HD HYUNDAI HEAVY INDUSTRIES

First Mover to De-Carbonization e-Fuel Engine

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2024.11.12

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ECO MOBILITY DYNAMICS

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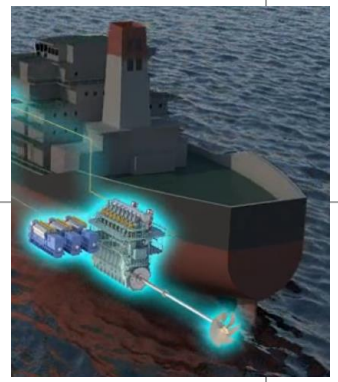
HD HYUNDAI HEAVY INDUSTRIES

About us....

ECO MOBILITY DYNAMICS, HHI-EMD

HHI-EMD(Engine & Machinery Business Unit) is the world's largest marine **2-stoke** and **4-stroke** engine manufacturer and produces our own 4-stroke engine model, the **"HiMSEN"**.

M/E

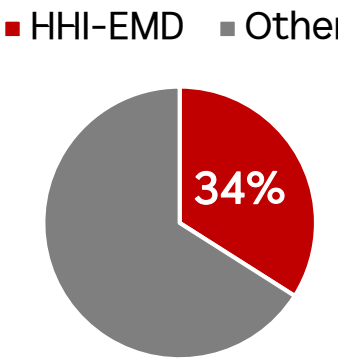


We are supplying engines for **one-third of the large commercial vessels** being built worldwide.

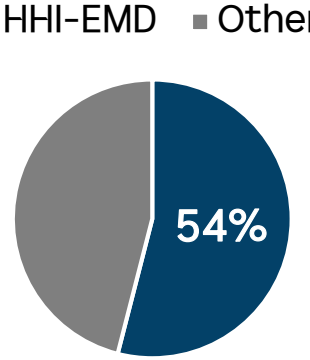
G/E (HiMSEN)

HHI-EMD Order Status in 2023

'23 Global M/S (kW)

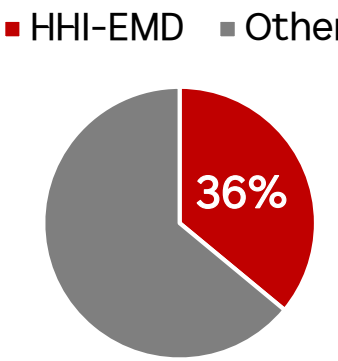


'23 Global **DF** M/S (kW)

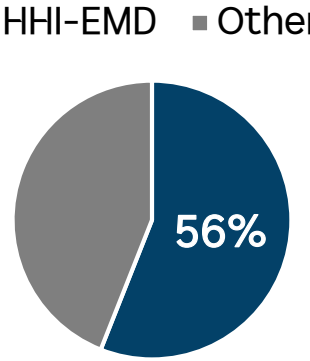


※ Clarkson, Marine low speed M/E base

'23 Global M/S (kW)



'23 Global **DF** M/S (kW)



※ Clarkson, 4-Stroke generator engine base

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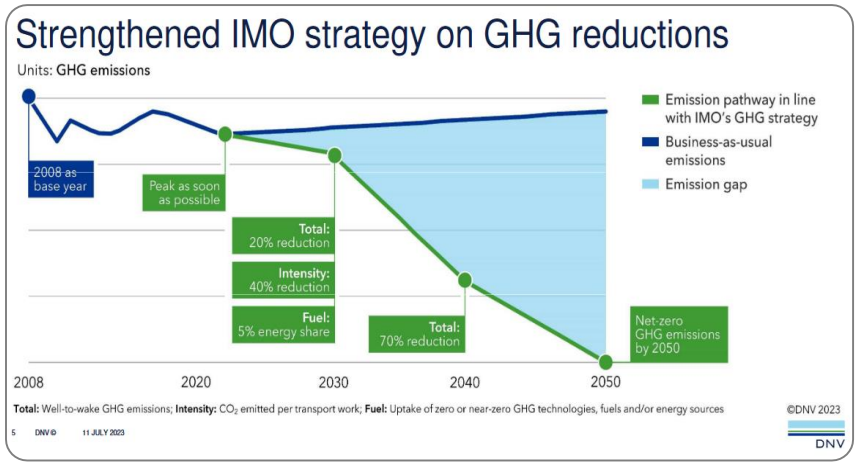
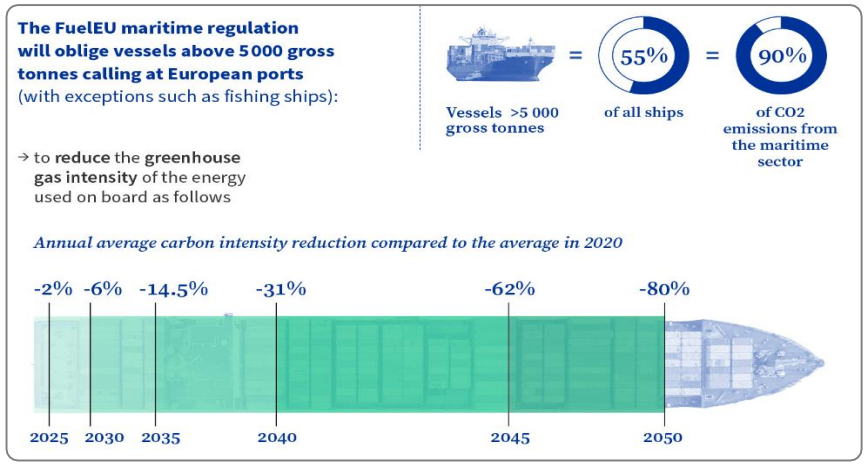
GHG Regulation

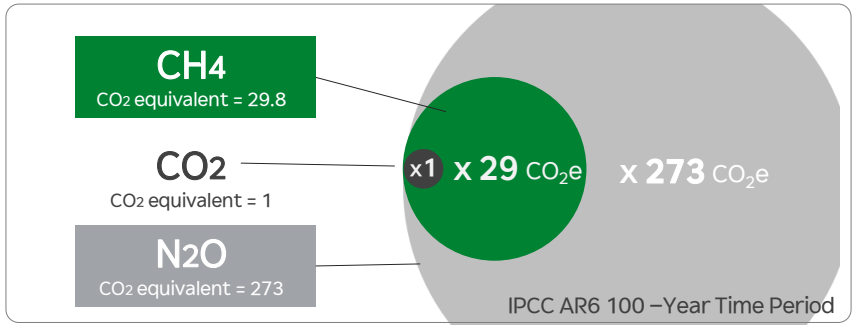
- **IMO** GHG Strategy 2023
  - 20% reduction by 2030, 70% reduction by 2040
  - Net-zero by 2050



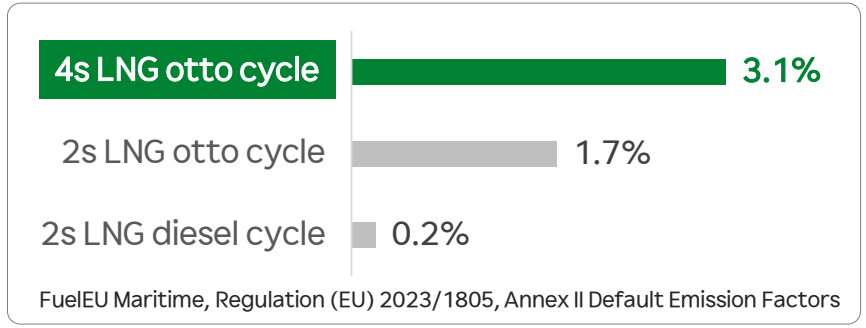
- **EU ETS, FuelEU Maritime** 2023
  - EU ETS : Extension to maritime transport from 2024
  - FuelEU Maritime : 80% reduction by 2050



- GWP of CH_4 and N_2O as GHG emission



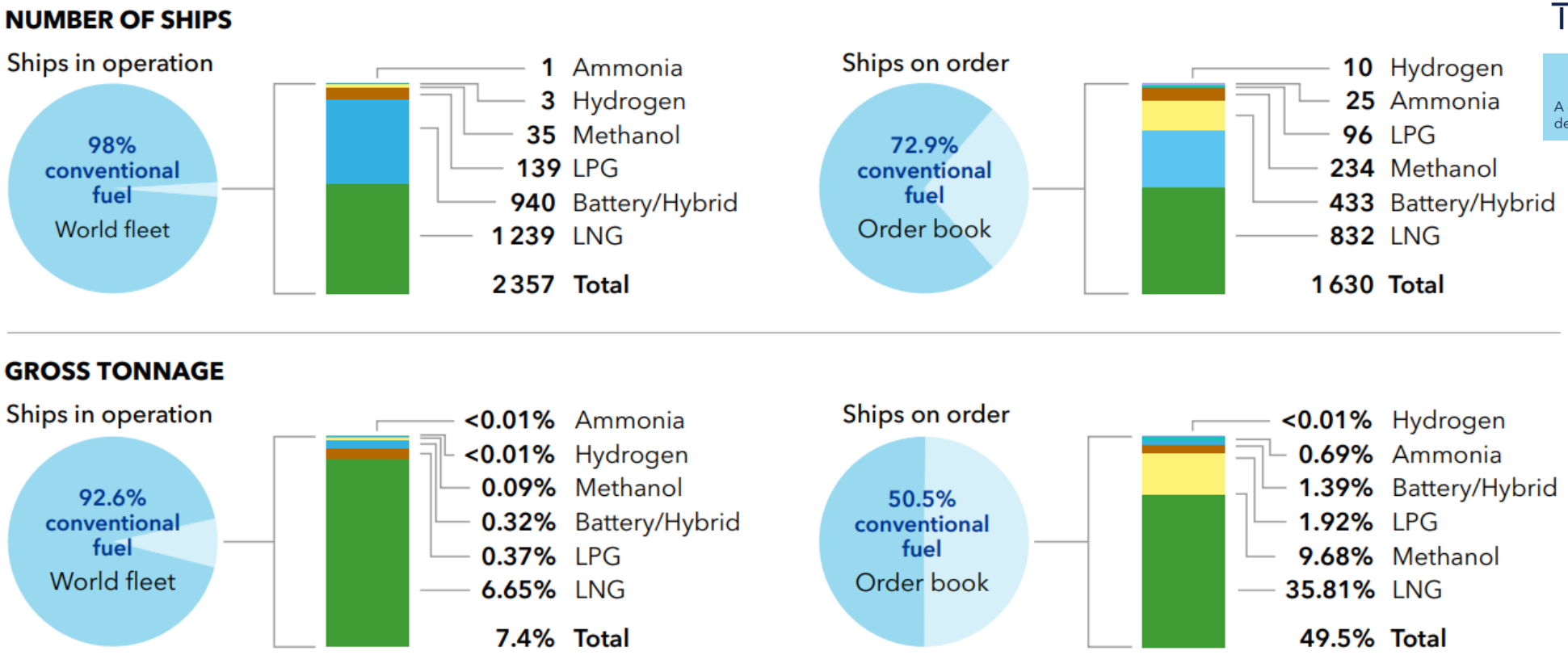
- Methane Slip of Engines (C_{slip} %)



Solution is required for GHG emission!

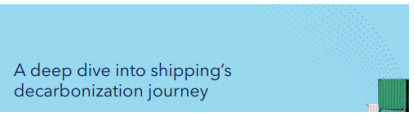
Countermeasures

- Engine with **Advanced technology** and **Renewable fuels**
  - **Minimize methane slip** in otto cycle gas engine.
  - In order to meet the regulation limit, **it is essential to use renewable fuels**!



Sources: IHSMarkit (ihsmarkit.com) and DNV's Alternative Fuels Insights for the shipping industry – AFI platform (afi.dnv.com)

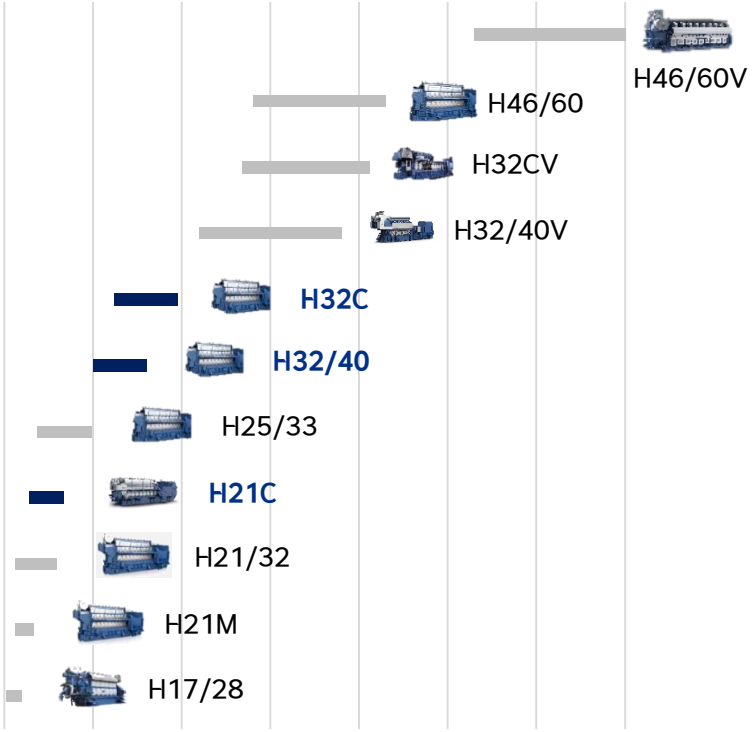
Alternative fuel uptake in the world fleet in number of ships(upper) and gross tonnage(lower), as of June 2024



Improvement HiMSEN

1st generation (2001~2011)

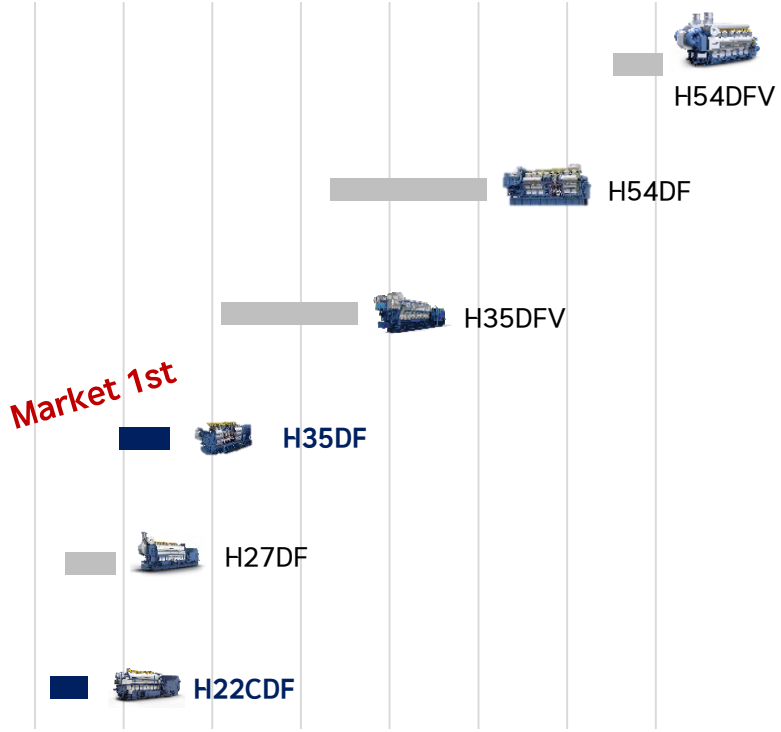
Diesel



New Beginner

2nd generation (2012~2021)

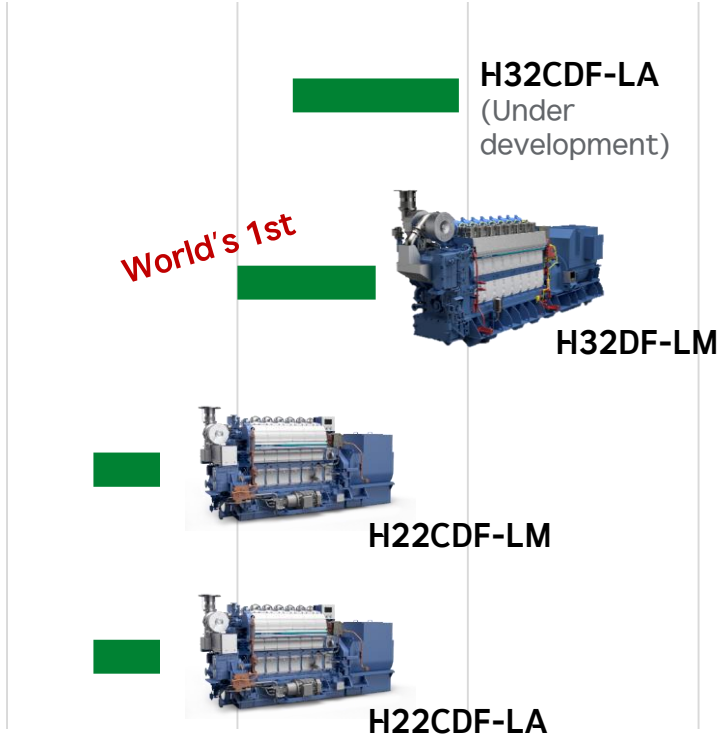
LNG DF



Fast Follower

3rd generation (2022~)

Methanol & Ammonia



First Mover

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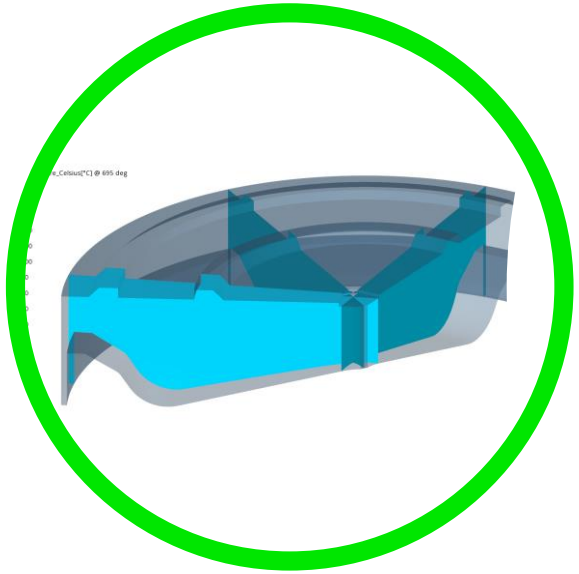
HiMSEN R&D

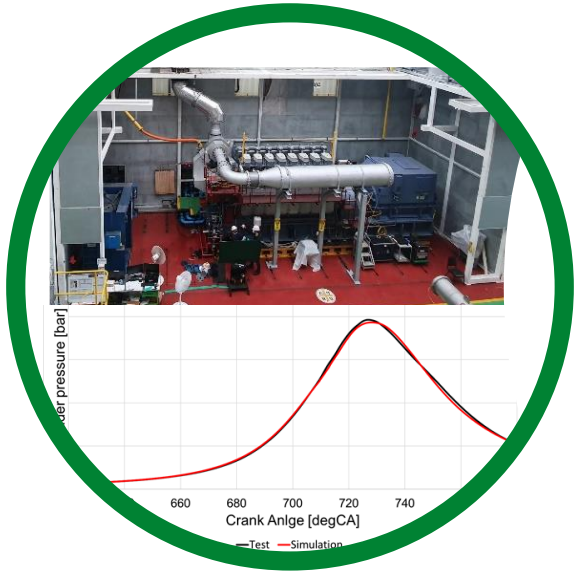
Faster and more accurate engine development

A.I. Simulation



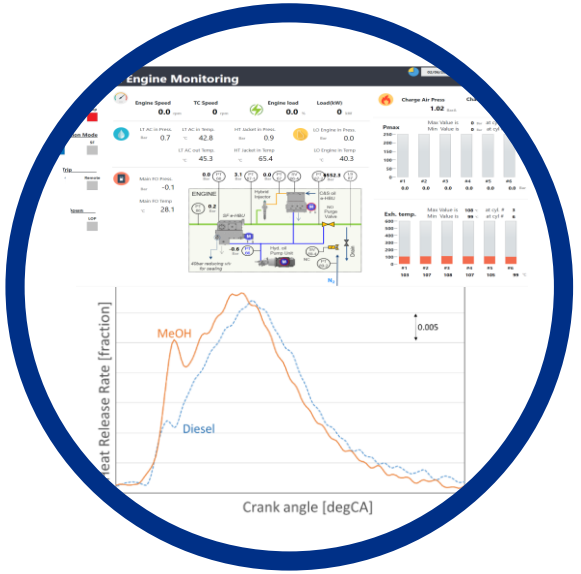
R&D know-how
Over 15,000 references

Proto Test



Test driven
Machine Learning

Optimization



Virtual & Real
Engine performance

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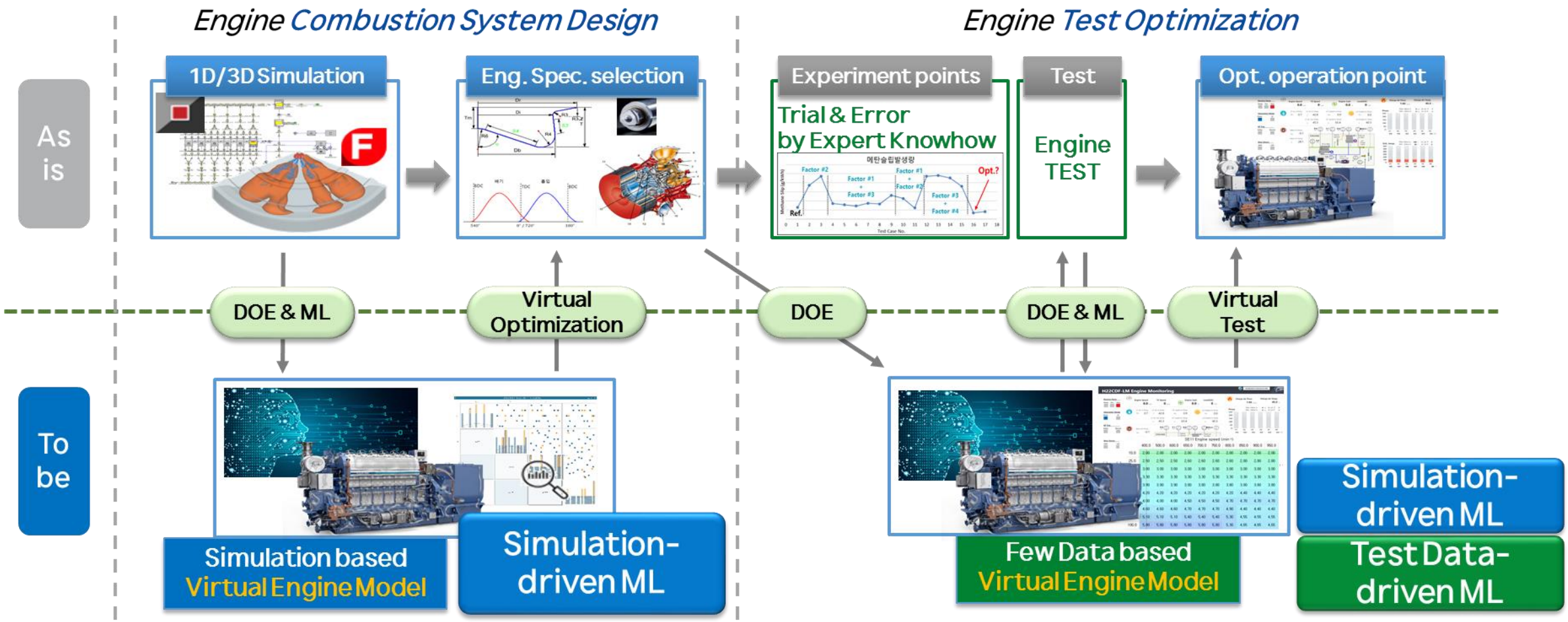
Virtual Engine Model in HiMSEN Development



Engine development period is shortened by applying ML model

to engine combustion system design and performance optimization test

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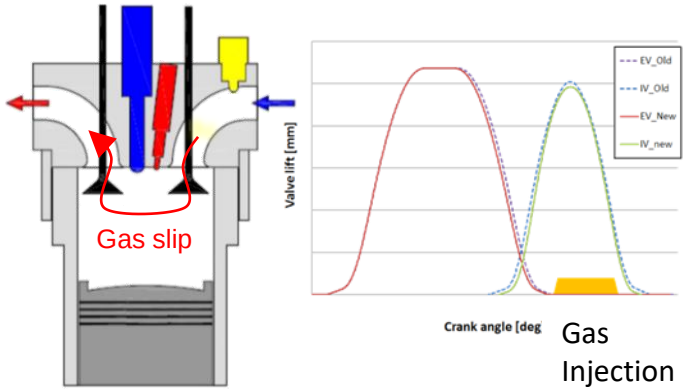
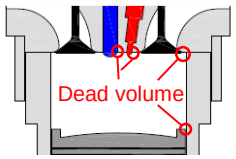
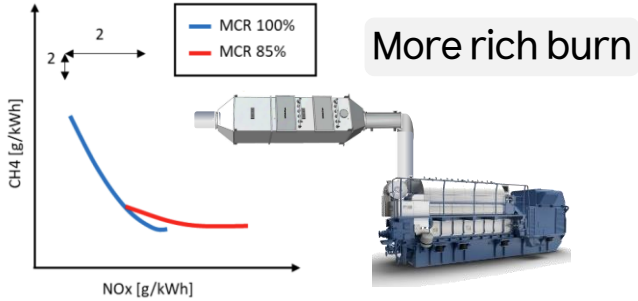
HiMSEN Strategy for reducing methane slip

	~2021	MSS (2022~) (Methane Slip Solution)	MSS 2 (2024~)
Technology		MPI Pre-pilot oil injection Mixing air & gas & pilot Promotion of flame propagation CCO Adv. of high-load combustion Nth GAV deactivation higher load combustion of active cyl. 	 More rich burn Trade-off effect between CH_4 & NOx
Valve timing opt.	○ (reduce CH_4 slip during valve overlap)	○	○
Intake port & Gas tube opt.	○	○	○
Low crevice volume	○	○○ (Further design improvement)	○○
NOx emission	IMO Tier 3	IMO Tier 3	IMO Tier 2
CH_4 emission	○	○○	○○○

Methane Slip Solution (MSS)

Cylinder Cut Off (CCO) and Multi Pilot Injection (MPI) – Alone or Combined

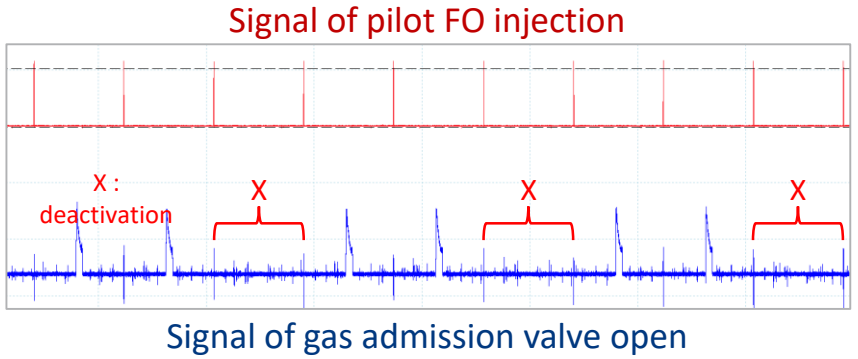
- Define optimized parameter depending on engine loads and operating conditions
- Applicable 0 to 50% load

CCO

Cut-off of every "Nth" cylinder according to firing order

Enhancement of combustion velocity and decrease in flame quenching

Automatic control of cut-off count for all cylinders to have the same numbers (%) of deactivations

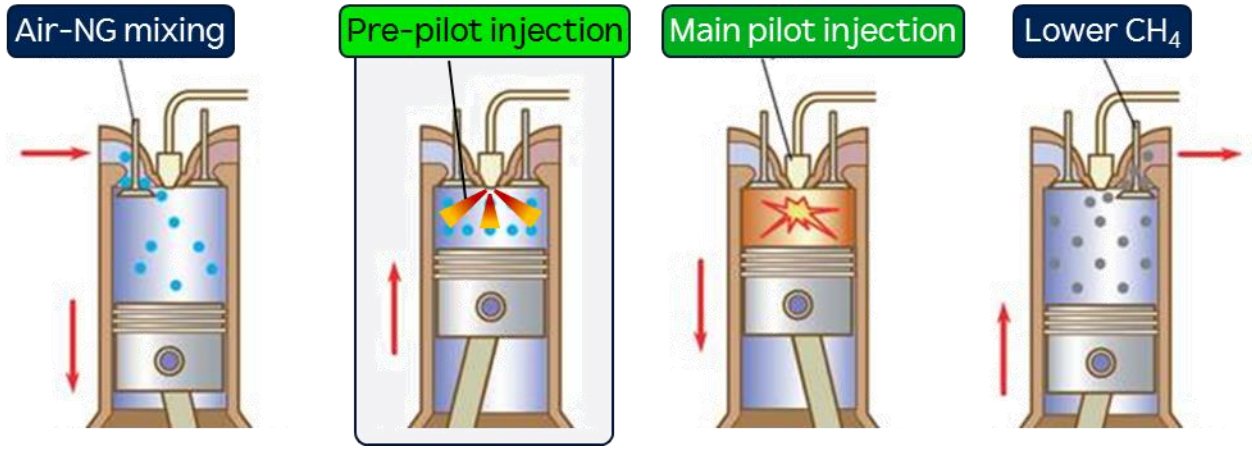


MPI

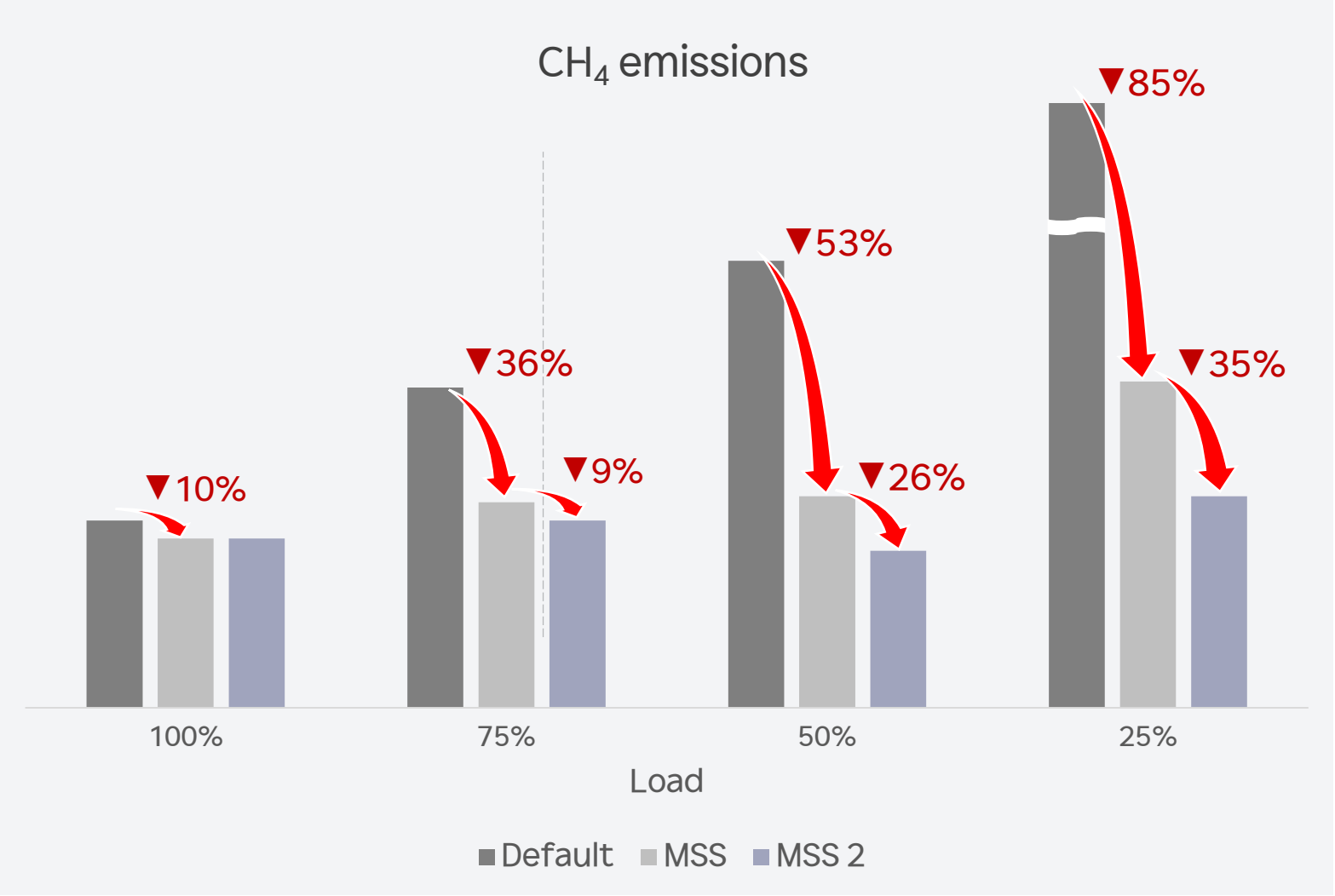
Multi injections of pilot fuel with optimized timing and quantity

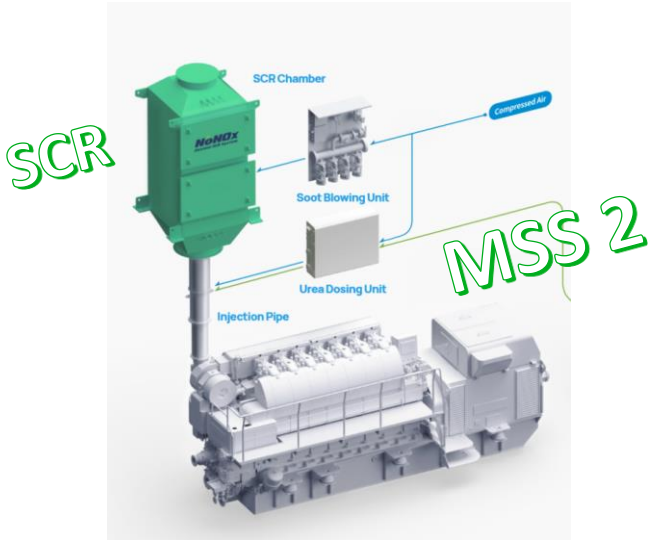
Improved combustion by pre-dispersion of pilot fuel

Automatic switch off of MPI in case of unstable operating conditions



Result of MSS & much lower crevice volume





- Utilizing the CH_4-NOx trade-off

- By utilizing MSS2
  - Comply with the IMO NOx Tier 2 limit
  - Lower CH_4 emissions
  - Higher exhaust gas temperature

- To keep the IMO NOx Tier 3 limit in gas mode
  - Necessary to operate SCR
  - Minor upgrade in SCR
  - Increased urea consumption

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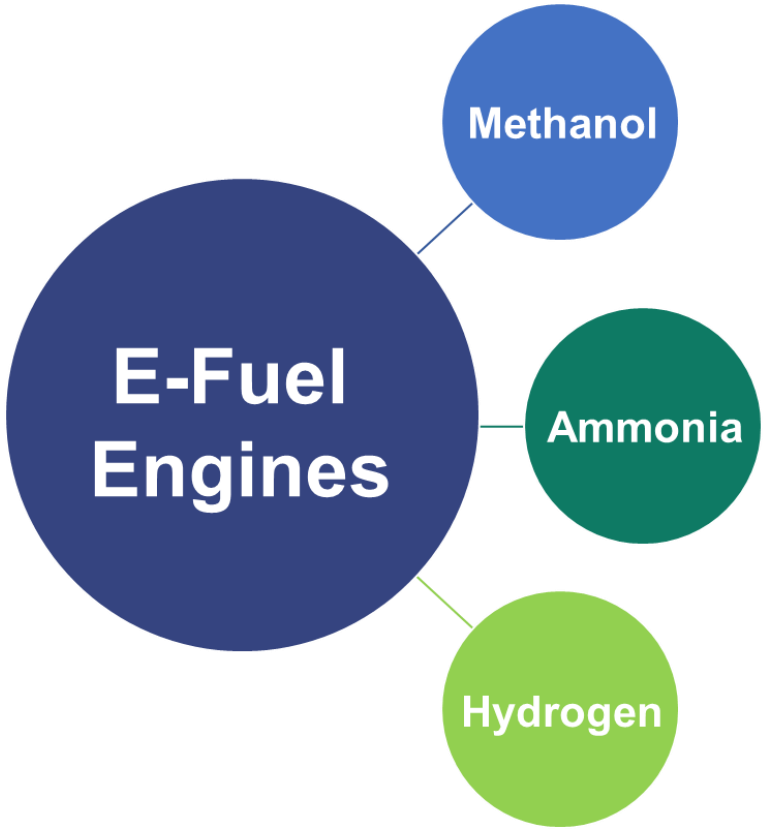
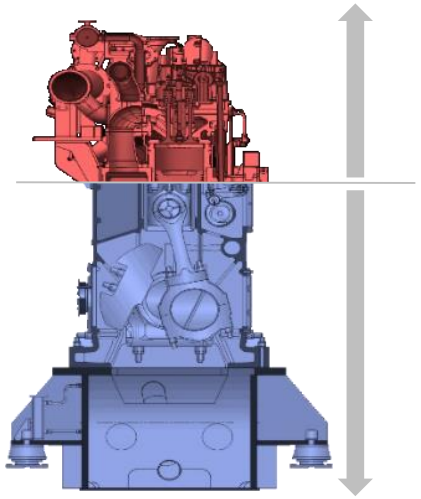
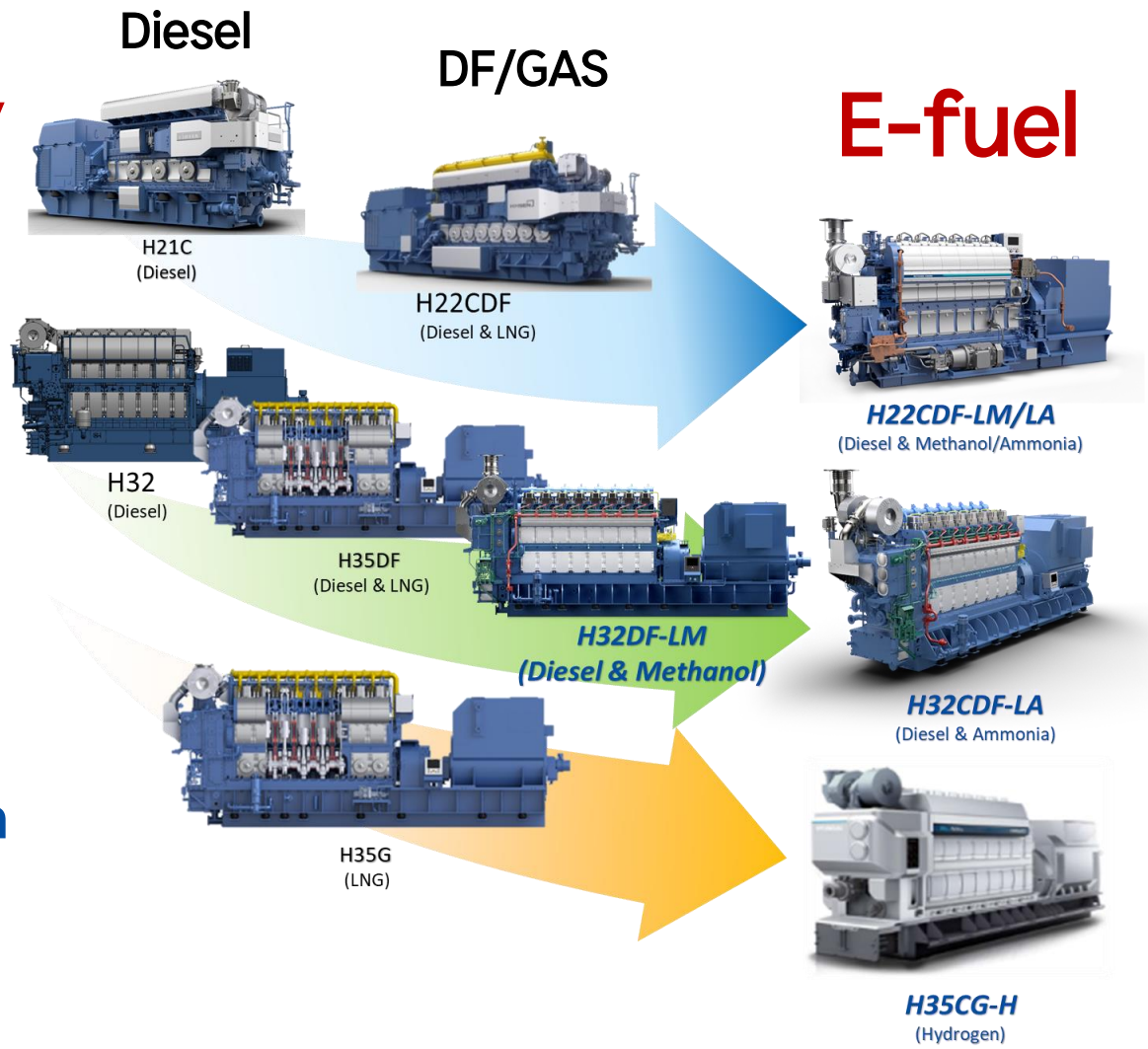
Developing based on proven HiMSEN platform



Up-to-date technology for E-Fuel engines (+ Fuel Flexibility)



Fully proven design from Diesel/DF engines



Development of e-fuel engines based on the proven HiMSEN engine platform

World 1st Methanol Fueled Containership

Type Approval Test

Engine Type : **H32DF-LM**
Class : ABS, BV, DNV, KR, LR, NK, RINA
Date : Sep. 2022

World's 1st

2,100 TEU Containership

Shipyard : HD Hyundai Mipo Dockyard
Vessel delivery : July 2023
M/E : 6G50ME-C9.6-LGIM
G/E : 6H32DF-LM (2 sets), 6H21M (1set)

World's 2nd

16,200 TEU Container Carrier

Shipyard : HD Hyundai Heavy Industry
Vessel delivery : Jan. 2024
M/E : 8G95ME-C10.5-LGIM
G/E : 6, 9H32DF-LM

TAT for H22CDF-LA (30th Sep. to 2nd Oct. 2024)

(engine output: 1.4MW~2.2MW)

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HD HYUNDAI HEAVY INDUSTRIES

R&D Partners

- We are continuously developing our technical expertise in collaboration with reliable R&D partners

HiMSEN Hydrogen Solution for suitable application

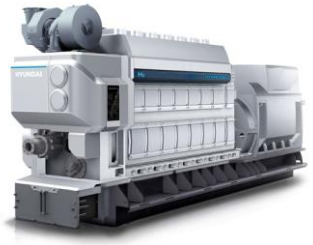
NG + H_2

- Retrofit for LNG-DF
- LNG Carrier

DIESEL + H_2

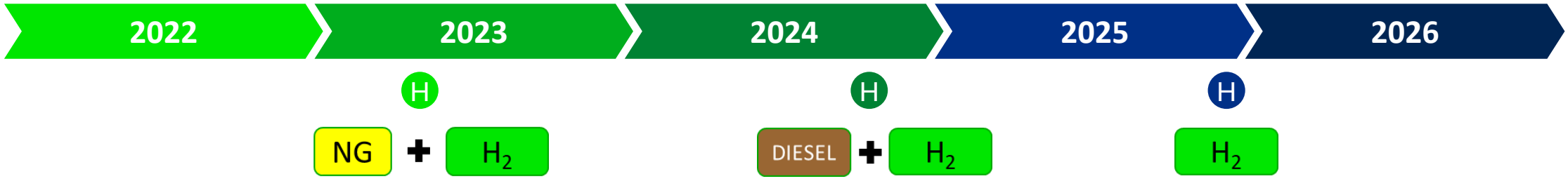
- Liquid H_2 Carrier
- Electric propulsion

H_2



- Green Power Plant
- Electric propulsion

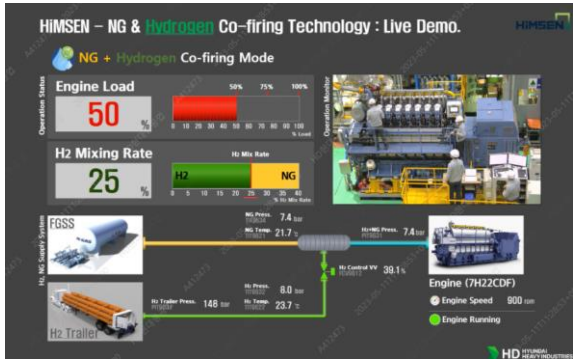
Development Roadmap



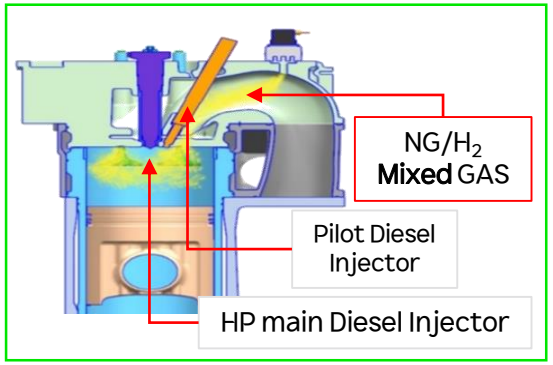
NG/H_2 Dual Fuel

< DNV AIP Award - Gastech 2022 >

< Demonstration event - 2023 >



< Live-Demo. Control system >



< NG/H_2 Combustion System >

Development Strategy

- → Stable & Safe operation : Making uniform mixing NG/H_2 precise mixing ratio control technology
- → Minimized retrofit : compared with LNG DF minimized part change
- → No Power/Efficiency De-rating
- → Verified GHG & Methane slip Reduction

Verified Emission Reduction Performance - Constant Hydrogen mixing ratio @ 25%vol

Emission Reduction(%)		GHG	Methane slip	Satisfied IMO NOx Tier III regulation
	Load 50%	-21% ↓	-40% ↓	(reduction ratio relative to NG only)
	D2 cycle	-17% ↓	-19% ↓	

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Future with HHI-EMD

- HiMSEN engines, **equipped with not only cutting edge methane slip prevention technology**, MSS2, but also **ready for the renewable fuels combustion**, Methanol, Ammonia & Hydrogen will help you to get through the environmental regulations and to maximize economic benefits at the same time.

THANK YOU