LGI) and will cover the Fuel Supply (FSS) system for feeding the MAN dual-fuel two-stroke ME-LGI engines.

One of the possible propulsion systems for vessels is dual-fuel (MDO/Ammonia) slow speed engine. Such a concept will make a flexible system allowing the operator to switch between fuel depending on fuel prices and environmental restrictions.

Ammonia-FSS configuration for conventional vessels with:

2 x 100% capacity for rotating equipment (High pressure Ammonia pump, Low pressure Ammonia pump and brine circulation pump) and 1 x 100% capacity for other equipments.

The Ammonia-FSS is designed for feeding the engine with typically capacity from 25% to 100% (design capacity). The flow could be reduced further by recycling the Ammonia back to Ammonia tanks.

The Ammonia-FSS could typically have a standalone system or be integrated in the overall control system for the Vessel.

3

〈 Outline Specifications of 84K Ammonia Carrier 〉

Researcher in charge: Dr. Seo, Youngkyun

Research Projects: Ammonia LFSS

Hazard Identification with DNV ('21.11)

159 accident scenarios (32 hazardous events) were identified at HAZID workshop.

Table 9-1 Risk Ranking (Current Risk)

		Consequence				
		C1	C2	C3	C4	C5
Likelihood	L7	0	0	0	0	0
	L6	0	0	0	0	0
	L5	1	4	0	0	0
	L4	3	23	102	0	0
	L3	0	1	5	0	0
	L2	0	0	6	14	0
	L1	0	0	0	0	0



Approval in Principle (AiP) by Lloyd's Register ('21.12)



APPROVAL IN PRINCIPLE (AiP)
AMMONIA FUEL SUPPLY SYSTEM FOR 84K AMMONIA CARRIER
KOREA RESEARCH INSTITUTE OF SHIPS & OCEAN ENGINEERING (KRISO)

Design Appraisal Document

APPROVAL IN PRINCIPLE (AiP) for
KOREA RESEARCH INSTITUTE OF SHIPS & OCEAN ENGINEERING (KRISO)'s
AMMONIA FUEL SUPPLY SYSTEM FOR 84K AMMONIA CARRIER

Appendix

Researcher in charge: Dr. Seo, Youngkyun

Research Projects: LH_2 FST

Development of novel designs for ship application and thermal insulation enhancement

- 400kg 316L/316HN LH2 FST is developed for hydrogen powered ships
- Novel designs are introduced and implemented to achieve both **structure integrity** and **high thermal insulation performance**.

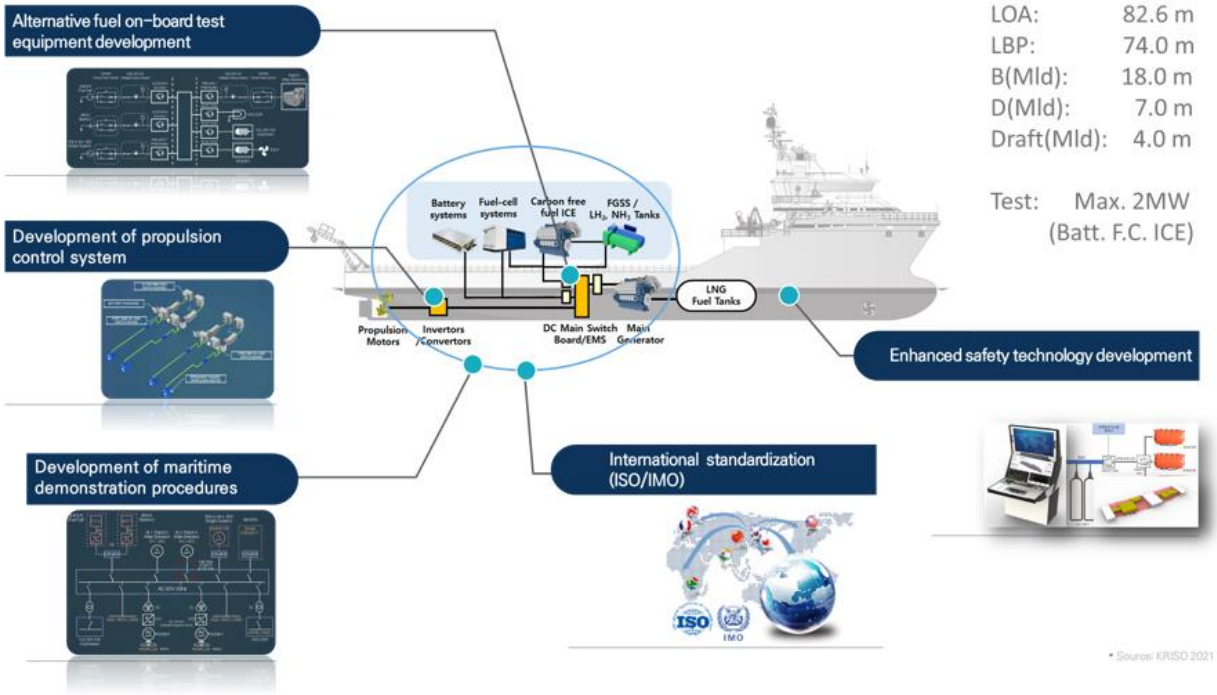


〈 400 kg 316L LH2 FST at KRISO Geoje R&BD Center 〉

Country	Liquid hydrogen fuel tanks for ships	
International		• MF Hydra: World's first LH_2 powered commercial vessel(Scheduled for 22') • C-type 80m^3 LH_2 FST(Not installed yet) • Material: 304L or 316L
Korea		• Korea's first AIP awarded LH_2 FST • Targeted for use on small coastal vessels • C-type 6m^3 LH_2 FST • Material: 316L(prototype, AIP), 316HN(AIP)

Research Projects: Marine Testbed Ship

- World first **2.2MW class multi-purpose hybrid marine testbed** for maritime demonstration of alternative fuels
- Verification and validation for alternative fuels and electric propulsion system

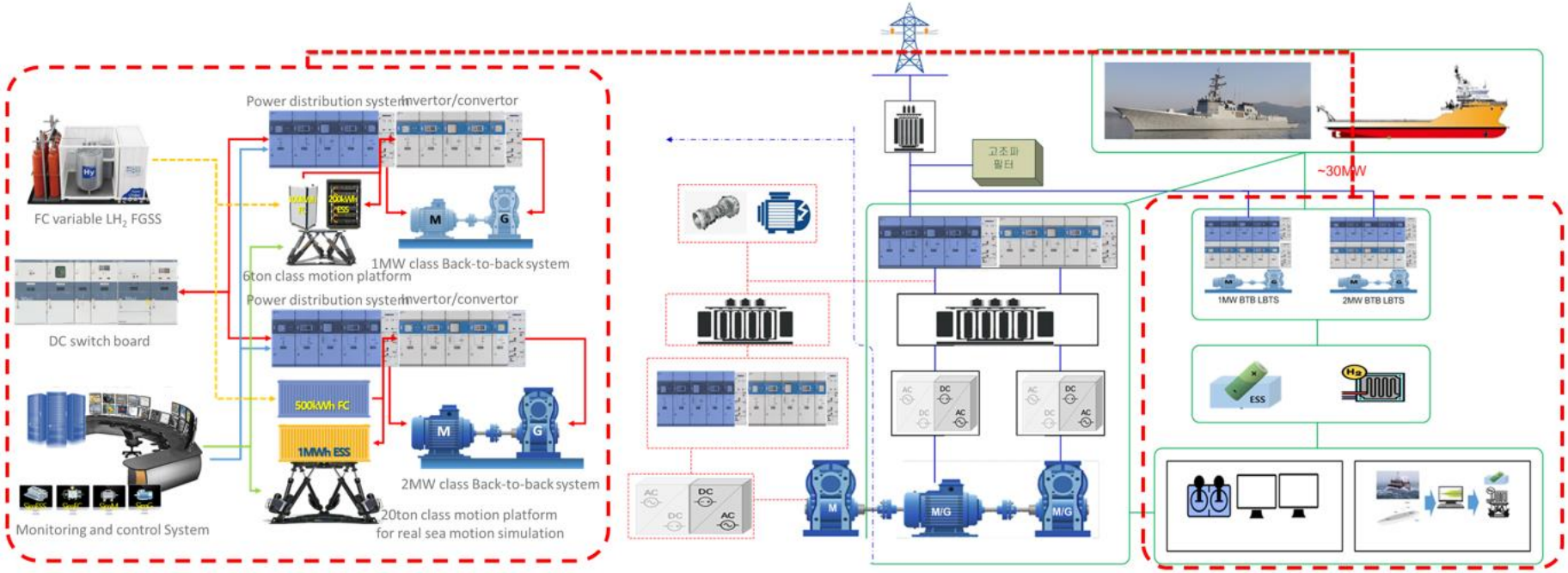




Researcher in charge: Dr. Kang, Hee Jin

Research Projects: Land-based Testbed

- On-land basis testbed for reliability, availability, maintainability and safety
- MW-class test of alternative fuels reflecting the actual marine environment
- Land test and evaluation of **up to 30 MW class** electric propulsion system



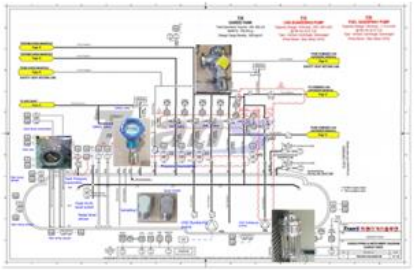
Researcher in charge: Dr. Kim, Yun Ho

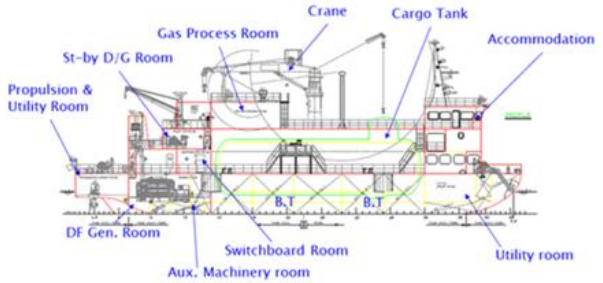
Research Projects: LNG/LH2 Bunkering

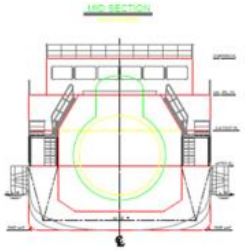
Development of LNG Bunkering vessel for coastal trading LNG fueled ship

- Title : Development of **LNG Bunkering vessel** for coastal trading LNG fueled ship
- Main Goal : Design and pilot test of **Ship-To-Ship** 500cbm LNG Bunkering System
- Organization : KRISO with 6 private companies (2018.4. – 2022.12.)
- (Future) Transferring 'K-LNG Dream', New Pilot project for LNG Bunkering SIMOPs









▪ **Hi-Mn. Cargo Tank**
(By POSCO)





















Research Projects: Fully Electrified Ship

Development and demonstration of a fully electrified car-ferry powered by removable battery systems

- World first removable ESS propulsion for car-ferries
- ISO container basis 800kWh removable ESS used for zero carbon ship operation



! Design of removable battery system



! Launch the car ferry and will start the trial run from Sept. 2022



Researcher in charge: Dr. Kim, Young-Shik

Technology Maturity of Low/Zero Carbon Fuels

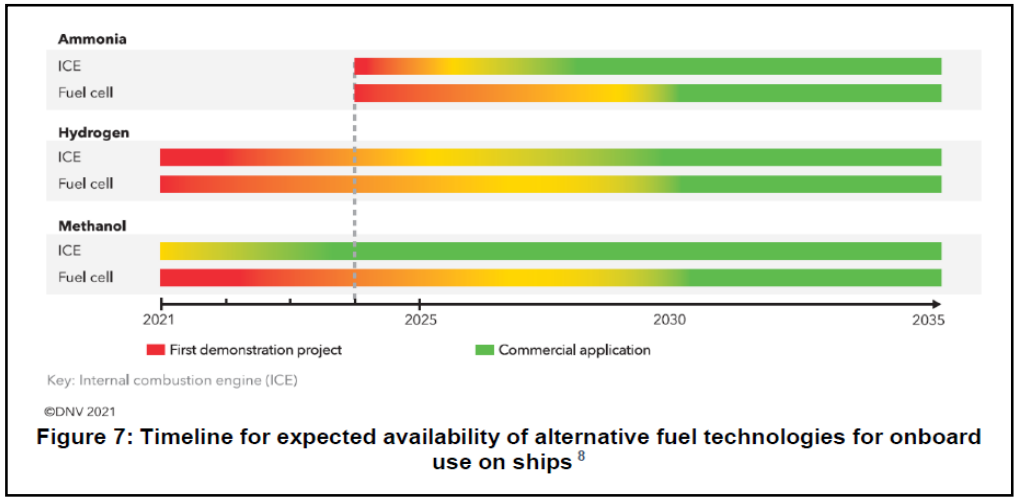
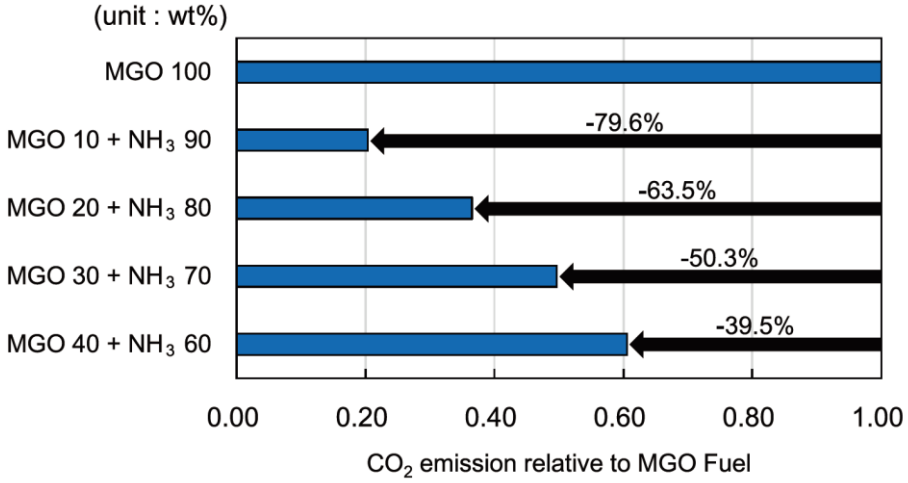


Figure 7: Timeline for expected availability of alternative fuel technologies for onboard use on ships [8]

Source: DNV, Maritime Forecast to 2050, 2021

〈 Methanol, Ammonia and Hydrogen Fuel Propulsion Technology Maturity〉

CO_2 Emission of Ammonia Fuel

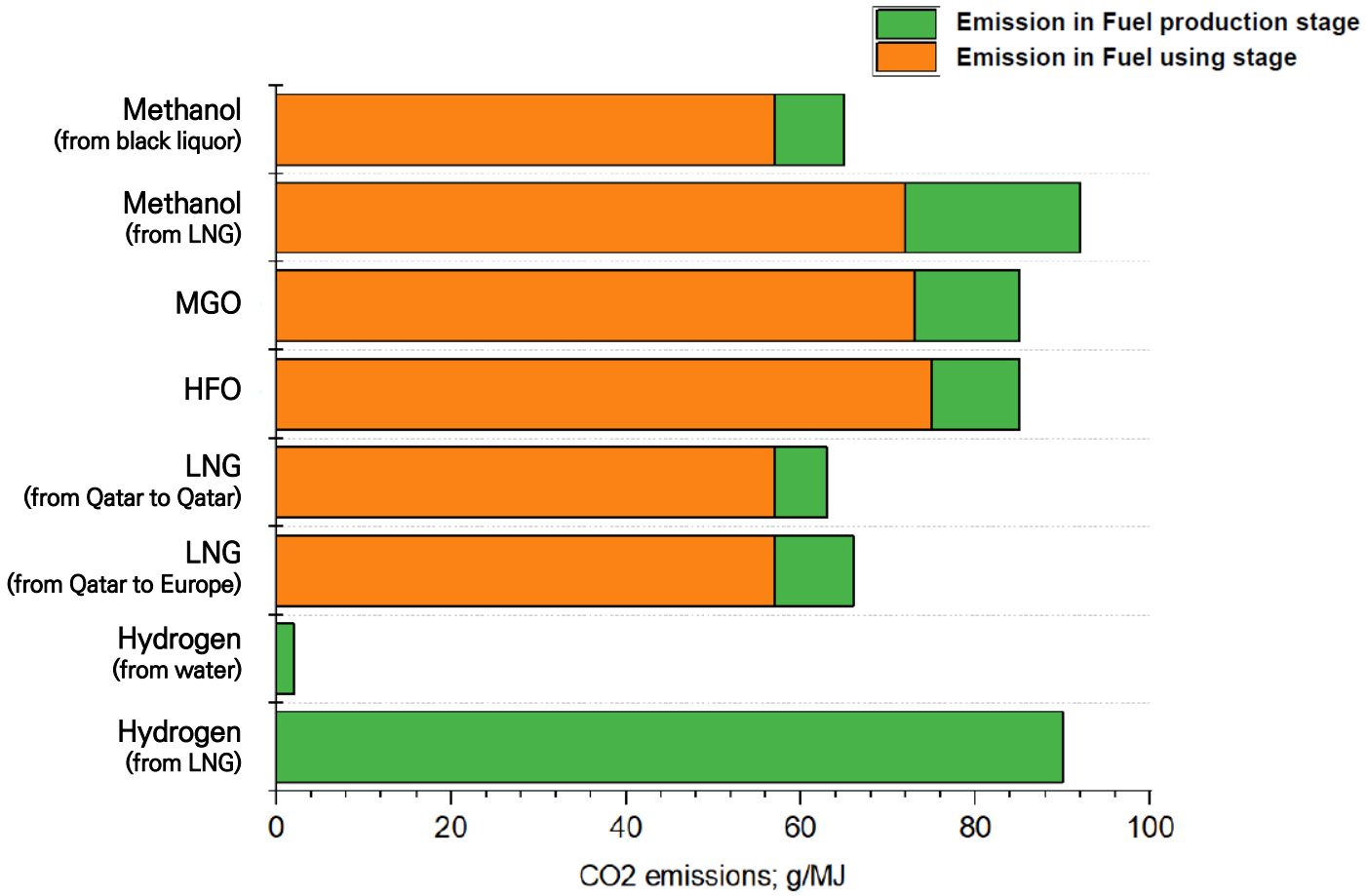


Source: KR, 2021

〈 CO_2 Emission of MGO & Ammonia Mixed Fuel compared to MGO only 〉

Is it really an eco-friendly technology?

Life Cycle Assessment (LCA)



Source: DNV. Maritime Impact Report of Carbon Emissions

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KRISO Research Project for Onboard CCS

Major Technologies for Decarbonization

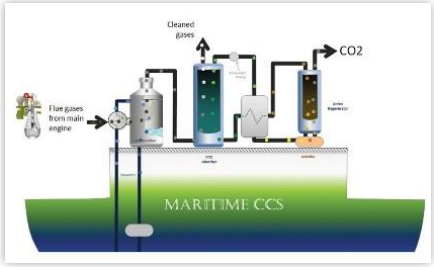
1

Eco-friendly future fuel



2

Onboard CCS



3

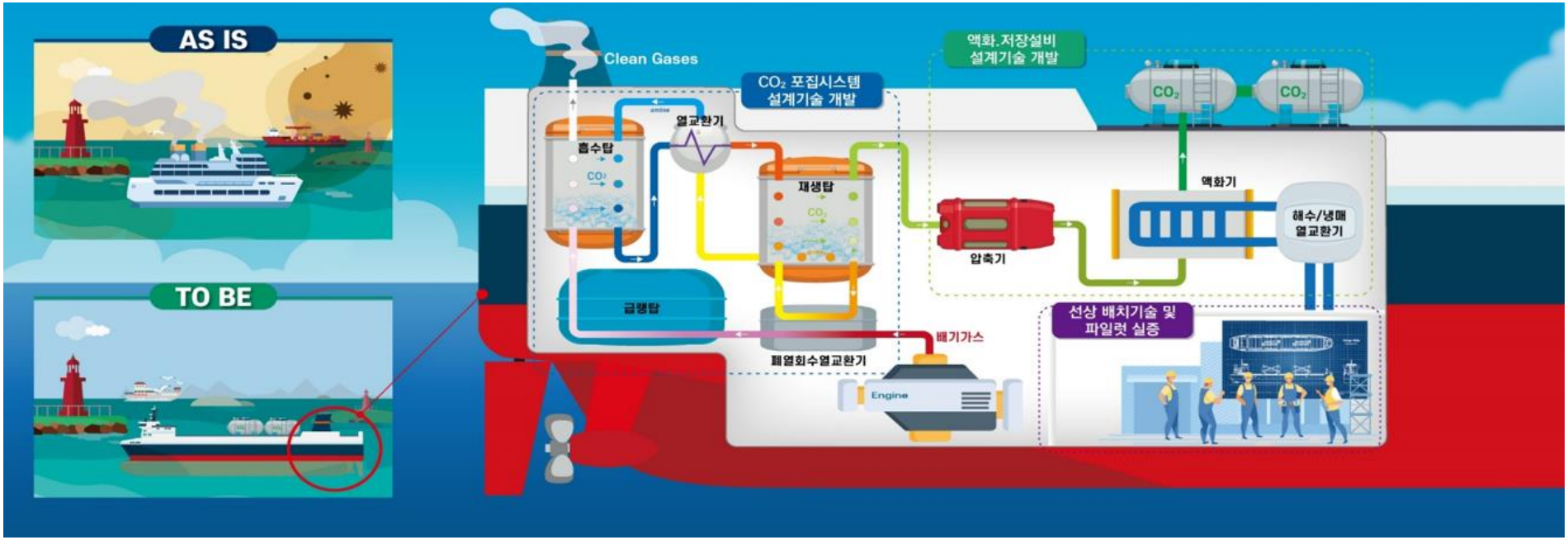
Digitization for decarbonizatio n



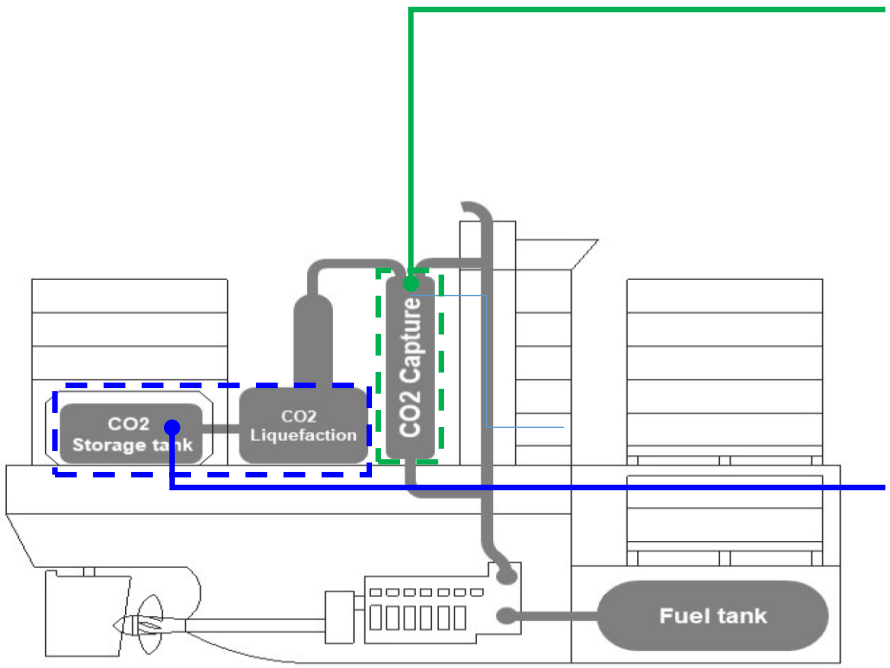
Bridging Technology

"It is expected to take a considerable amount of time to commercialize production system, bunkering system, and propulsion system for zero carbon fuels, so it is necessary to review the onboard carbon capture system as a stepping stone technology."

- Carbon Capture and Storage (CCS) is a mature technology.
- Low input/operation cost compared to zero carbon fuel propulsion technology.
- Necessity of verifying economic feasibility and stability in consideration of various types of ships, size of ships, and fuel oil.



KRISO OCCS Research Planning Overview



① CO_2 Capture Technology

Absorption
Cryogenic
Membrane
Adsorption

② CO_2 Onboard storage technology

High-pressure gas CO_2 storage method
Medium pressure liquid CO_2 storage method
Solid CO_2 storage method (dry ice)
Liquid products from conversion reactions (e.g. methanol)
Solid products from conversion reactions (calcium carbonate, hydrates, etc.)

Source: Lee S.H., KAIST, 2021

4

Conclusions

Conclusions

R&D direction for IMO mid-term measures

- Onboard Carbon Capture System (OCCS) as a "stepping stone technology"
- Low-carbon/zero-carbon fuel propulsion system
  - LNG + OCCS technology combination (GHG reduction capacity about 30% ~ 50%)
  - Ammonia fueled ship (GHG reduction capacity about 50% ~ 80%)

+

R&D direction for IMO long-term measures

- Development and demonstration of technologies for **zero carbon fueled (ammonia, hydrogen)** ships
- **Construction of electric motor-based (including ESS) propulsion system** for ocean-going ships
- Fuel price ↑ ↑ ↑ → Important for **energy saving devices (ESD), treatment technology of marine bio-fouling,** and **integrated energy control system**

+

- Along with the improved technologies of ship propulsion systems, onshore infrastructure including production facility, bunkering system, and onshore CCS value chain is significant.


Thank you for your attention!
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