Status of technologies and safety standards for Ammonia fueled ships

ACS Seminar 2022

Korean Register

GreenShip Technology Team

Park Junesung

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1. Issue - Decarbonation

IMO GHG Strategy

IMO GHG Strategy

VISION ▸▸▸ **Decarbonization** — Phase GHG emissions of ships out ASAP in this century

TARGET ▸▸▸

1. **Carbon Intensity to decline**
   - **Further Phases of EEDI for New Ships**
2. **Carbon Intensity to decline**
   - (**tCO2/ton·mile**) **40% by 2030** and **70% by 2050** compared to 2008
3. **GHG emissions to peak and decline**
   - **Peak** GHG emissions as soon as possible
   - (**Total annual emissions**) **50% by 2050** compared to 2008

Tech. M for Ex. Ship ➔ EEXI
Operational Measure ➔ CII

2018–2023 Short-term measures

- Improvement of **EEDI and SEEMP**
- Develop **technical and operational energy efficiency** measures for both new and existing ships with **three-step approach**
- Existing **Fleet Improvement** Programme
- **Speed** optimization and reduction
- Measures for **methane** and **VOCs**
- **National** Action Plans, **Technical** cooperation and capacity-building, **Port** development (AMP etc), **R&D** activities, **Incentives** for first movers, Lifecycle **guidelines** for fuels, **GHG study**

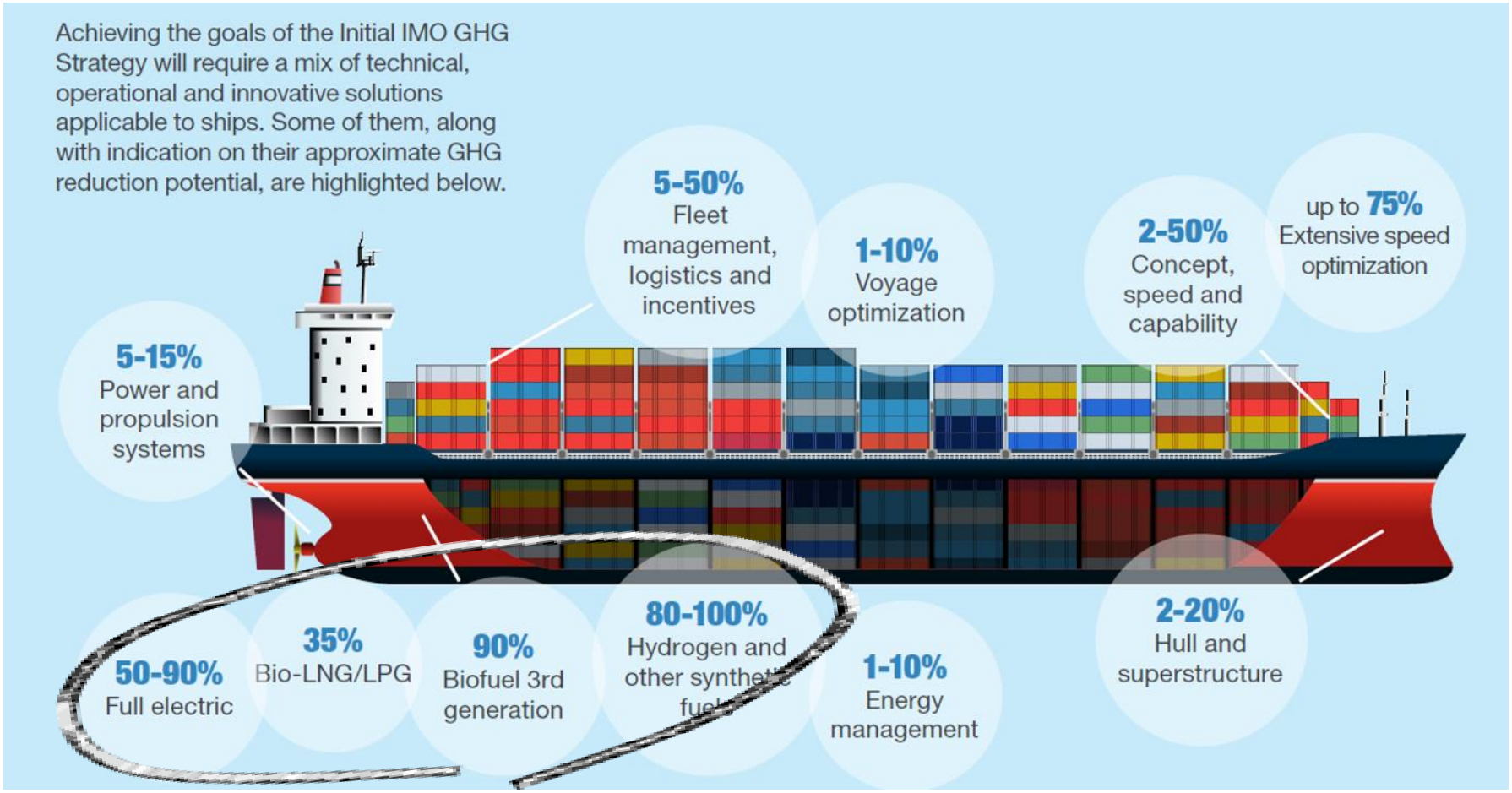
2023–2030 Mid-term measures

- Programme for **alternative fuels**
- **Operational energy efficiency measures** for both new and existing ships
- **Emission Reduction Mechanism (MBM)**
- **Technical** cooperation and capacity-building, **Feedback** mechanism

Beyond 2030 Long-term measures

- **Zero-carbon or fossil-free fuels**
- **Emission Reduction Mechanism**

IMO GHG Strategy



Source: IMO action to reduce greenhouse gas emissions from international shipping, IMO

2. Alternative Fuels

Low-carbon · Carbon-free fuels / Carbon Neutrality

LNG / LPG / Methanol

LNG - methane slip regulation?

- ✓ Methane GWP : 28 X ~ 84 X
  - HP DF engine : 0.1~0.3 g/kWh
  - LP DF engine : 1.6~2.4 g/kWh

iCER : X-DF 2.0(WinGD)

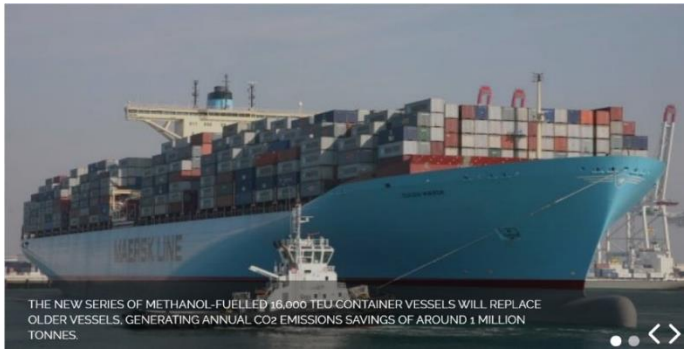
EGR : MEGA engine(MAN ES)

LPG Fueled Ship = LPG Carrier ??

- ✓ ME-LGIP 30 ships contracted ('19~'20)
- ✓ Possibility of expansion such as passenger ship, Costal ship, OSV, etc.

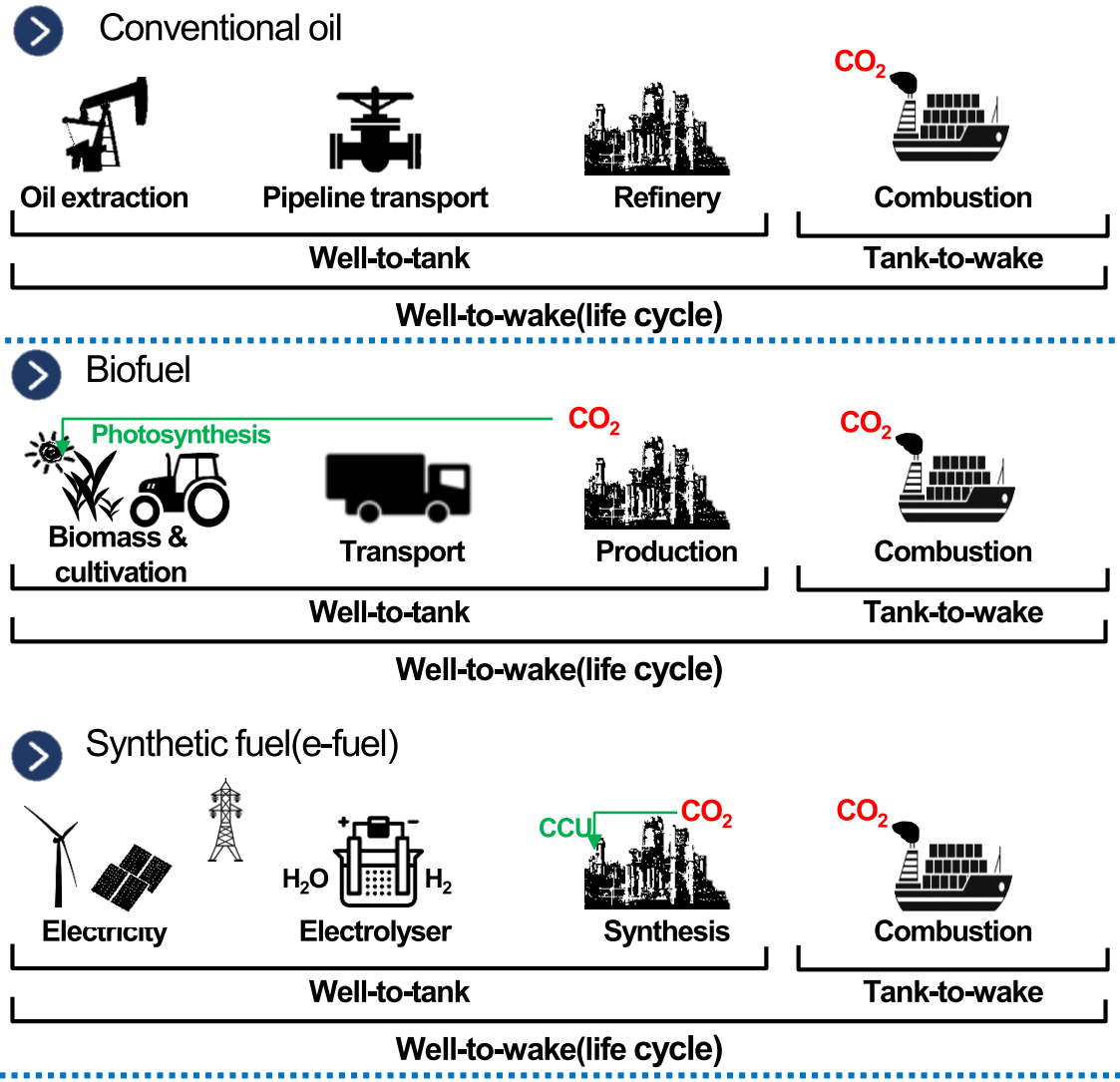
Methanol = Carbon Neutral ??

- ✓ Maersk 16,000TEU 12 ships
- ✓ "carbon neutral methanol"
- ✓ bio-methanol & e-Methanol



(source: www.maersk.com, 24 Aug. 2021)

Fuels & Well to Wake



IMO GHG regulations

Tank to wake
Vs.
Well to wake(or propeller) ?

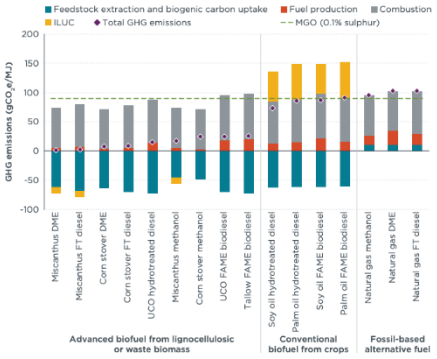
Carbon Neutral Fuel !

Bio / Synthetic – Oil / Gas

Diesel Oil : MSC, CMA CGM, Maersk, Hapag-Lloyd

- ✓ Common Blending fuel: B20(80% LSFO & 20% biodiesel)
  - Supply stability : Supply and demand competition with other industries
  - price competitiveness and stability
  - Life-cycle GHG (100-year GWP)

Fuel	Price 30/1/2020 (USD per metric tonne)
IFO380	295[1]
VLSFO	475.5[1]
MGO	492[1]
UCOME	1215[2]
TME	1190[2]
SME	976[3]
FAME	740[3]



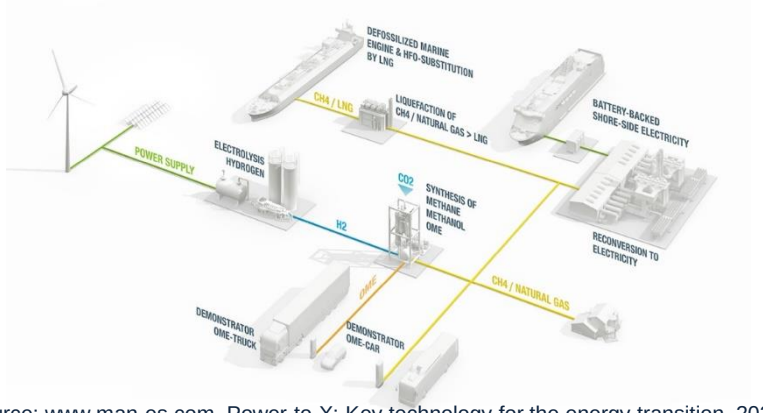
Advanced biofuel & Waste biomass

Bio-methane : CMA CGM

- ✓ Waste + residual agricultural products :12,000ton → 1,400TEU(Rott.-St.PT.)
- ✓ 67% CO2 ⇓, well-to-wake

Synthetic NG (SNG) - MAN ES

- ✓ Renewable energy (wind, solar)
- ✓ Wes Amelie ← LNG & SNG

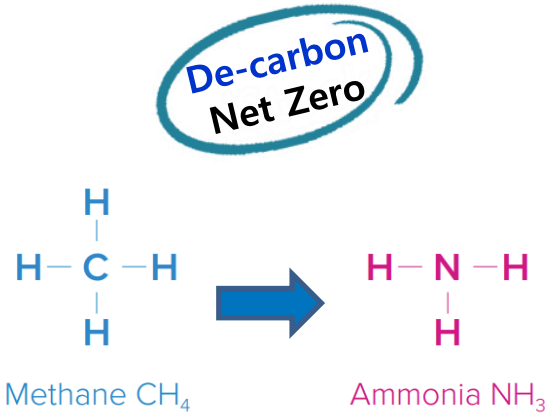


(Source: www.man-es.com, Power-to-X: Key technology for the energy transition, 2020)

Ammonia

Characteristics of Ammonia as a fuel

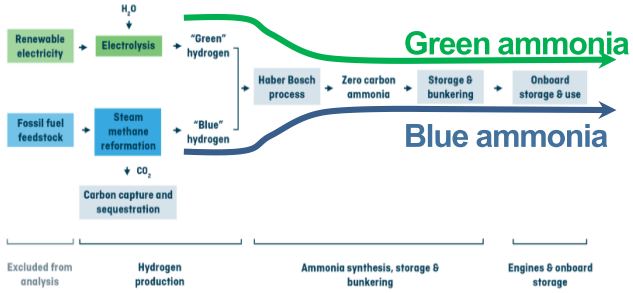
- ✓ Easy to store in liquid state (−33℃ or 20℃, 7.5 bar), but...
  - − Abt. 4 times storage space required compared to existing MGO, Toxicity + Corrosion
  - − Material : Cooper & Zinc **X**, − Stress Corrosion Cracking
- ✓ Fire &Explosion ↓ , Fuel Nox → **SCR / EGR**
- ✓ Global Production → Transport Network



Ammonia engine development in progress (MAN / Wartsilla vs HHI / STX-E)

Ammonia needs to be linked to the value chain of the hydrogen industry

- ✓ Green/Blue Hydrogen → Ammonia production
- ✓ Use of ammonia as a means of transporting hydrogen
  → Close to ammonia economy



(Source: www.globalmaritimeforum.org, zero carbon ammonia production chain, June 29, 2020)

Hydrogen! Incomplete hero

Ultimate fuel / Technical hurdle / Economic security

- ✓ Needs to overcome technical difficulties
  - − Fuel storage: liquid/gas condition, H_2 damage. (20k, high pressure, H_2 metal penetration).
  - **- Challenges for shipbuilding industry : H_2 Fuel/Cargo Containment system**

〈ClassNK hydrogen carrier : Small〉

〈Large liquefied hydrogen carrier〉

〈Hydrogen fueled ship〉

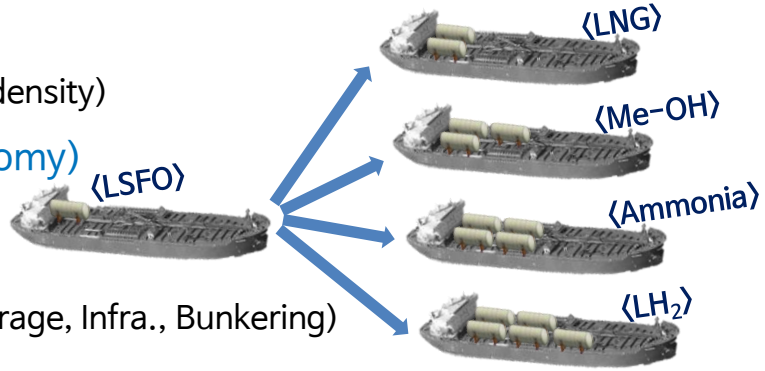
- ✓ Engine(30~45 £/kW) vs Fuel Cell(100 £/kW)
- ✓ Need government policy support to secure economy(ex.H_2 value chain)

Review of alternative fuels

A review of applicability / affordability / eco-friendliness

Limitations & Trade-off

- ✓ Limited ship space and fuel load (volume/weight/energy density)
- ✓ Reduction of GHG (Environment) vs Cargo Loss (Economy)

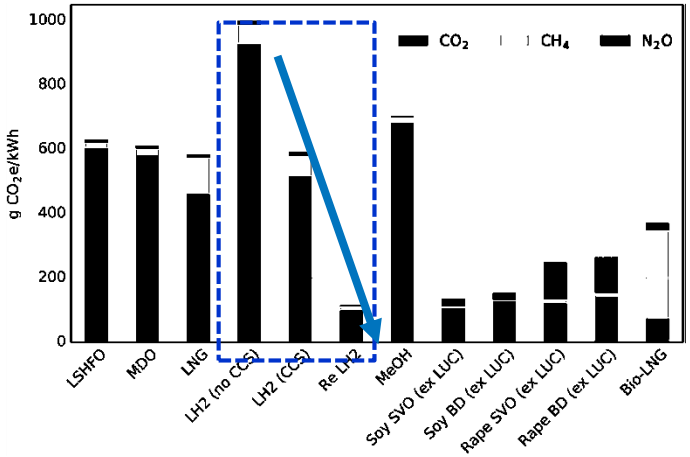


Cost of fuel Life cycles (Production, Transport, Storage, Infra., Bunkering)

- ✓ High cost of H_2 transportation and Synthetic fuel production
- ✓ Fuel Cost depending on the method of production and transportation
- ✓ Need to analyze costs according to MBM, Gov. Subsidy etc.

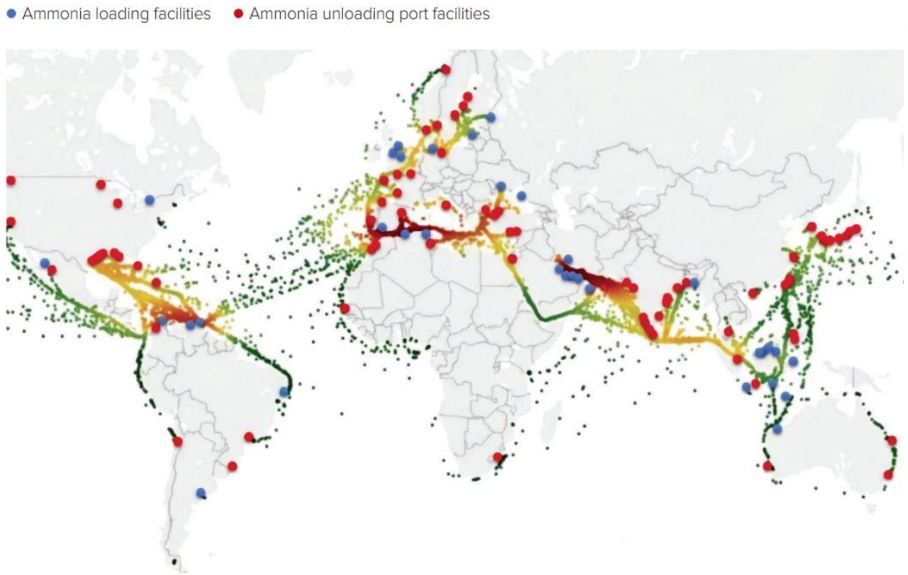
Total GHG of fuel Life cycles (Well - to - wake)

- ✓ CO_2 emission, including CH_4, N_2O, etc.

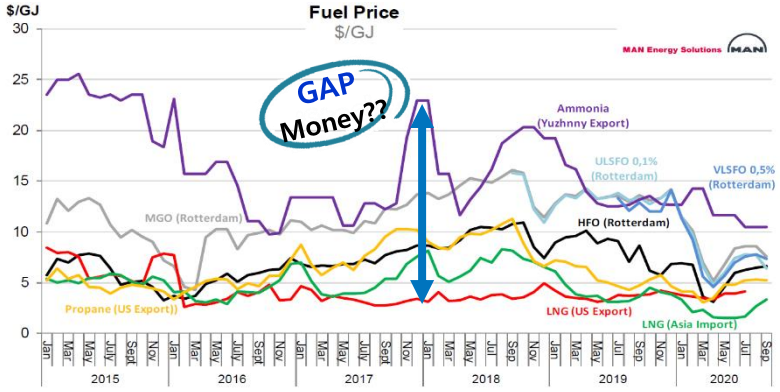


Supply & Demand

- Fuel Production → Supply(Port) → Demand and Price stability
  - ✓ Expansion of production /transportation Infra. is required to secure alternative fuel economy
    - Ammonia, linked to H2 economy: Green ammonia
    - Ammonia Carrier → **Ammonia Fueled Ship**



(Source: The Royal Society, Ammonia: zero-carbon fertiliser, fuel and energy store, 2020)

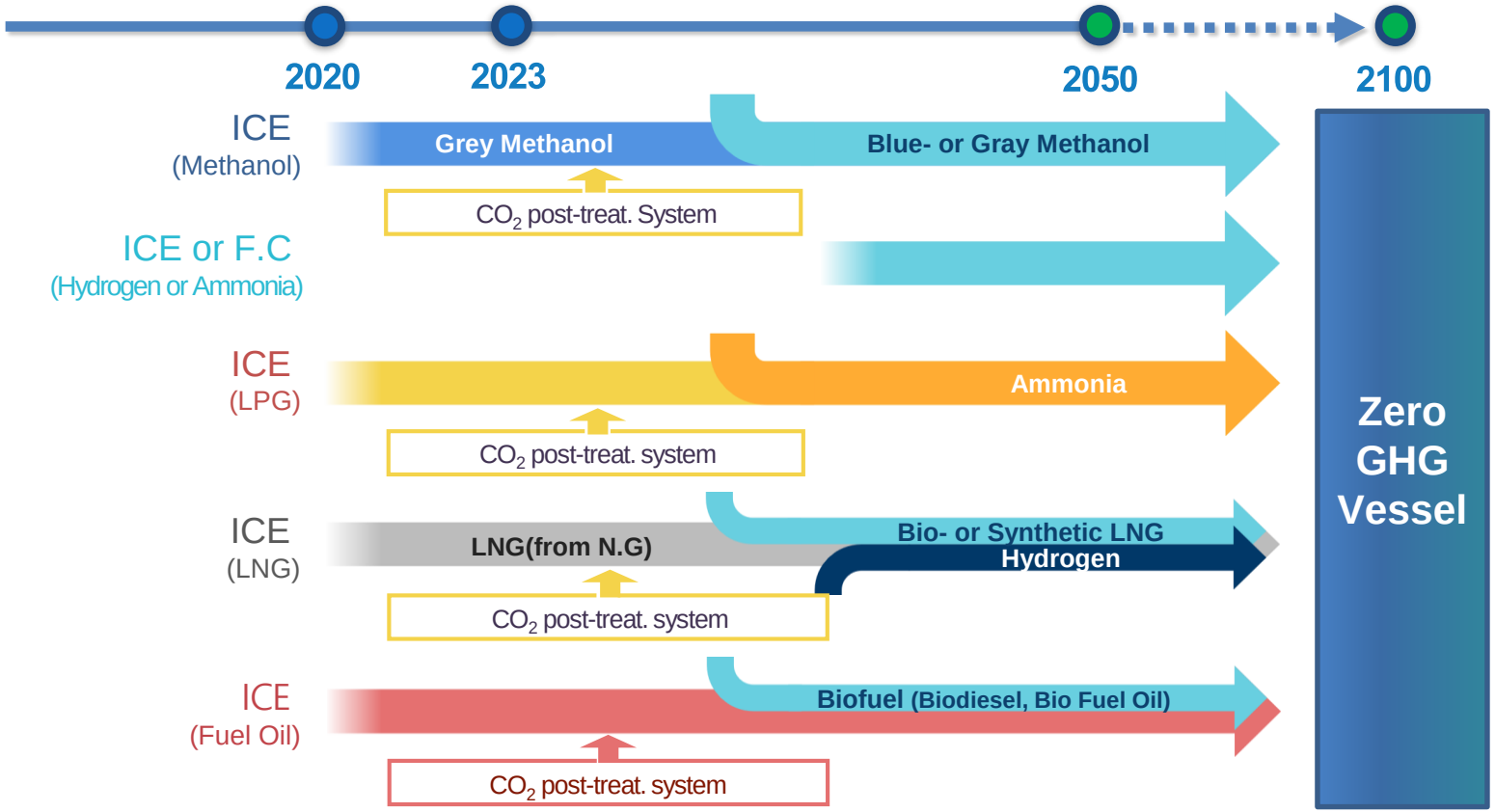


(Source: Riviera webinar, LPG; the green pathway demystified, Nov. 2020)

	2025-2030		2040-2050	
	USD/MT	USD/GJ	USD/MT	USD/GJ
VLSFO (<0.5%S)	500-600	12.5-15	500-600	12.5-15
Conventional Ammonia	250	13.5	250	13.5
Blue Ammonia	350-400	18.8-21.5	350-400	18.8-21.5
Green Ammonia	400-850	21.5-45.7	275-450	14.8-24.1
Hybrid Green Ammonia	300-400	16.1-21.5	250	13.5

Uncertainty of Alternative Fuel

- HFO → LSFO → LNG → Ammonia → H_2
  - ✓ Difficult to predict due to many issues such as environment, price, supply, and safety



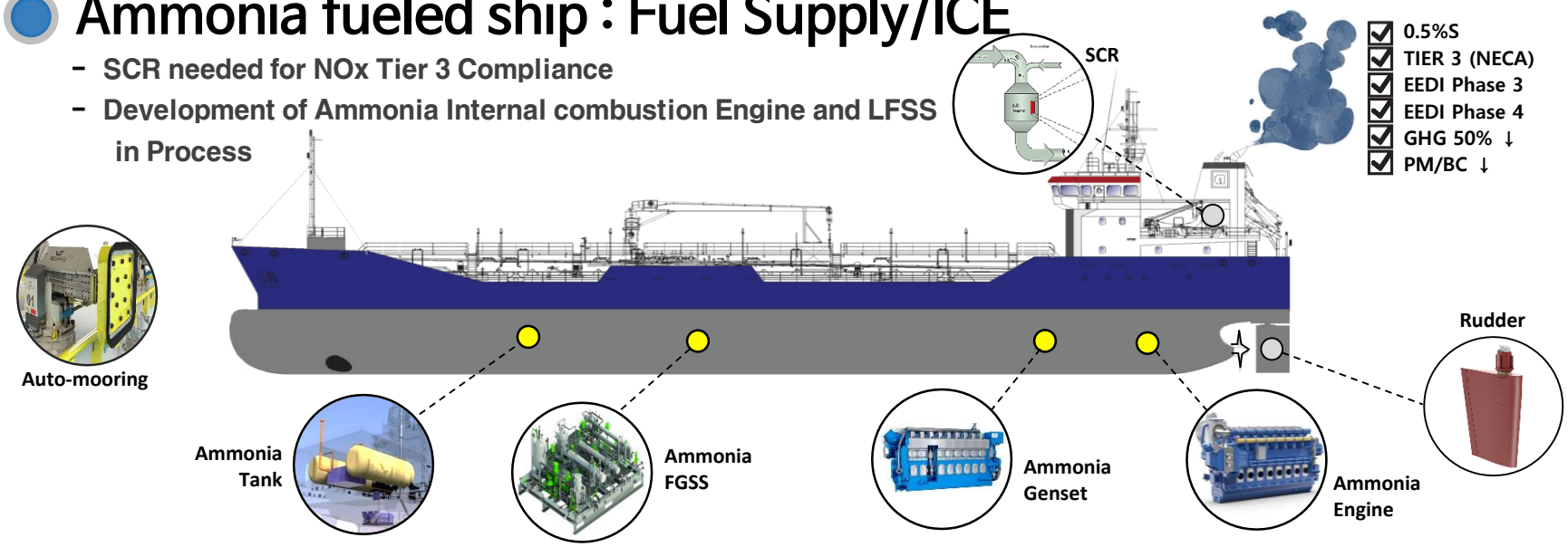
3. Ammonia as a Fuel

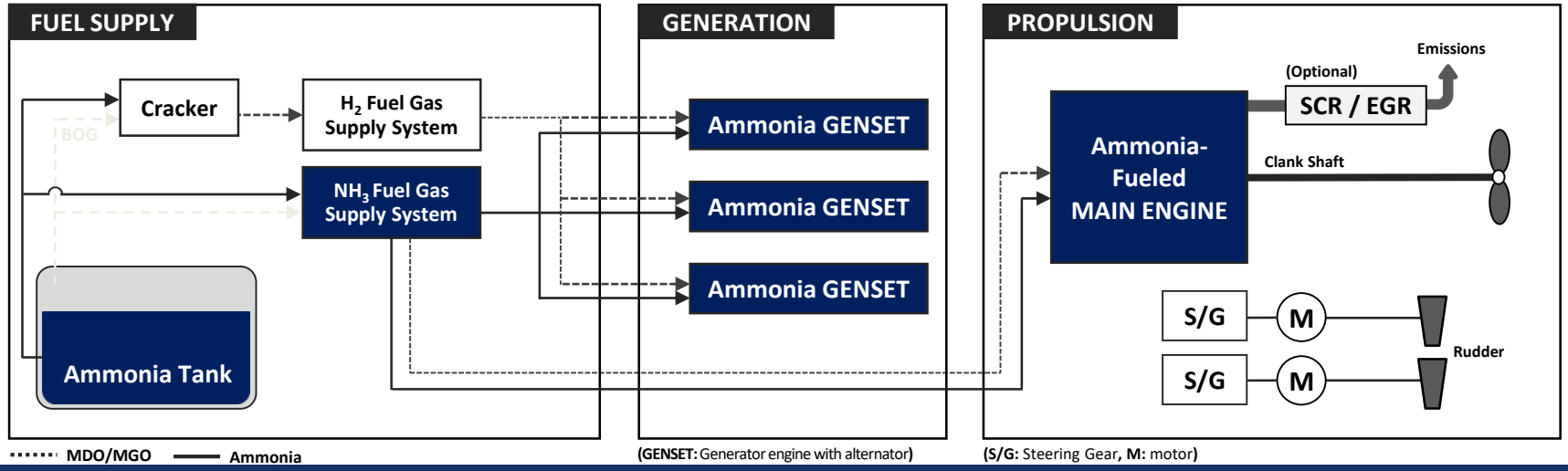
R&D in KOREA, Safety and requirement

Ammonia Fueled Ship

Ammonia fueled ship : Fuel Supply/ICE

- SCR needed for NOx Tier 3 Compliance
- Development of Ammonia Internal combustion Engine and LFSS in Process

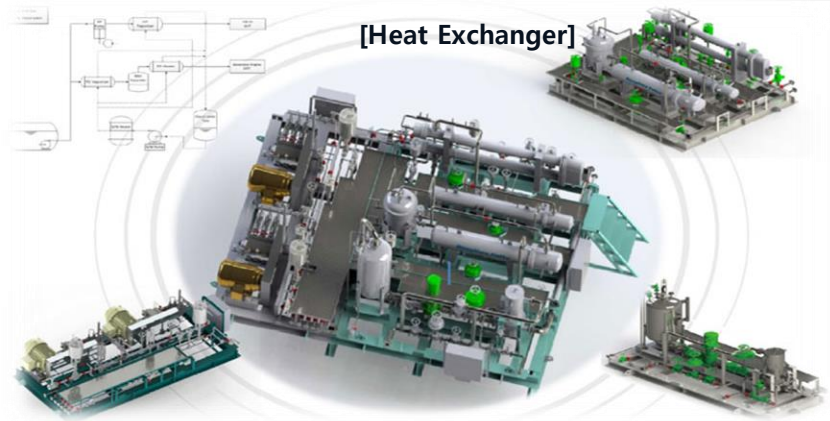


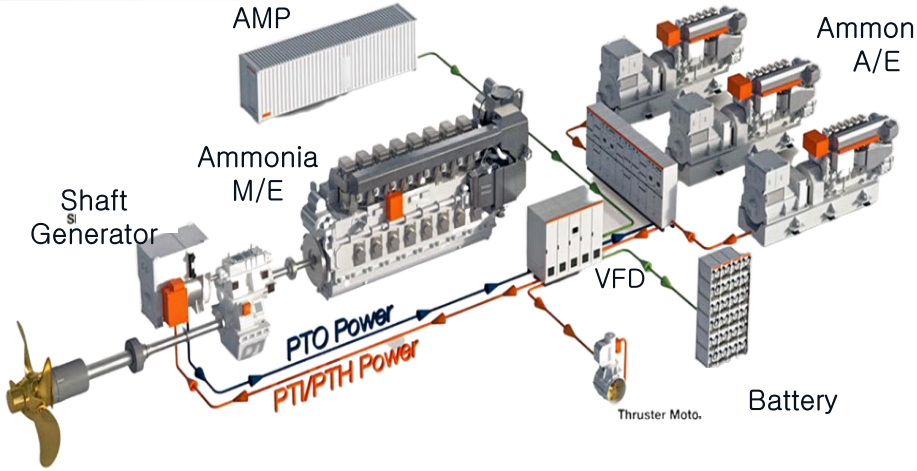


R&D - LFSS in KOREA

Korean Government Launches Development Support Project for Green Ship Technologies in 2022

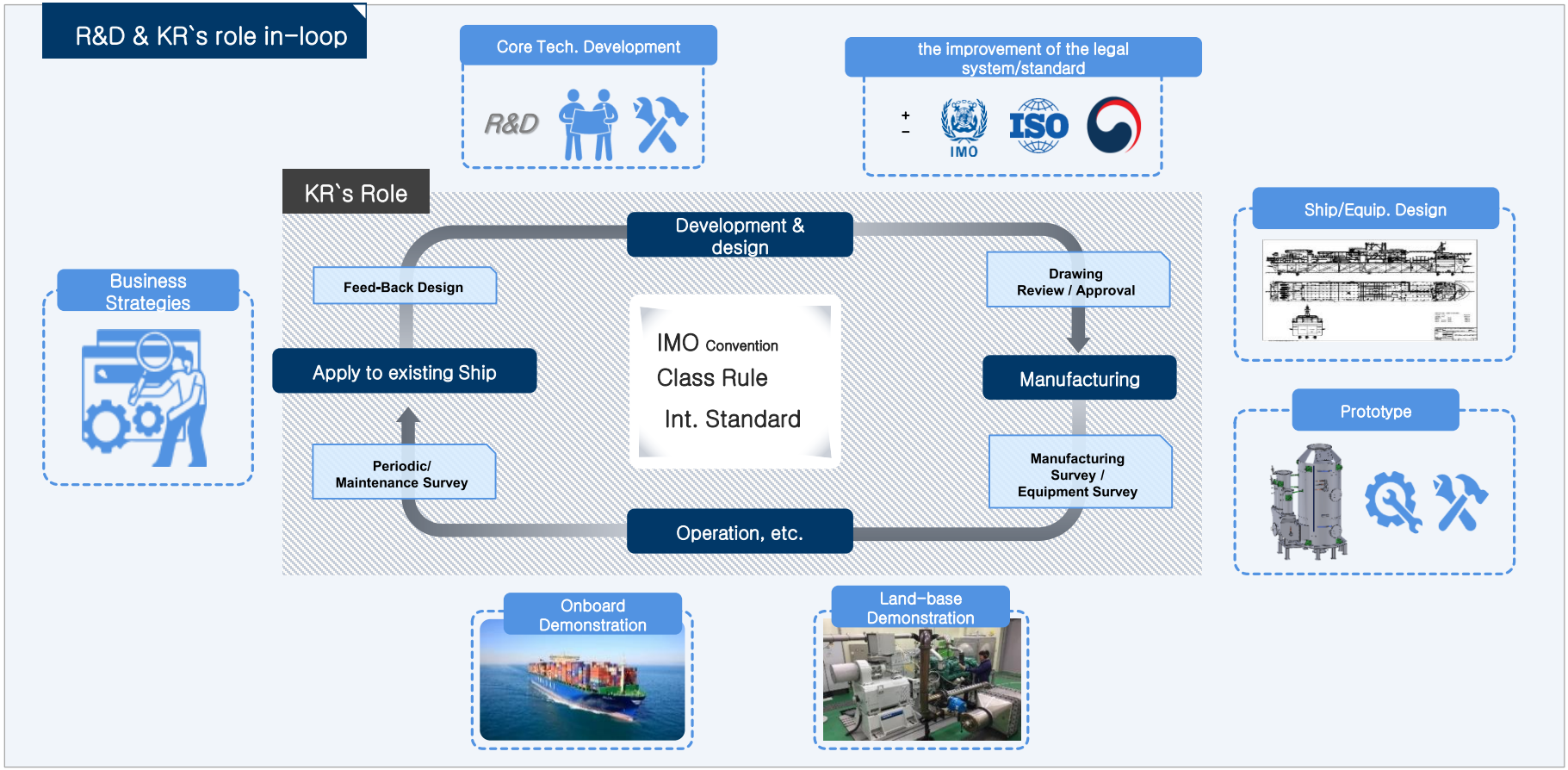
- ✓ Liquid Fuel Supply System
- ✓ Hybrid-Propulsion System
- ✓ Ammonia Internal Combustion Engine





KR`s role in R&D

- R&D → Design → Prototype → Test & Demonstration → Sea Trial → Commercialization
  - ✓ KR`s advanced support from technology development to commercialization



Status : Code Development

Proposal for developing provision

- MSC 104/15/9 (Japan, Singapore, ICS, INTERCARGO)
  - Development of non-mandatory guidelines
- MSC 104/15/10(Japan) : HAZID of Ammonia fueled Ship
  - Concept ship of DF 80K Bulk Carrier
  - Toxicity of Leakage Gas → safety measures for crew

Direction of developing provision

- MSC 104/15/30(Japan)
  - Combustion Characteristics
    : Ignition, Flammable limit , Burning velocity
  - Low risk of fire/explosion
  - More toxic accidents than fires
  - Proposal of direction of Technical Provision (based on IGF, focusing on toxicity)

Status

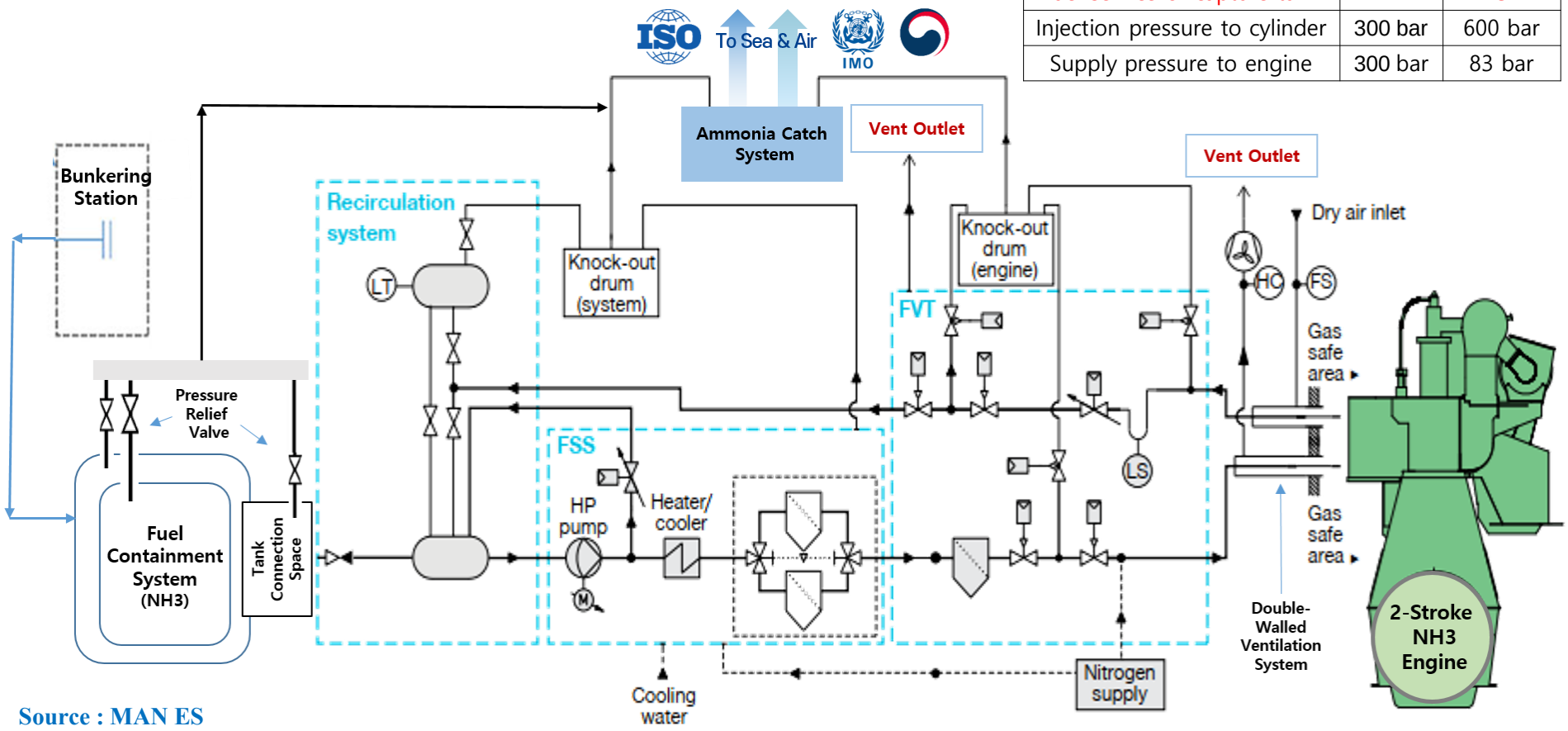
- CCC 7/3/8 (EU 27th member states), CCC 7/3/10 (CESA)
  - to include Ammonia fuel ship`s provision in CG work program
- CCC 7 WG Report (CCC 7/WP.3)
  - plan on Provision of ammonia fueled ship included finally
- Ammonia-CG Round 3 finished(`22.6)
  - Collecting Info. on toxicity. possible technical measure

Fuel supply system (for MAN ES, ME-LGIA)

Liquid Fuel Supply System for Diesel cycle Engine

- ✓ Similar to existing fuel supply system

	ME-GI	ME-LGIA
Phase of Fuel	Gas	Liquid
Fuel recirculation	X	O
Fuel service or capture tank	X	O
Injection pressure to cylinder	300 bar	600 bar
Supply pressure to engine	300 bar	83 bar



Source : MAN ES

Toxicity Issues (SGMF Workshop)

- ✓ **Thresholds for Toxicity :** to Set concentration limits and toxic hazard zones
  - Exposure limit
    - Considering the amount of inhalation (concentration X exposure time) that affects the human body
      : There are many uncoordinated criteria for land ammonia.
    - Considering 30 ppm as the concentration setting for toxic hazard zones
  - Toxic hazard zone
    - Gas safety Space in ship : Machinery space, Fuel Preparation room, Bunkering station
    - Establishing Toxic hazard zones through CFD based on 30 ppm
- ✓ **Characteristics of ammonia to be considered**
  - Identified as smell even at a small concentration
  - Difficult to be identified as smell when exposed to a small concentration for a long time.
  - Lighter than air, but can sink to the floor in response to ambient humidity.
  - Soluble in water → Wet-type ammonia capture system
- ✓ **Discharge of aqueous ammonia solution**
  - Marine discharge of aqueous ammonia solution is considered to be toxic -〉 neutralization needed before discharge -〉 Discharge limit is required

Class Guideline

Class Guideline or Rule for Ammonia Fueled Ship

No.	Class	Title
1	KR	Guidelines for Ships Using Ammonia as Fuels
2	BV	NR 671 Ammonia fuelled ship
3	DNV	DNV Rules for classification: Ships, Pt 6, Ch 2, Sect 14, Gas fuelled ammonia
4	ABS	Guide for Ammonia Fuelled Vessels 2021
5	NK	Guidelines for Ships Using Alternative Fuels (Edition1.1)
6	RINA	RINA Rules for the Classification of Ships
…..	……	……

Ammonia discharge to ambient – Class Guidelines

	IGF (LNG)	Class guideline			
		KR	BV	ABS	DNV
Normal	Through Vent mast	Minimizing ammonia gas/ Prohibiting ammonia liquid	① 30ppm by using capture Sys.	Prohibiting ammonia gas	Prohibiting ammonia gas/ 30ppm at vent mast
Emergency			① / ② Dilution sys.	Minimizing ammonia gas	-

Common Requirements

IGF Code

Fire Safety
: Considering the flammability

- **Gas leakage and accumulation**
  - Double-walled pipe
  - Ventilation, Gas detection, DBBV
- **Fire protection**
  - Explosion-protected Elec. Equipment
  - Shutdown of Elec. Equipment
  - Classification of hazardous areas
  - Distance between gas leak source and safety zone
- **Prevention of fire spread**
  - A-60 insulation & cofferdam
  - Fire detection & extinguishing system

Additional requirement for NH_3 fueled ship

: considering toxicity, corrosiveness and other properties

Toxicity

- Protective Gear, Eye washer
- Limitation of the accumulated Ammonia gas
  - More Ventilation
  - Permissible concentration (25ppm, 300ppm)

Corrosion Reactivenes

- Materials limited : Tank, pipe etc.
- Welding heat treatment
- Water content of ammonia

others

- Prohibiting ammonia gas/liquid from venting
- Considering phase changes in the system

Discussion required for future

Toxicity-related requirements

- **Ammonia gas released**
  - Ventilation (↑ or ↓ ?)
  - Gas Concentration for safety measures
  - Gas removal system on-site (ex. Water spray etc.)
- **Definition of hazardous** (toxic) **areas**
  - Reference concentration (ex. toxic zone 0…2 ?)
  - Analysis of dispersion, and standard method or scheme
  - Ship arrangement (Vent Mast, Vent outlet, Bunkering manifold, etc.)
- **Ventilation to ambient**
  - Ammonia processing system (scrubber?)
  - Permissible Ammonia concentration (25ppm or 300 ppm ?)

Requirements for fire safety

- **Separation of space or room (A-60 and/or Cofferdam ?)**
- **Are there any mitigation requirements compared to LNG fueled ships?**

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