

KSOE

KOREA SHIPBUILDING &
OFFSHORE ENGINEERING

Status and Prospect of Eco-Friendly Fuel Ship Development

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HYUNDAI HEAVY INDUSTRIES GROUP

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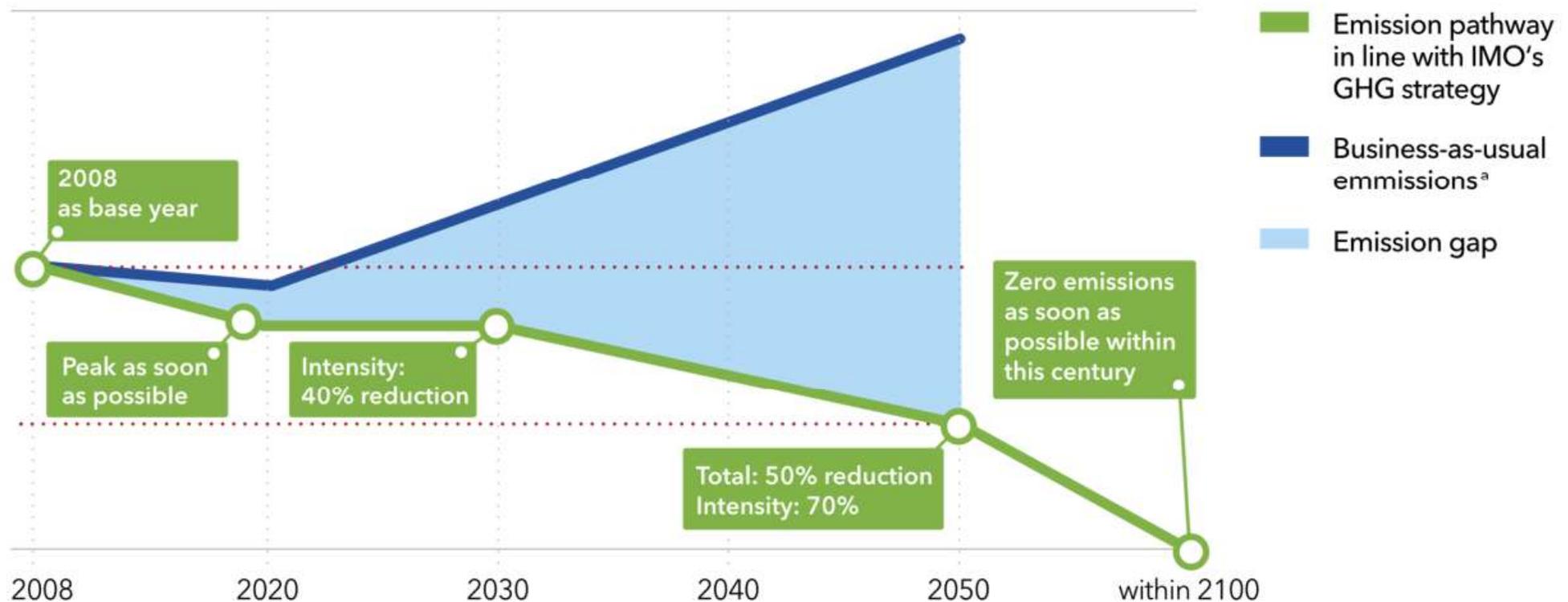
1. Change in Shipbuilding Market
 - Market Issue & Status
 - GHG Regulations
2. Requirement and Prospect of Alternative Marine Fuel
 - IMO & EU regulation for Alternative Fuel
 - Fuel Mix and Choice
3. Status and Prospect of Eco-Friendly Fuel Ship
 - LNG / Methanol / Ammonia Fueled Ship and Engine
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1. Change in Shipbuilding Market

Market Issue

- **Decarbonization:** For IMO 2050 vision, GHG emission per transport work should be reduced 40% by 2030 and 70% by 2050, compared to 2008.
- More Ships will be propelled with alternative fuels like LNG, LPG, Methanol, Ammonia or Hydrogen

Units: GHG emissions



Source: DNV GL (2018)

1. Change in Shipbuilding Market

Market Status – Increase of D/F Ship Order

- Global orders of D/F(Dual Fueled) Ships are increasing continuously for recent 4 years.
- D/F ship order of HHI group is increased substantially from 6% in 2018 to 59% in 2021
- LNG is the main stream of alternative fuel for decarbonization.
- Methanol-fueled ship gets bigger and is focused as the carbon-neutral option.
- Ammonia will be one of the main alternative fuel options for net zero operations

D/F Ship Orders in HHI Group

(Unit: EA)

Year	Orders	D/F Vessels	(%)	LNG	LPG	Methanol	Ethane
2018	161	10	6%	10	0	0	0
2019	146	39	27%	23	8	2	6
2020	105	40	38%	22	8	6	4
2021	216	127	59%	71	45	9	2



Methanol-fueled Container ('2021 ordered, Maersk/HHI)

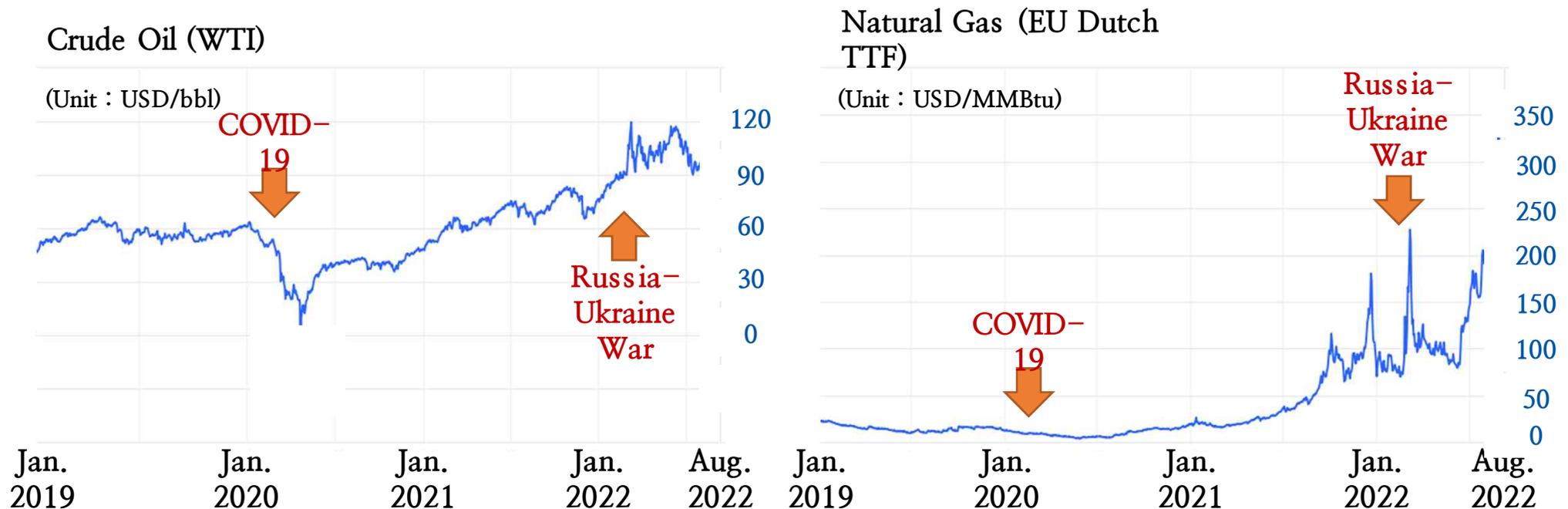


EPS plan to order ammonia carrier from HHI(2022)

1. Change in Shipbuilding Market

Market Status – Volatility in Fuel Price

- LFO¹⁾ price plunged due to COVID-19 but increased recently
- LNG was influenced by COVID-19 but maintained the relatively stable price level
- Russia-Ukraine War leads increase of the volatility of fuel price



< Fuel Price Trend for Crude Oil and LNG >

(1) LFO: Light Fuel Oil

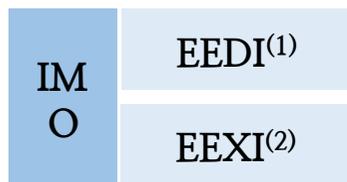
1. Change in Shipbuilding Market

GreenHouse Gas Regulations in Maritime Industry

- Existing GHG regulations, More Stringent; New Ones, Enforced Soon
- Wider scope of greenhouse gas and Wider cover of fuel life cycle
- Holistic care for whole shipping business

Holistic and Monitoring-based

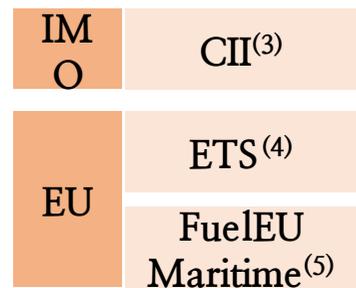
Technical Measure



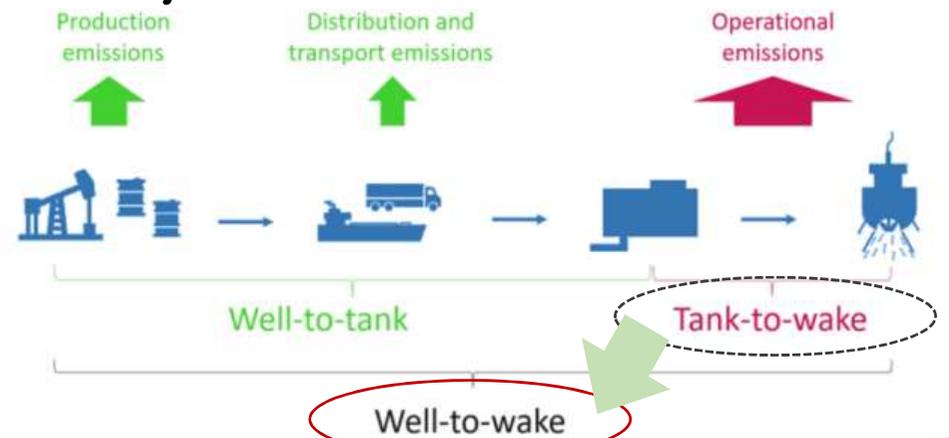
Technical Measure



Operating Measure



Life Cycle Consideration



Addition of GHG



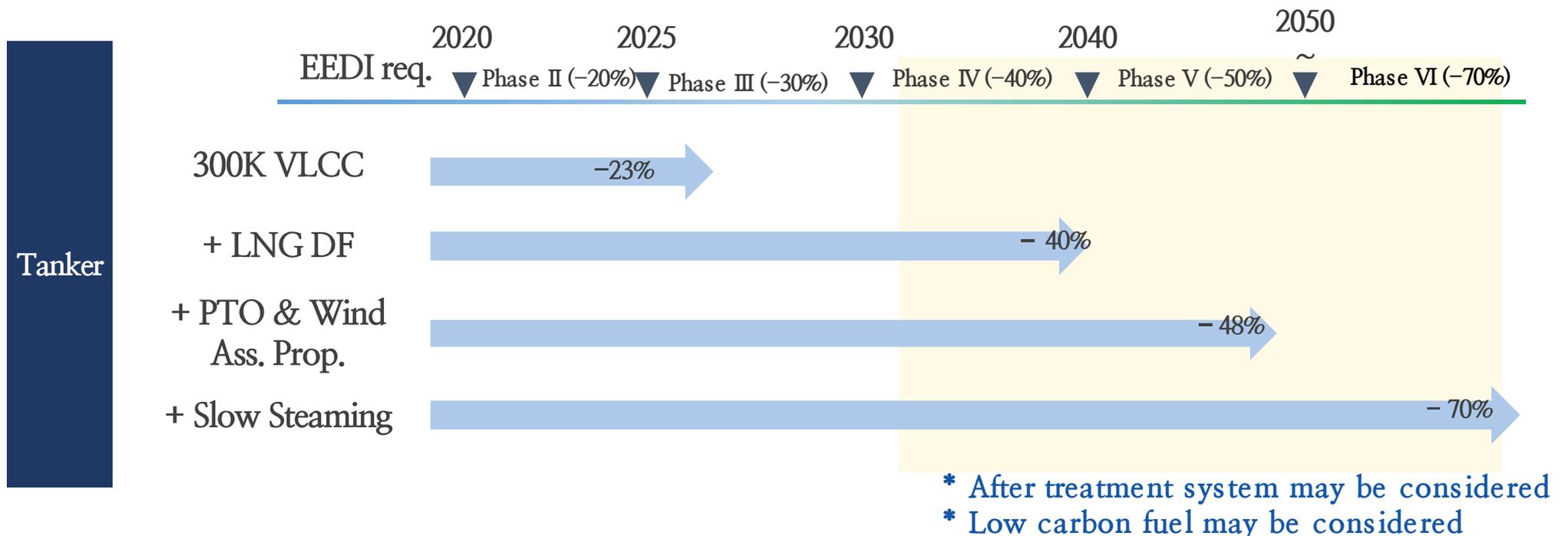
(1) EEDI: Energy Efficiency Design Index (2) EEXI: Energy Efficiency Existing-ship Index (3) CII: Carbon Intensity Indicator

(4) ETS: Emissions Trading System (Proposed by EC, 2021.07.14) (5) Proposal by ITRE (2022.06.13)

2. Requirement and Prospect of Alternative Marine Fuel

Countermeasures for EEDI Regulation

- EEDI can be satisfied by measures such as LNG, ESD¹⁾, slow steaming
- Although slow steaming could be applied for several types of ship for EEDI, it has limitations in terms of logistics speed and attainable maximum GHG reduction.
- Low carbon fuel would be applied for EEDI around 2040.

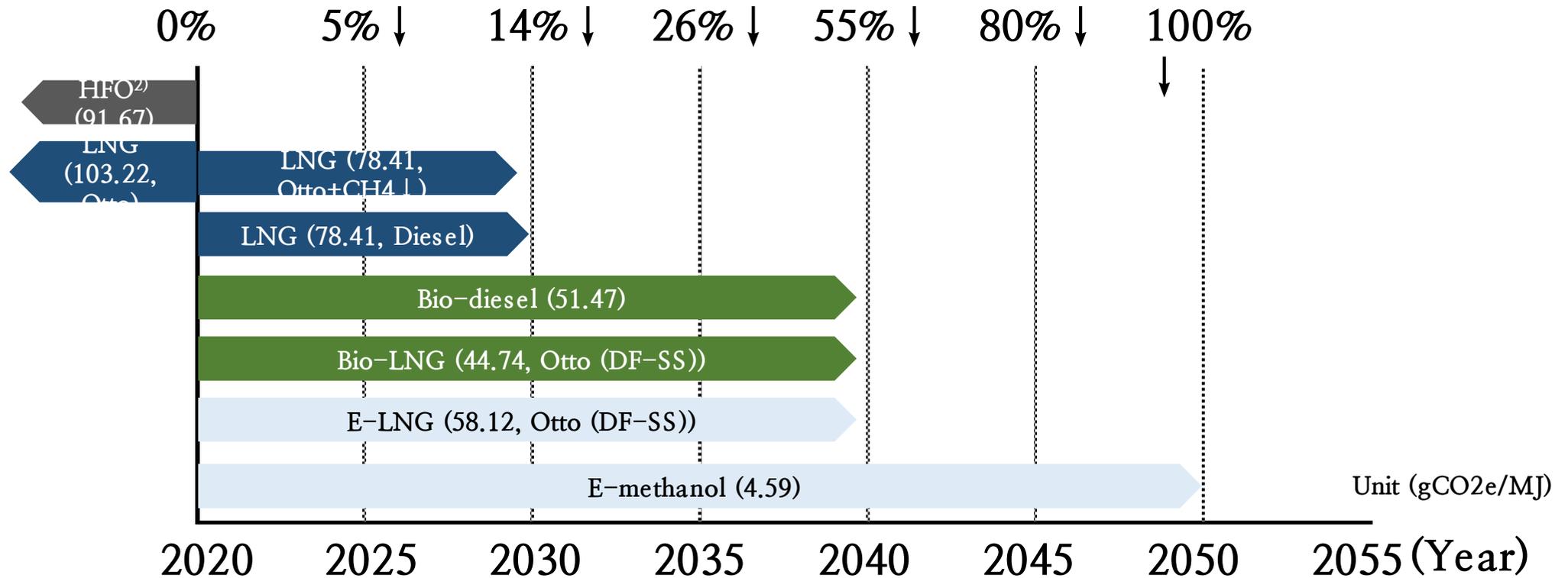


< Countermeasure for EEDI Regulation for 300K VLCC >

2. Requirement and Prospect of Alternative Marine Fuel

Requirement of Decarbonized Fuel

- Well-to-Wake Standards : FuelEU Maritime (EU, '23), GHG Fuel Standard (IMO, TBD¹⁾)
- Carbonized fuel would give financial penalty to ship company
- Low-carbon fuel mix is required for LNG after 2030 not to pay penalty.
Target Reduction Ratio (Compared to 2020 = 90.1 gCO₂e/MJ)

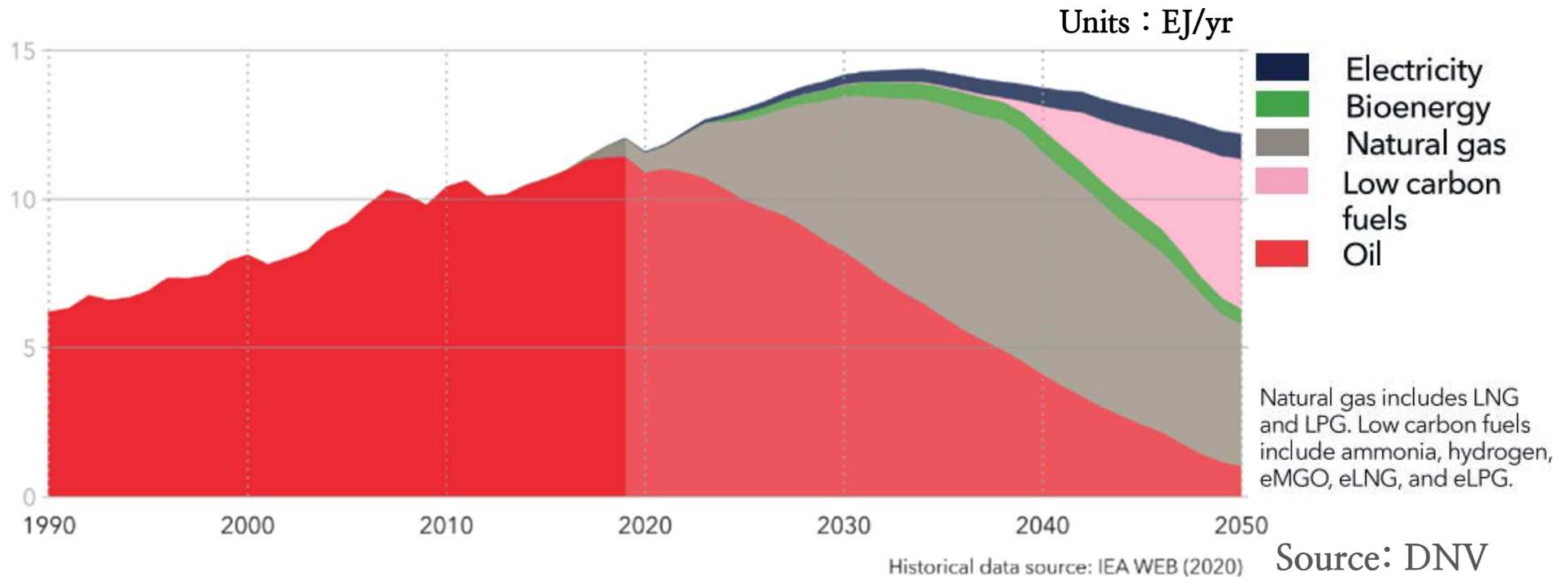


〈 No penalty condition for various fuels on FuelEU Maritime regulations 〉

2. Requirement and Prospect of Alternative Marine Fuel

Fuel Mix for Decarbonization

- Big change in fuel from mostly oil to alternative fuels with low- / zero-carbon
- There's great uncertainty what will be the most competitive future fuel
- The low-carbon fuels like LNG are the realistic solution for now
- The commercialization of zero-carbon fuel would take a long time



〈 World maritime subsector energy demand by carrier 〉

2. Requirement and Prospect of Alternative Marine Fuel

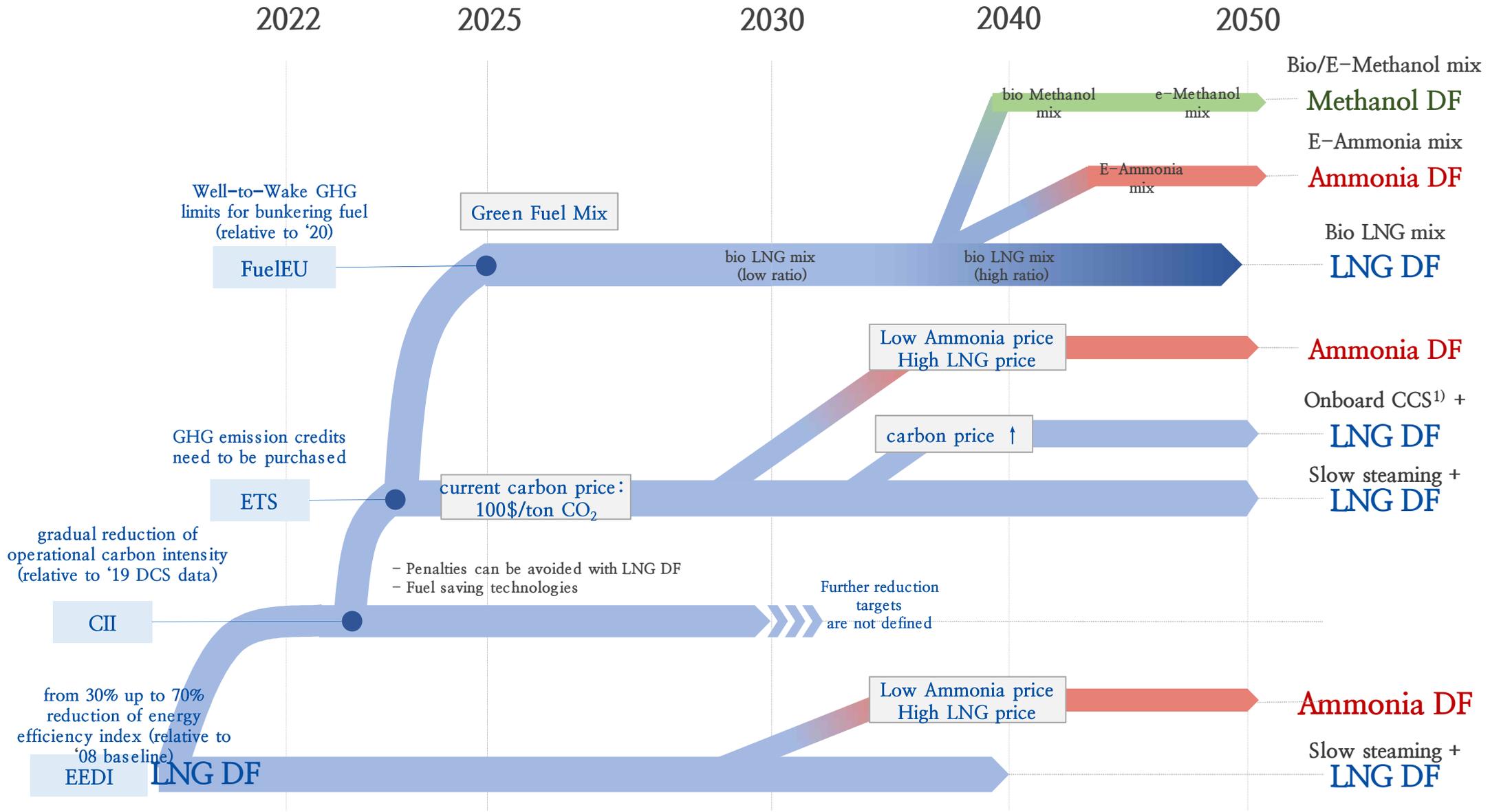
Fuel Option for Decarbonization

- Fuel based oil : Superior to alternative fuels in all respects except green credentials.
- LNG : an main option of the next superior marine fuel. Good availability, maturity of technology, price and low carbon
- Methanol, Bio-/e-fuels, Hydrogen, Ammonia : Alternative fuel options with green credentials

	Availability	Infrastructure & Storage	Maturity of technology	Energy density	Price	Green credentials
VLSFO/MGO	Green	Green	Green	Green	Green	Red
LNG	Green	Yellow	Green	Yellow	Green	Yellow
LPG	Green	Yellow	Yellow	Yellow	Green	Yellow
Methanol	Yellow	Yellow	Green	Yellow	Yellow	Yellow
Bio-/e-fuels	Red	Green	Yellow	Green	Red	Light Green
Hydrogen	Red	Red	Red	Red	Red	Light Green
Ammonia	Red	Yellow	Red	Yellow	Yellow	Light Green

2. Requirement and Prospect of Alternative Marine Fuel

Regulation and Fuel Path



(1) CCS: Carbon Capture & Storage

3. Status and Prospect of Eco-Friendly Fuel Ship

LNG Dual Fueled Ship

- Most Feasible Solution Today
- Energy Saving Measures for overcoming Energy density
- CO₂ / Methane Capture for Green credentials
- Energy saving measures for alternative emission fuels (Bio-LNG, H₂ mix)

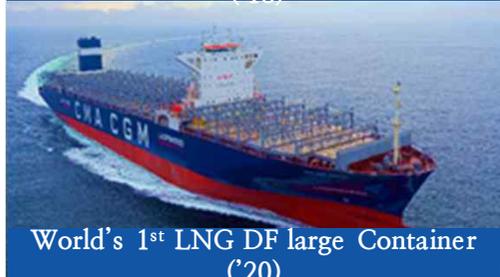


Prolonged Use,
Possible

Record of HHI Group



World's 1st LNG DF Aframax tanker ('18)



World's 1st LNG DF large Container ('20)



180K LNG DF Bulk Carrier ('20)

Developed



Engine Mounted Generator

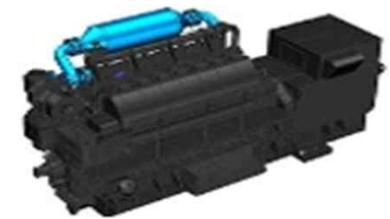


Air lubrication system

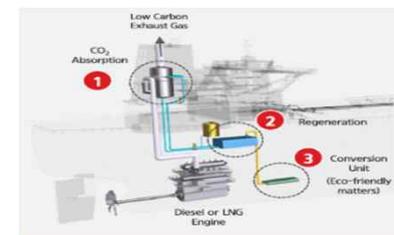


Wind assisted propulsion

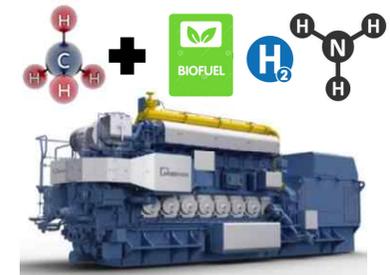
To Be Developed



Methane Slip Reduction System



CO₂ Capture/Reduction



Mixed Combustion Engine

3. Status and Prospect of Eco-Friendly Fuel Ship

LNG Dual Fueled Engine – Methane Slip Reduction for M/E¹⁾

- Methane slip reduction solution: EGR system in 2-Stroke Otto cycle engine
- Max. 50% methane slip reduction by exhaust gas recirculation (EGR)



[ME-GA with EGR]
World's first ME-GA at HHI-EMD

shop

- R&D & FAT at HHI-EMD (2022)
- Engine type: G70

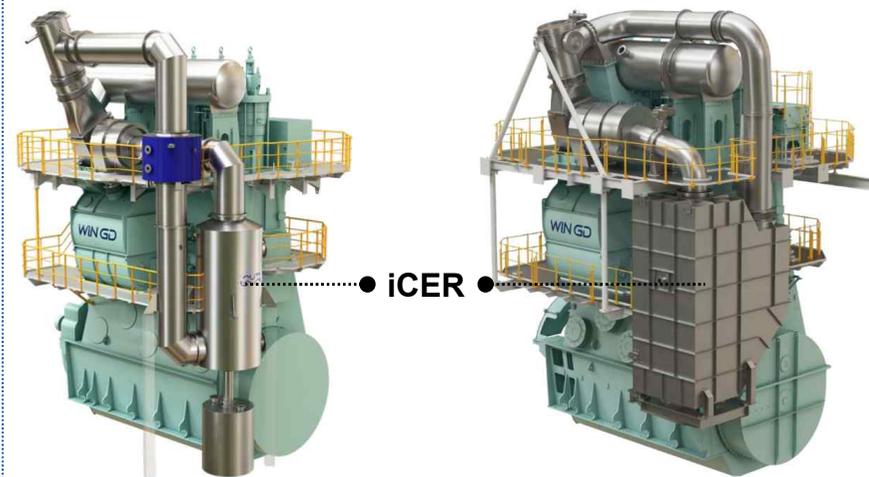


[Engine type: 5G70ME-C10.5-GA]



[X-DF with iCER²⁾ on-engine]
Collaboration with WinGD

- Engine integrated LP-EGR solution
- Suitable engine outline for LNGC
- Full scale prototype test by 2022



[iCER off-engine]

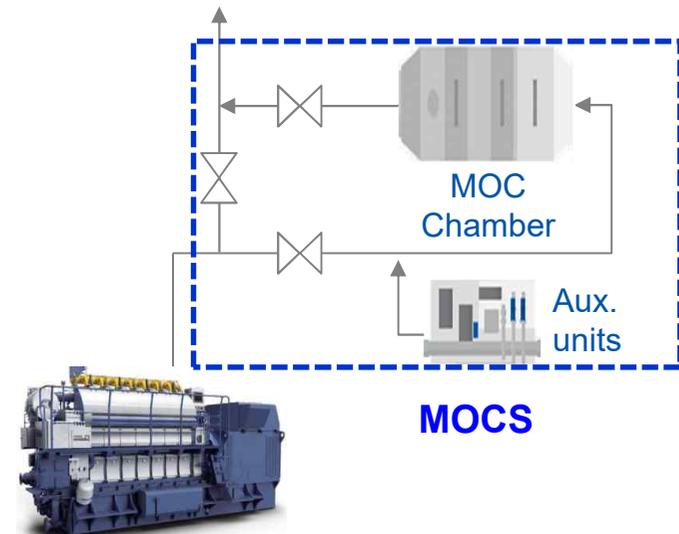
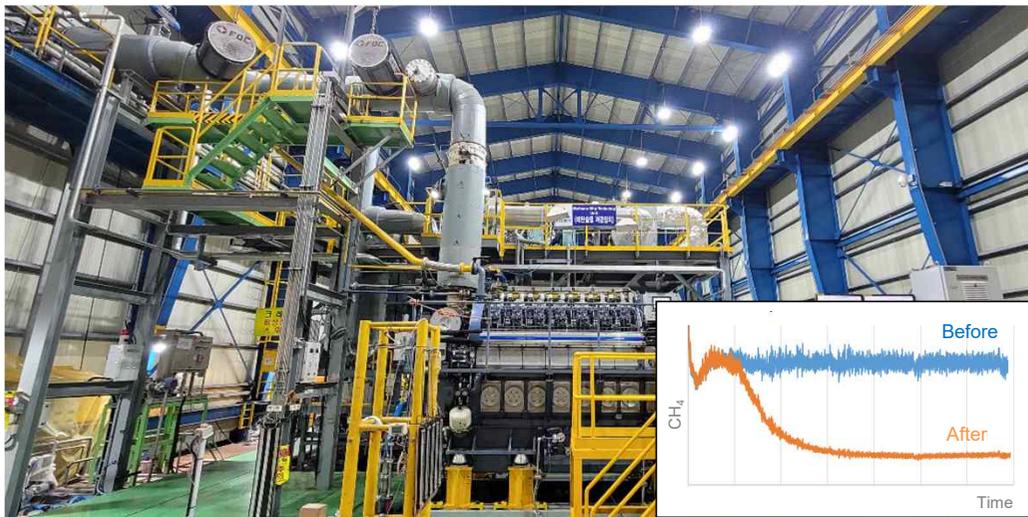
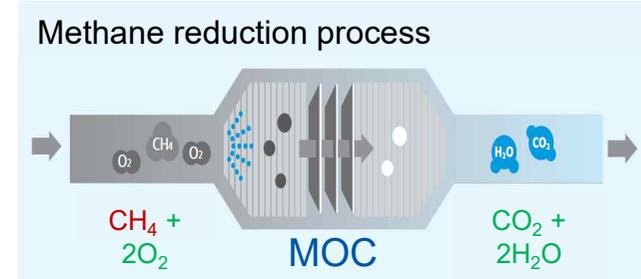
[iCER on-engine]

(1) M/E: Main Engine (2) iCER: intelligent Control by Exhaust Recycling

3. Status and Prospect of Eco-Friendly Fuel Ship

LNG Dual Fueled Engine – Methane Slip Reduction for G/E¹⁾

- Methane slip reduction solution: MOCS (Methane Oxidation Catalyst System)
- Methane slip mitigation by after treatment Catalyst (MOC²⁾)
- Required a certain temperature for CH₄ oxidation as a stable molecule
- System verification in progress for launching in 2023



(1) G/E: Generator Engine (2) MOC: Methane Oxidation Catalyst

3. Status and Prospect of Eco-Friendly Fuel Ship

Methanol Fueled Ship

- Mature technology similar to conventional HFO. Need to be scaled-up.
- CO₂ 11% reduction /w methanol (TTW) + additional emission reduction (PM/Smoke, SO_x, NO_x)



Supply chain is the main key factor (Bunkering infrastructure)

〈Maersk’s Strategy for Green Methanol Supply〉

〈 World’s 1st Methanol-fueled PC 〉
(’2016, HMD)



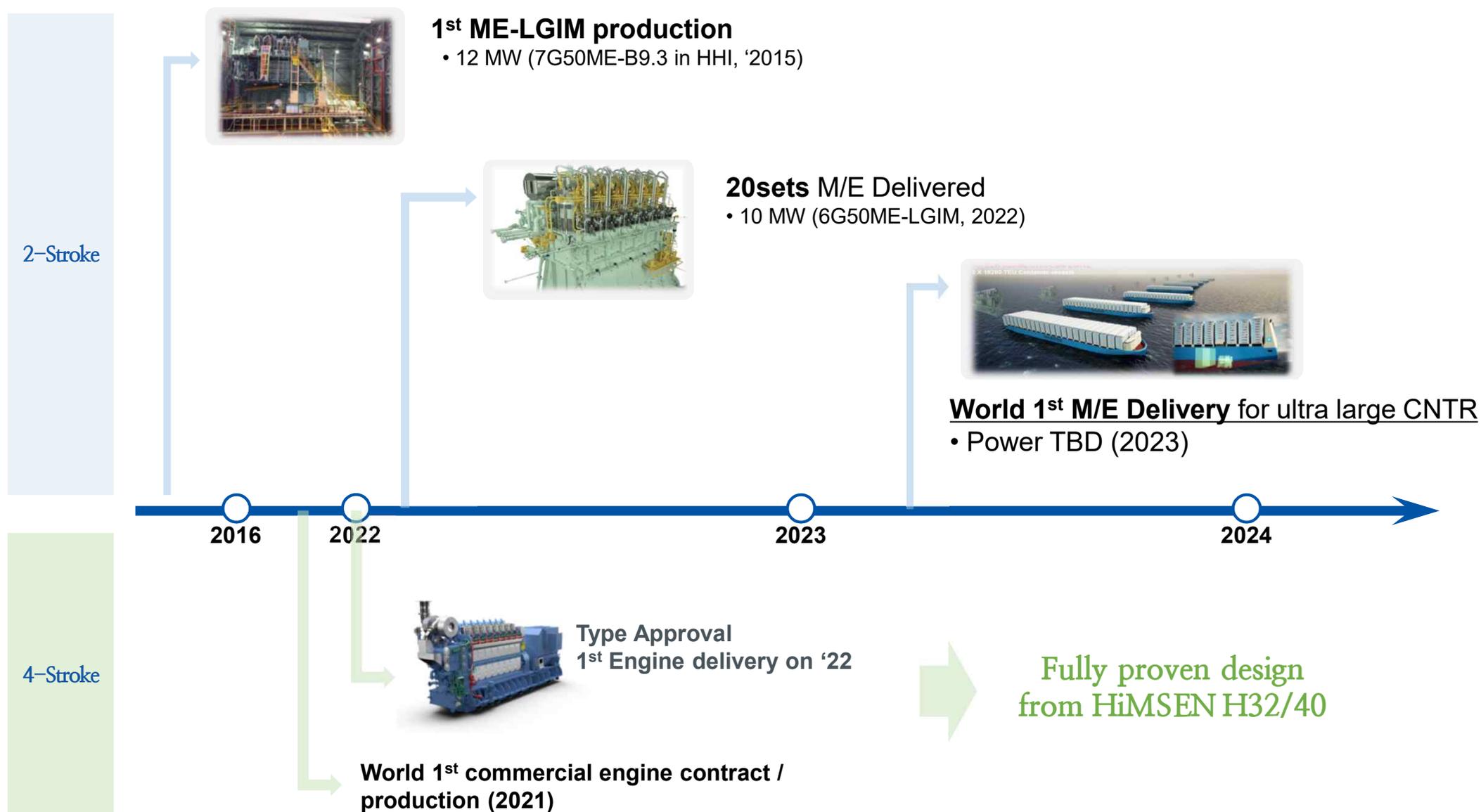
〈 Methanol-fueled Container 〉
(’2021 ordered, Maersk/HHI)

Company	Type	2024~25 (t/year)	After Add (t/year)	Geography
CIMC ENRIC	Bio-	50,000	200,000	China
European Energy	E-	2~300,000		North/South America
GTB ⁽¹⁾	Bio-	50,000	300,000	China
Orsted	E-	300,000		North America
Proman	Bio & E-	100,000		North America
WasteFuel	Bio-	30,000		South America
Total		7~730,000	500,000	

(1) GTB: Green Technology Bank

3. Status and Prospect of Eco-Friendly Fuel Ship

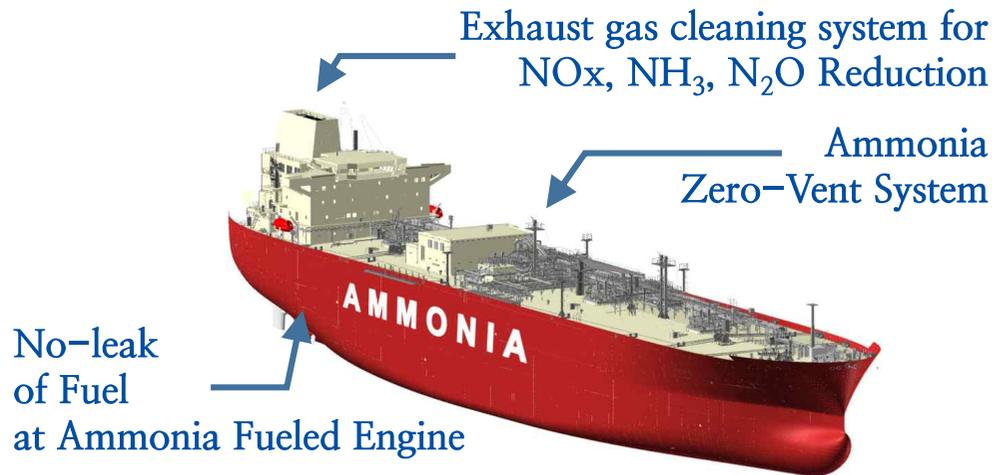
Methanol Fueled Engine – Scaling-up for ultra large Container Ship by 2023



3. Status and Prospect of Eco-Friendly Fuel Ship

Ammonia Fueled Ship (Carbon-Free Vessel)

- Ship and outfitting system considering ammonia's toxic, low viscosity.
- Ammonia is difficult to ignite and, to be solved in engine side.
- Ship yard preparing in-house LFSS, toxicity control system, and EGCS solutions
- First full-package of ammonia fueled ship will be got ready in 2024
- EPS-HHI signed MOU for Ammonia DF gas tanker delivered as early as 2025. (2022)

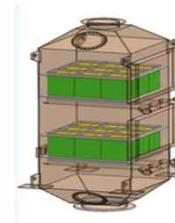


〈Zero-Emission and Zero-Venting Ammonia-fueled Ship for Safety〉

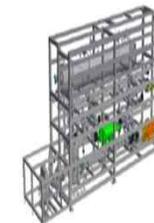
	Availability	Infrastructure & Storage	Maturity of technology	Energy density	Price	Green credentials
Ammonia	Red	Yellow	Red	Yellow	Yellow	Green
Developed		To be developed				
Fuel Tank ✓	NO _x control ✓	LFSS (~'23)	Propulsion system (~'24)	Dual toxicity control system (~'23)	EGCS (~'24)	



Tank Design



De-NO_x



LFSS



Engine



NH₃ Catch

3. Status and Prospect of Eco-Friendly Fuel Ship

Ammonia Fueled Engine

2-Stroke



[MAN-ES]

- Ammonia Fueled Engine launch in 2024 (ME-LGIA)
- MOU for Ammonia Fueled Carriers on 6th June 2022 (EPS, MPA, ABS, MAN-ES, HHI)



[WinGD]

- Ammonia engine MOU on 7th June 2022 (WinGD, HHI-EMD)



4-Stroke



[MAN-ES]

- Ammonia Engine launch after 2025



[Wartsila]

- Tech ready 2023, Volume ramp-up 2025



[HHI]

- Ammonia Fueled Engine launch in 2024



[Single cylinder test Engine : SCH32]



[Ammonia HiMSEN concept]

4. Conclusion (1/2)

Regulations

Evolve faster
and stricter

- ✓ Technology for decarbonization should speed up
- ✓ Operational measure to be provided
- ✓ Uncertainty of regulation to be minimized

Fuels

Various fuel path
after 2040

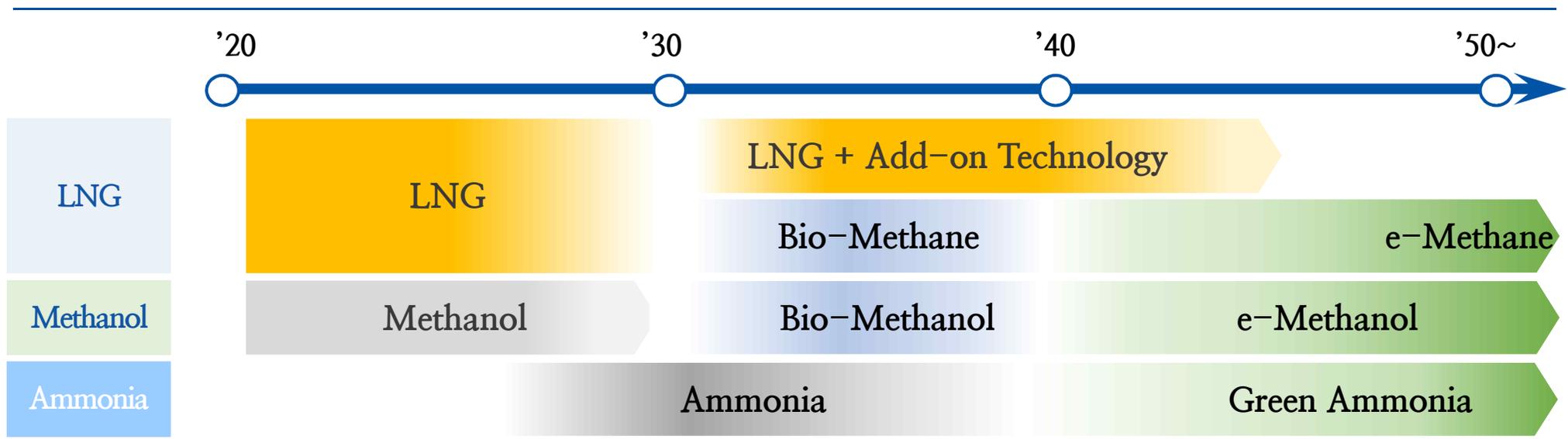
- ✓ Flexible technology for fuel mix to be prepared
- ✓ High efficiency ship for increased fuel cost
- ✓ Cross industry collaboration for supply chain

4. Conclusion (2/2)

HHI Group's Prospect for Alternative Fuels

- LNG can be main fuel till 2040 in view of technology, availability, price and low carbon
- Methanol and ammonia will also be used in short/mid terms by owners securing supply chain.
- Fuel for mid-/large- sized ships will be 'LNG + add-on technology', 'Bio-/e- methane & methanol' until green ammonia has a competitive cost.

Roadmap of next fuel for mid-/large- sized ship



Thank you!

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