



SEA JAPAN  
Private seminar

# Japan Engine Corporation Technology to move the next generation



Japan Engine Corporation

Apr. 22, 2022

Japan Engine Corporation

Technology to move  
the next generation

**UE Engine**

**GHG reduction**

**Digitalization**

**Conclusion**

# JAPAN ENGINE CORPORATION (J-ENG)



**MITSUBISHI HEAVY INDUSTRIES  
MARINE MACHINERY & ENGINE  
(MHI-MME)**

## **Marine Engine Division**

- New engine development
- Licensing
- After-sales service

## **Marine Machinery Division**

- MET Turbochargers
- Boiler & Turbines
- Propellers etc.



## ***KOBE DIESEL***

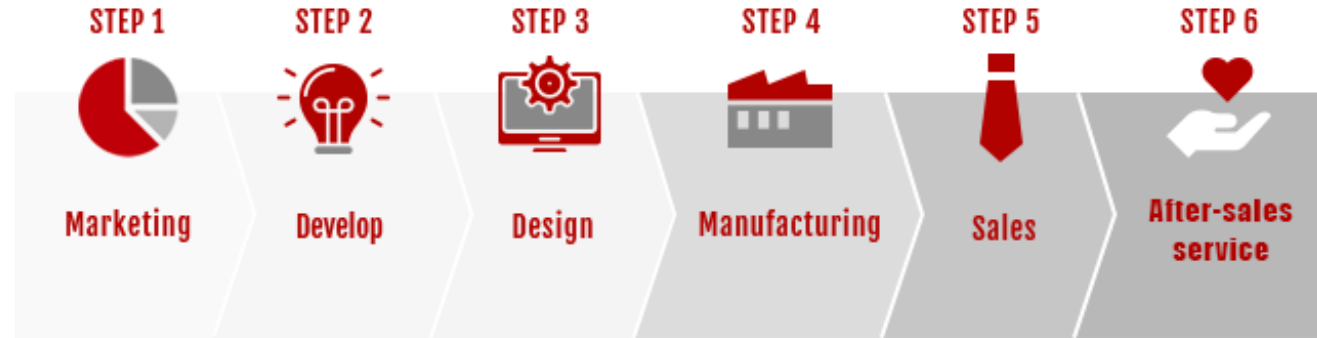
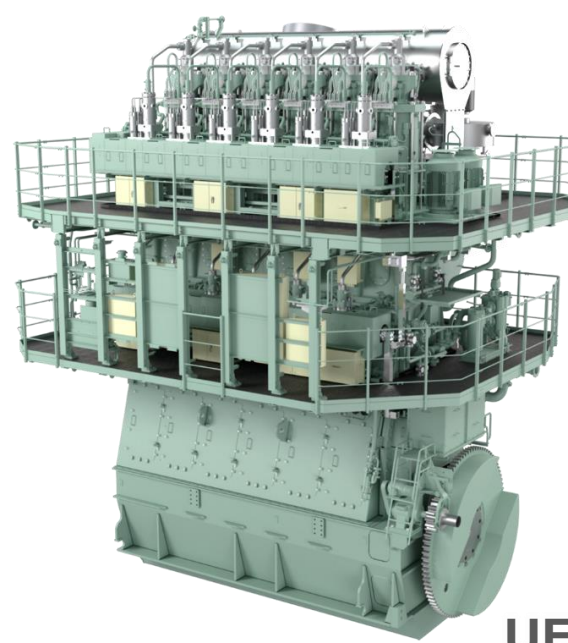
- Production design
- Manufacturing
- After-sales service

Sophisticated Technical support

## **MITSUBISHI HEAVY INDUSTRIES**

### **- Research & Innovation Center**

- Technology Strategy Office
- Value Chain HQ.
- ICT Solution HQ.



## UE Engine

Main propulsion engine, low-speed marine 2-stroke engine  
Purely Japanese brand, one of the three brands in the world

## Our Business

The only licensor in the world with an integrated system from  
Development to after-sales service  
Contribute to shipping and shipbuilding industry

# Development History of UE Engine



6UEC50LSH-Eco

5UEC50LSJ

6UEC42LSH-Eco



6UEC50LSE

6UEC35LSE-Eco



8UEC60LSII-Eco

1955

1960 1970 1980 1990 2000 2005 2010 2015 2020 2025

H<sub>2</sub> (UEC-LSGH)

NH<sub>3</sub> (UEC-LSJA)

UEC42LSJ

UEC35LSJ

UEC50LSJ

UEC33LSH

UEC42LSH-Eco

UEC50LSH-Eco

UEC33LSE

UEC80LSE-Eco

UEC35LSE UEC35LSE-Eco

UEC45LSE-Eco

UEC45LSE

UEC50LSE UEC50LSE-Eco

UEC60LSE UEC60LSE-Eco

UEC68LSE

UEC52LSE UEC52LSE-Eco

UEC-LSII UEC-LSII-Eco

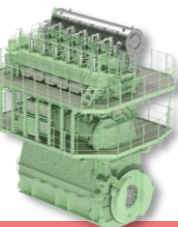
UEC-L/LA/LS

UEC-H/HA

UEC-A/B/C/D/E

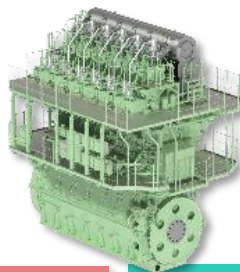
Eco, LSJ : Electronically controlled engine

## Engine Development



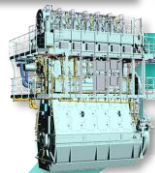
### UEC50LSH-Eco-C2

First engine completed



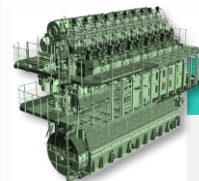
### UEC60LSE-Eco-A2

First Low SFOC version entered in service



### UEC45LSE-C1

First engine completed



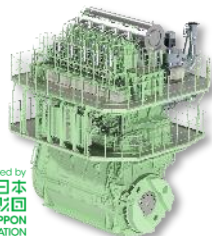
### UEC50LSE-Eco-B1

First 10cyl engine completed



### UEC50LSJ

First MGO mono-fuel engine completed



First engine completed with EGR system

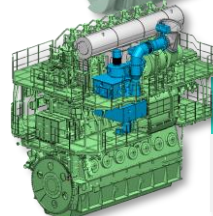


### UEC50LSH-Eco-C3

First engine completed with EGR system

### UEC42LSH-Eco-D3

初号機完成、EGR付き



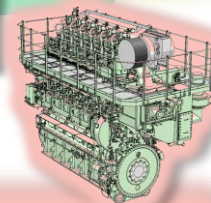
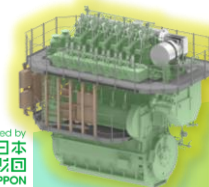
### UEC60LSE-Eco-A2

First EGR equipped engine completed



### UEC35LSJ

2022 first engine will be completed



### UEC33LSH-C2

2022 first engine will be completed

**New developments Under planning**

2017.4

2018

2019

2020

2021

2022

# Green technology

## Toward Carbon neutral in 2050

### Carbon-free fuel

Started research on combustion using carbon-free fuel

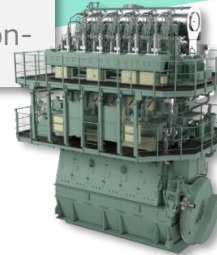


### Hydrogen fueled engine

- Consortium of Japanese engine manufactures are formed
- HyEng Corporation Established
- Adopted for Japanese Government's NEDO Green Innovation Fund project

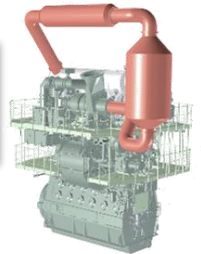
### Ammonia fueled engine

- Adopted for Japanese Government's NEDO Green Innovation Fund project



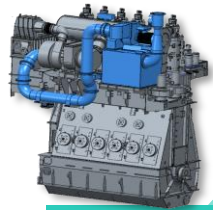
### HP-SCR system

Added Tier III lineup



### LP-SCR system

First Engine completed



### LP-EGR system

Development completed

2017.4

2018

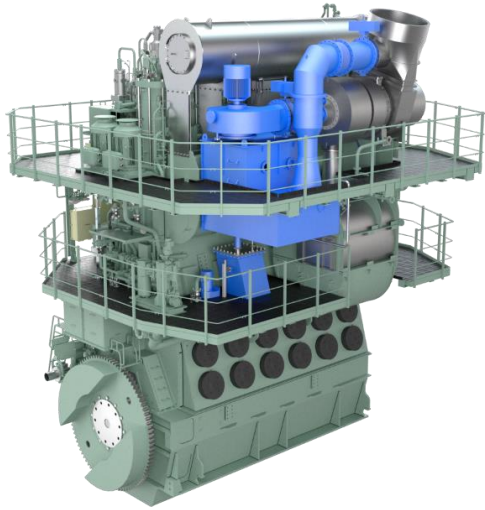
2019

2020

2021

2022

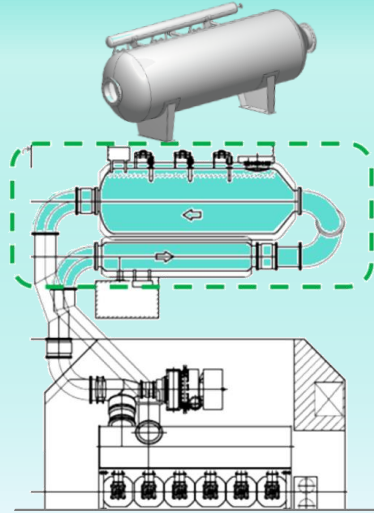
# NOx Tier3 technology line-up



## LP-EGR

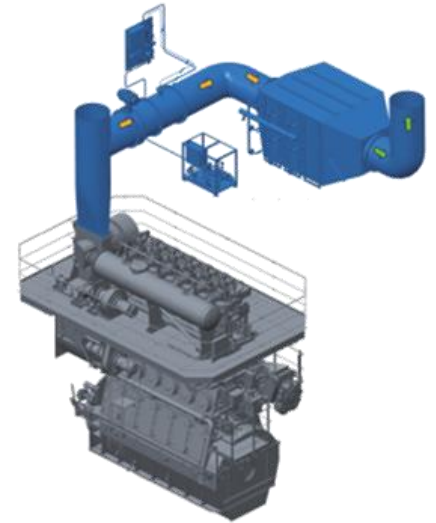
Compact installation · Low OPEX  
Zero-breed-off system

## Newly added



## HP-SCR

Installed in engine room  
Easy apply with SOx scrubber

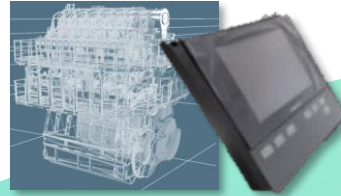
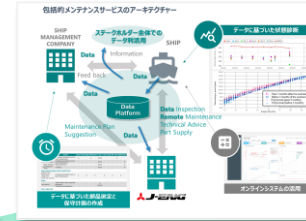


## LP-SCR

Simple system configuration  
Easy arrangement

**All in-house developed No black box**





**Bearing temperature monitoring system**  
This system consists of sensors and about 1000 data points.

**Bearing wear monitoring system**  
This system consists of bearing wear sensor, water content sensor, and 1000 data points.

**Cylinder pressure control and monitoring system**  
This system consists of 1000 data points.

**Eco engine waveform monitoring system**  
This system is installed as an additional system as well as cylinder pressure control and monitoring system, and consists of lift sensors of fuel injection pump / upper exhaust valve driving system, pressure sensor of cylinder lubricator, ASU, HUB unit and PC.



### Eco control system 4G

Launched 4<sup>th</sup> Generation

### Eco control system 5G

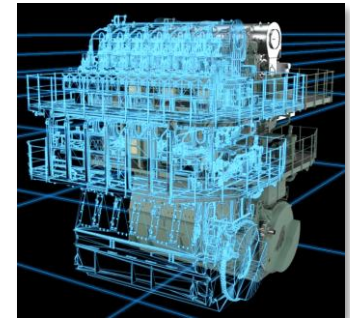
Started research on next-generation engine control system

### CBM・Monitoring

Started research on maintenance according to actual operation conditions

### Remote monitoring Condition diagnosis

Engine for coastal vessels to which Advanced Ship Safety Management System is applied



### Toward Digital Twin



# J-ENG



**SUSTAINABLE DEVELOPMENT GOALS**  
17 GOALS TO TRANSFORM OUR WORLD

×



We support the Sustainable Development Goals (SDGs).



## New UE Licensee

Guangzhou Diesel Engine Factory (GDF)

## UE Training center

Newly at head office factory  
UE/Eco training, Tier3 and GHG related equipment

## Integration of bases

New office building and automated warehouses completed  
Integrate bases of all departments;  
Sales / Development / Product Design / Procurement / Manufacturing / QA·QC / AS

J-ENG founded



2017 Apr

2018

2019

2020

2021

2022

# Latest topics



2022.03.09

Press

## J-ENG granted GDF to the license on manufacturing and sales of UE Engines

GDF: Guangzhou Diesel Engine Factory Co., Ltd.



Guangzhou Diesel Engine Factory Co., Ltd.

### GDF

Medium speed (4-stroke) engine manufacturer with top market share in China, founded in 1911

Licensed manufacturing and sales of UE engines in order to meet the increasing demand for main engines for coastal vessels in China

### Production schedule

Over 30 sets of engines including latest UEC42/50LSH-Eco are ordered in short term

# UE Licensee (UE Engine Manufactures)

China

Korea

Japan

**CSE**

**China Shipbuilding Industry Corporation Diesel Engine Co.,Ltd**

- QMD: Qingdao Haixi Marine Diesel Co., Ltd. (Qingdao)
- YMD: Marine Diesel Engine Co., Ltd. (Yichang)
- DMD: Dalian Marine Diesel Co., Ltd. (Dalian)



**GDF**

**Guangzhou Diesel Engine Factory Co., Ltd.**

- Jingjiang Co., Ltd. (Jingjiang)



**YDE**

**Zhejiang Yungpu Diesel Engine Co., Ltd.**  
(Ningbo)



**HHI**

**Hyundai Heavy Industries Co., Ltd.**  
(Ulsan)



**J-ENG**

**Head office & Factory**  
(Akashi)



**AKASAKA**

**Akasaka Diesels Ltd.**  
(Yaizu)



**BDD**

**Shipbuilding Industry Corporation (SBIC) /Bach Dang Demco**  
(Haiphong, Vietnam)



Vietnam

Japan Engine Corporation

Technology to move  
the next generation

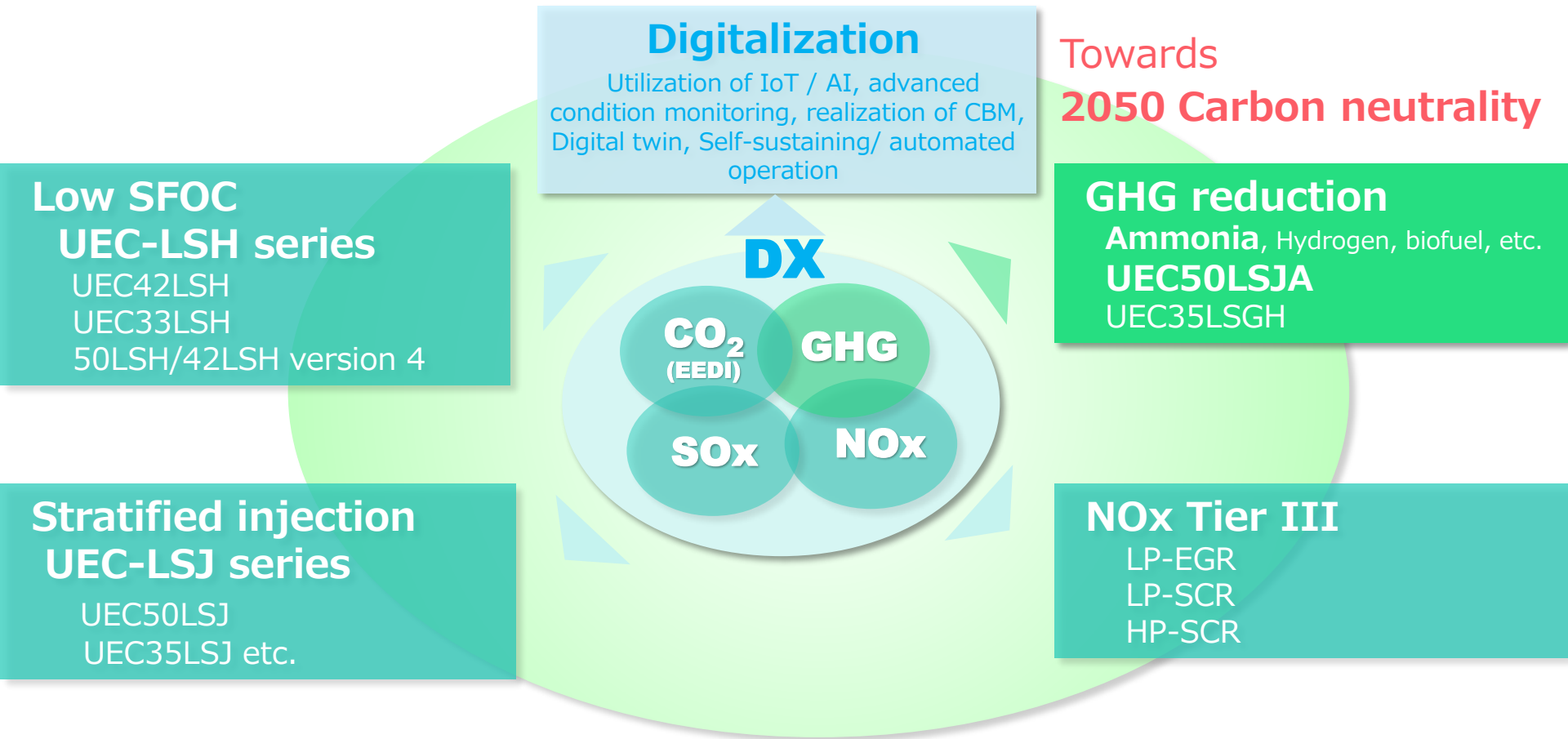
UE Engine

**GHG reduction**

Digitalization

Conclusion

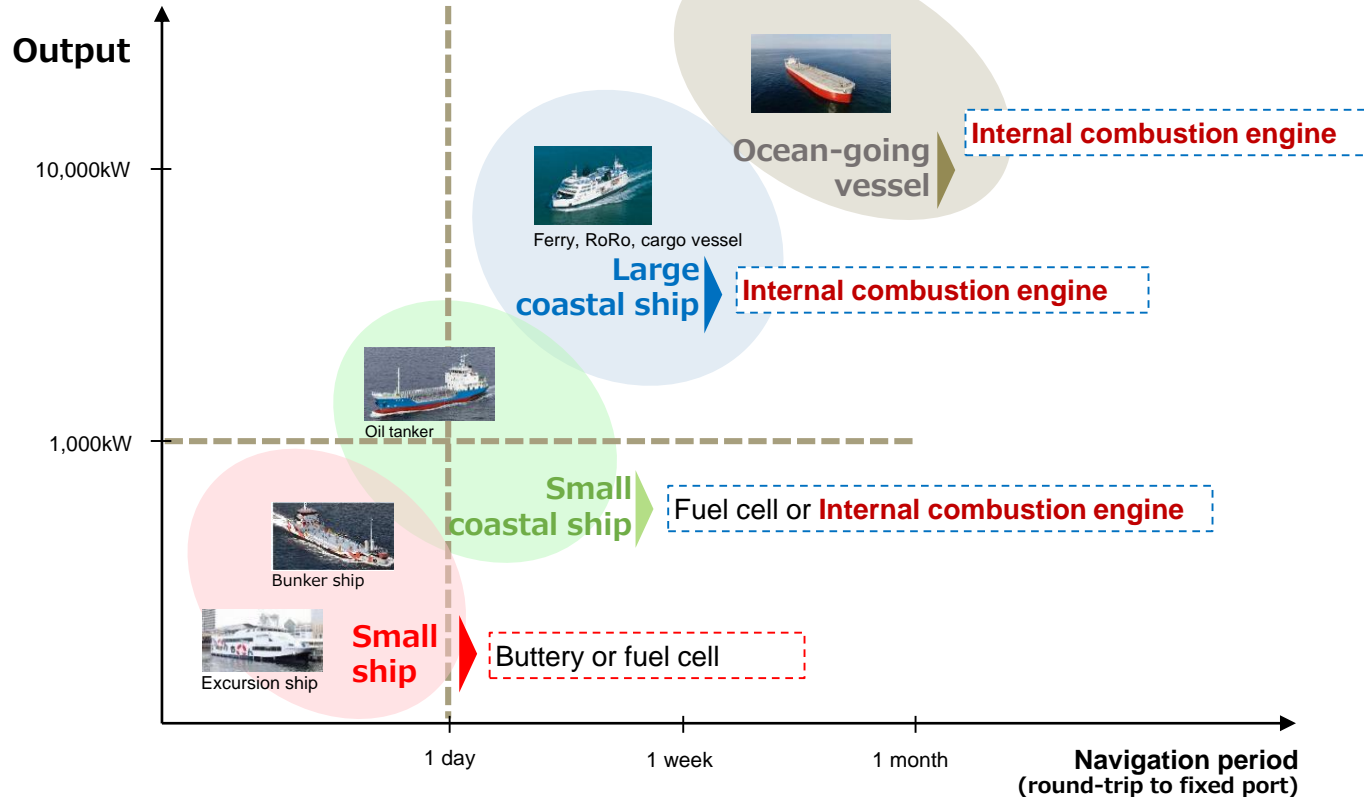
# Technical Strategy for UE Engine



Towards  
**2050 Carbon neutrality**

## ICE is best solution for large coastal ship and ocean-going vessel

ICE : Internal combustion engine



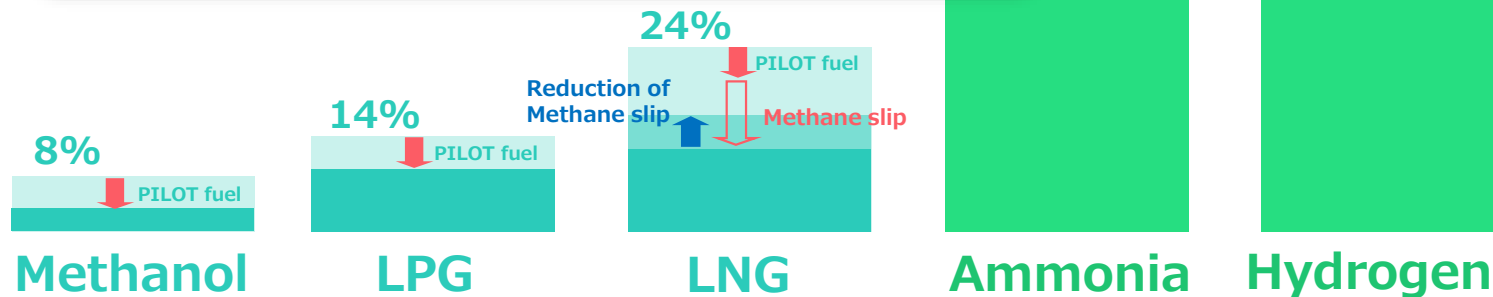
# GHG reduction with low-carbon or carbon-free fuel

## Carbon free fuel

Ammonia, Hydrogen  
Increase of co-firing range is  
technical task for ammonia

## Low carbon fuel (from fossil fuels)

GHG reduction below 25%  
Bridge solutions



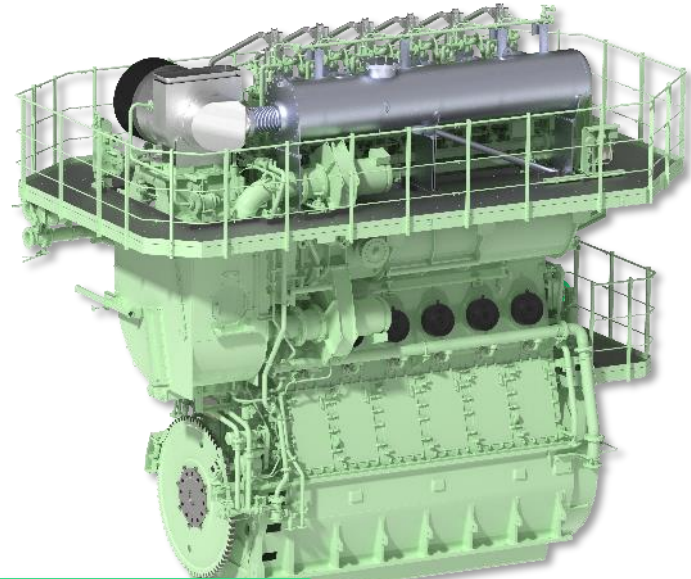


## Ammonia fueled engine UEC-LSJA



**LSJ+Ammonia**

## Hydrogen fueled engine UEC-LSGH



**LSGi+Hydrogen**

Japan Engine Corporation

Technology to move  
the next generation

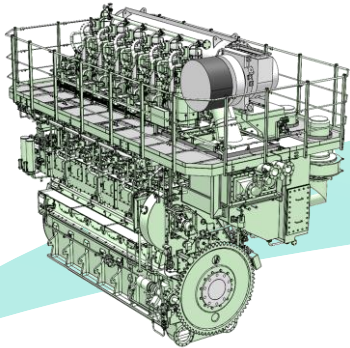
## GHG reduction

**UEC-LSH/LSJ engine**

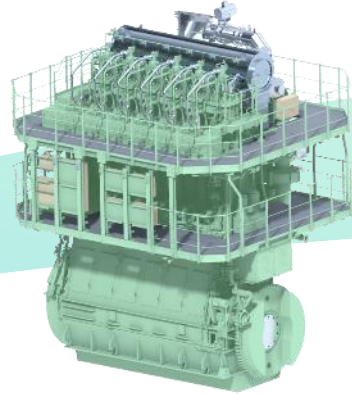
Ammonia fueled engine

Hydrogen fueled engine

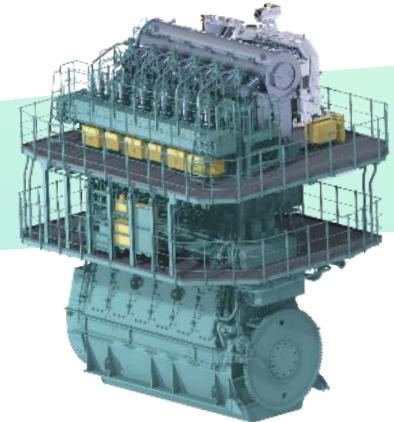
# Fuel-efficient UEC-LSH series



**UEC33LSH**  
since 2022



**UEC42LSH-Eco**  
since 2021



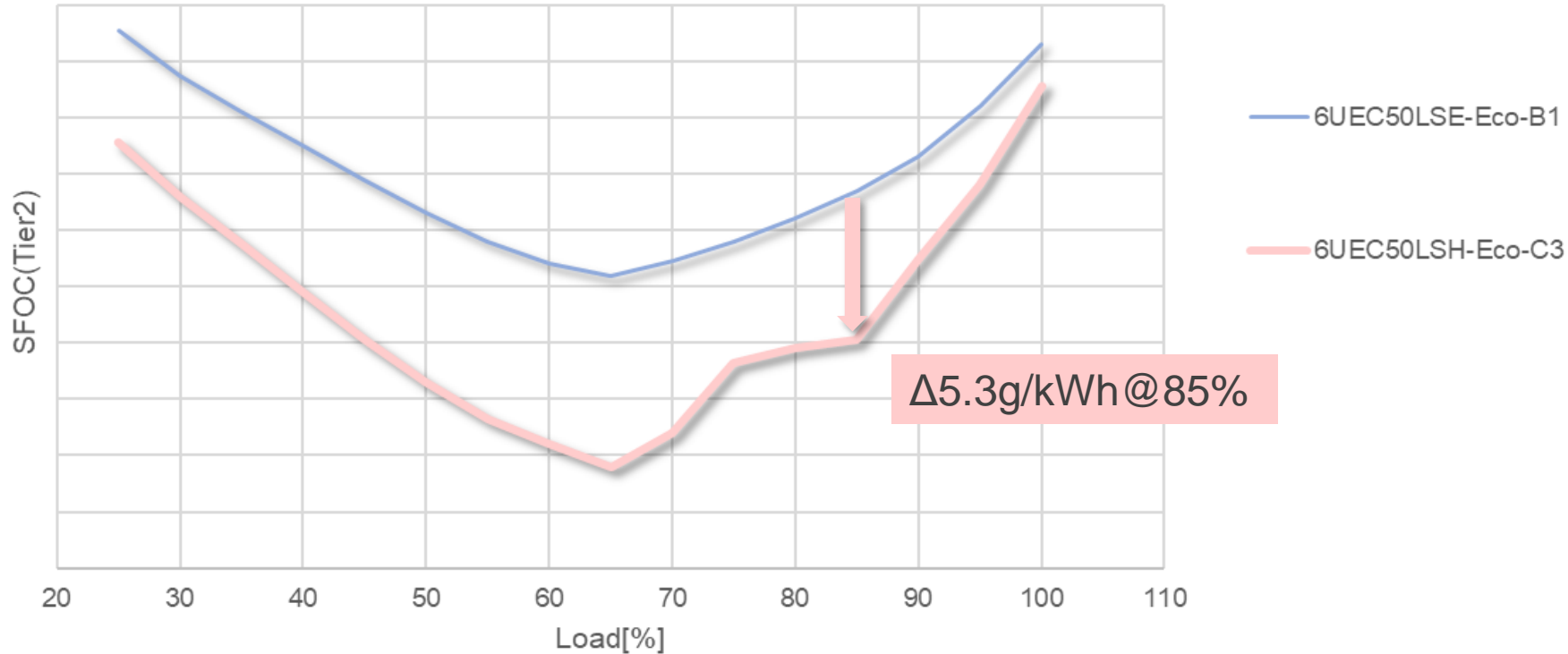
**UEC50LSH-Eco**  
since 2015

The **UEC-LSH** engine is based on the fuel-efficient technology of the UEC-LSE engine.

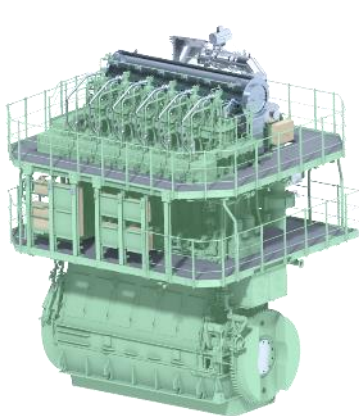
**Further fuel efficiency** achieved with **Combustion mode optimization, Loss reduction and optimization etc.**, of each part

In addition, **Version 4** with additional fuel efficiency will be Launched.

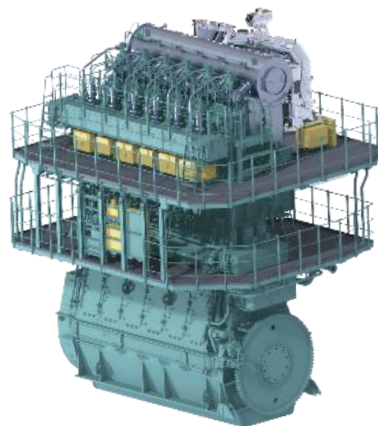
## UEC-LSH significantly reduces SFOC from UEC-LS



# Further SFOC reduction “Version4 Engine”



**UEC42LSH-Eco-D4**



**UEC50LSH-Eco-C4**

## Easy application

Modified fuel injection system based on conventional engine  
Future retrofit is possible

## OPEX reduction

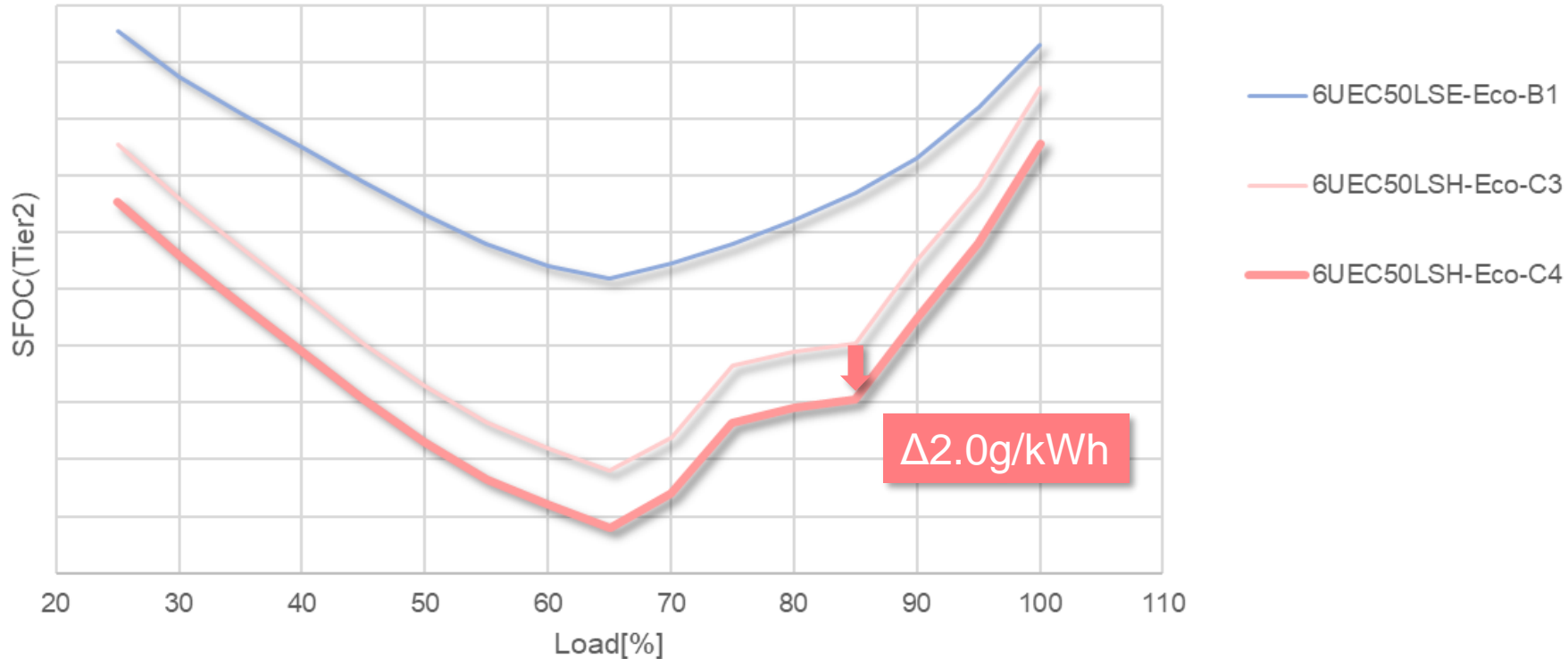
Low SFOC at entire load range  
Measure against Fuel Price Increase

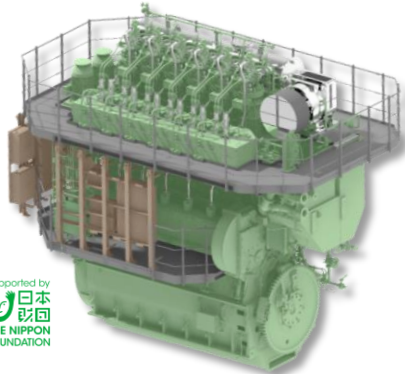
## Expandability to new Fuel

Configuration of Eco control unit is same as Ammonia / Hydrogen fueled engines  
It leads expandability to new fuel in future

# Further SFOC reduction "Version4 Engine"

## UEC-LSH-Ver.4 reduces SFOC at entire load range vs Ver.3





Supported by  
  
 THE NIPPON  
 FOUNDATION

6UEC35LSJ



Supported by  
  
 THE NIPPON  
 FOUNDATION

6UEC50LSJ

UEC-LSJ series

## Excellent fuel-efficient engine

J-ENG's

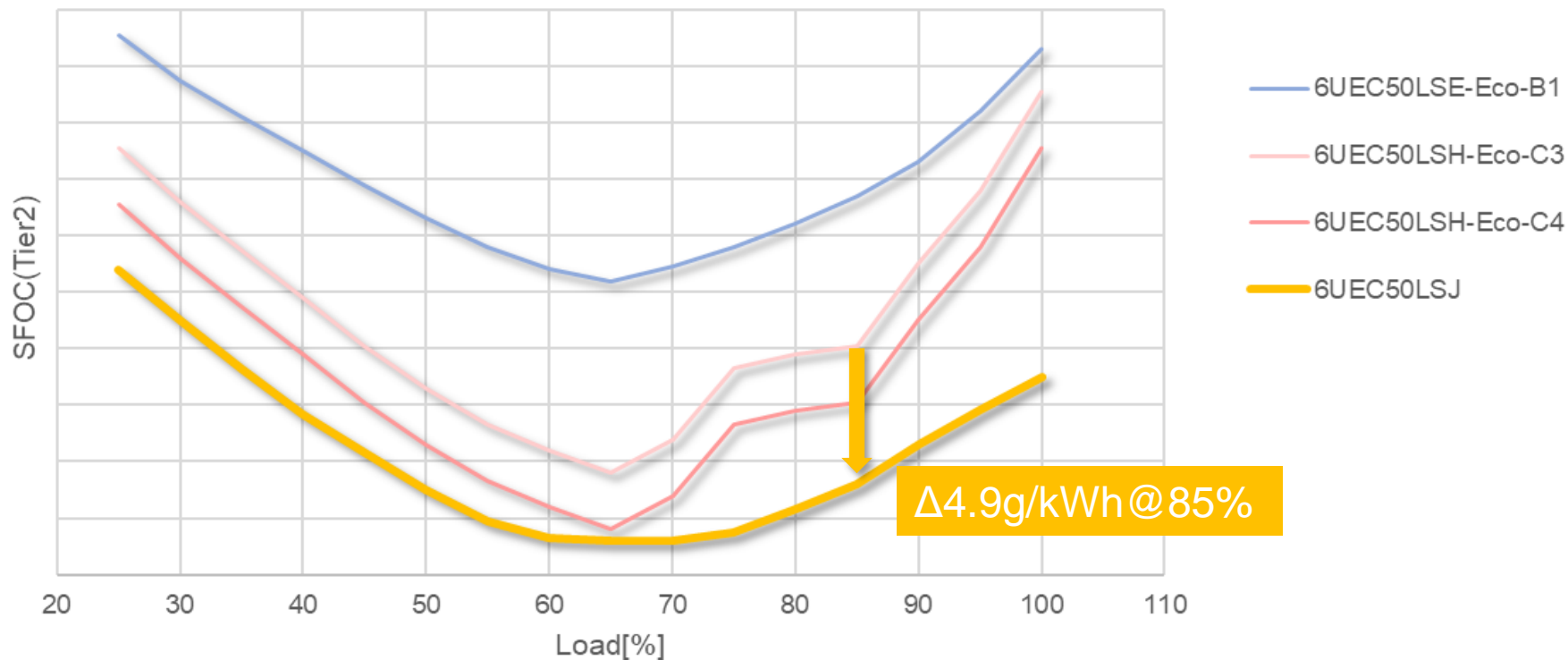
**Stratified injection system** is applied.

Fuel and water are layered and injected.

**Achieved Significant fuel efficiency** without NOx increase.

It is possible to apply **carbon-free fuel** such as **ammonia** instead of water to layered injection, and to further reduce GHG by using biofuel, etc., especially as a solution for zero emission of small and medium-sized vessels. We have received more inquiries.

## UEC-LSJ significantly reduces SFOC from LSH-Ver.3





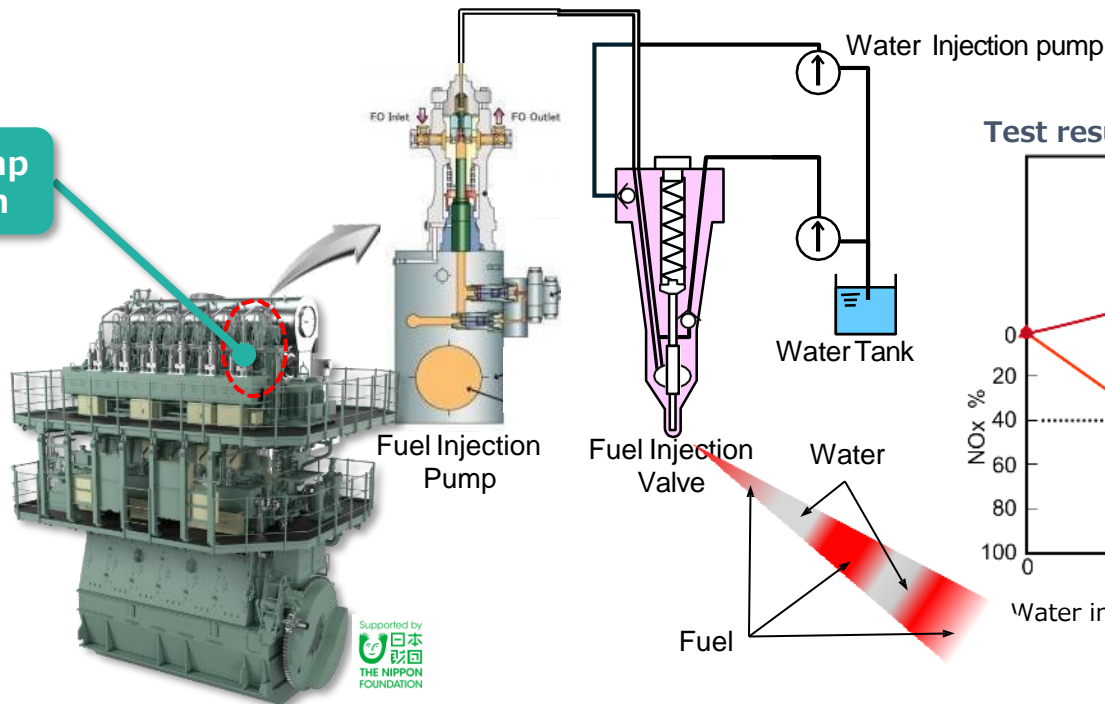
## Water pumped into fuel line during non-injection period, Injected by Fuel Pump

### Fuel valve and pump for water injection

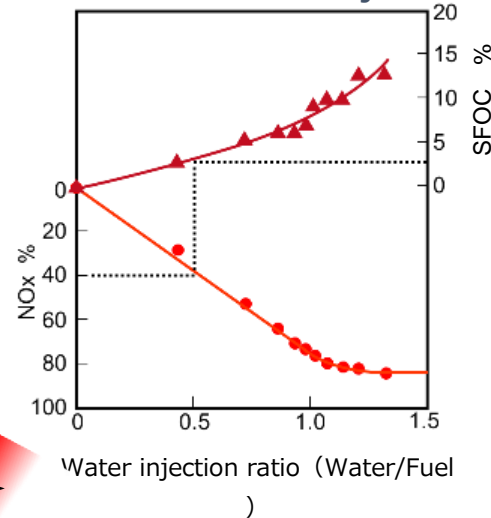
Only SWI system is added to the existing engine

N/A heat trace  
(Steam heating for fuel is not applied)

In case of MGO/MDO mono-fuel



### Test result of water injection



# Stratified Water Injection unit for UEC50LSJ

## Stratified water injection unit

Water injection pump

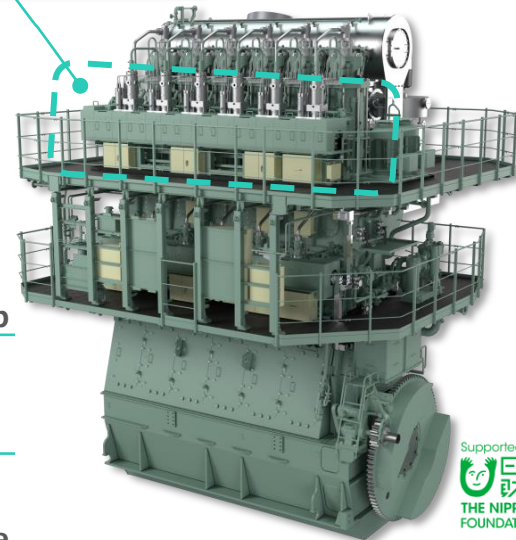
Solenoid valve  
(for water injection)

Fuel pump

Control valve unit

Solenoid valve  
(for fuel injection)

Accumulator block



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## **GHG reduction**

UEC-LSH/LSJ engine

**Ammonia fueled engine**

Hydrogen fueled engine

**Ammonia fueled engine** (bore 50cm class) will be **completed in 2025**. Then it will be installed to **Ammonia powered ammonia gas carrier**, which will **enter in service in 2026**.

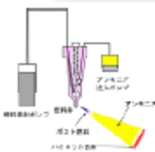


**Engine Development**

- **Establishment of Ammonia combustion technology / Design of Ammonia fueled engine**

**Coastal trading vessel (Ammonia fueled tug boat) Development and Actual operation**

Completion, Enter in service



Combustion technology



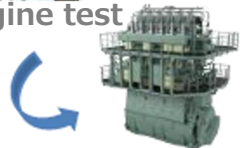
- Social implementation of Domestic 4-stroke ammonia fueled engine
- Realize the world's first ammonia fueled vessel

**Ocean going vessel (AFAGC) Development and Actual operation**

Completion, Enter in service



Single cyl. engine test



Engine Design & Manufacture



- Social implementation of Domestic 2-stroke ammonia fueled engine
- Social implementation of Domestic 4-stroke ammonia fueled auxiliary engine
- Social implementation of Ocean going vessel (AFAGC)
- Realization of Low carbon marine transportation of Ammonia

Press release on October 26, 2021

October 26, 2021

**Demonstration Project Begins for Commercialization of Vessels Equipped with Domestically Produced Ammonia-Fueled Engine**

**-- Utilizing the Japanese Government's Green Innovation Fund --**

NYK Line  
 Japan Engine Corporation  
 IHI Power Systems Co., Ltd.  
 Nihon Shipyard Co., Ltd.  
 Nippon Kaiji Kyokai (ClassNK)

NYK Line, Japan Engine Corporation, IHI Power Systems Co., Ltd., and Nihon Shipyard Co., Ltd. (i.e., "the Companies") are pleased to announce that Japan's New Energy and Industrial Technology Development Organization (NEDO) has approved the Companies' participation in a demonstration project for the commercialization of vessels equipped with a domestically produced ammonia-fueled engine as part of the Green Innovation Fund project.\* The demonstration project, which is scheduled to begin in December with ClassNK added to the Companies, aims to use ammonia as fuel to significantly reduce greenhouse

## Develop Ammonia fueled engine with bore 50cm class



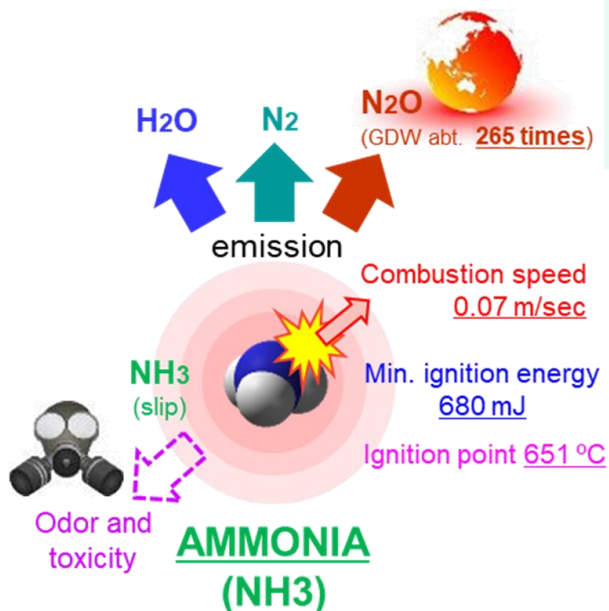
## Hardly-flammable

**Slow** Combustion speed : 1/5 of methane,  
**High** minimum self-ignition temp : 651 degC

→ **Stratified injection** to optimize Combustion

**N<sub>2</sub>O** Nitrous oxide GWP of 265 times that of CO<sub>2</sub>

→ **Stratified injection** to minimize N<sub>2</sub>O



Fuel NO<sub>x</sub> Nitrogen in fuel may cause Fuel NO<sub>x</sub>

→ After treatment (SCR) application

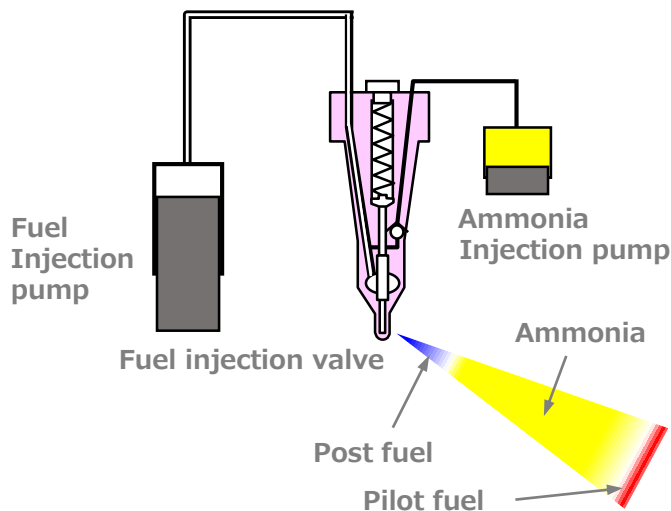
## Toxicity

→ Double wall piping, Purging, separation, recovery equipment  
 Applying safety measures

Corrosive

→ Material with corrosion resistance

J-ENG's technology  
**Stratified Ammonia injection**  
 for Ammonia fueled engine



## J-ENG's unique technology

- One fuel valve for two different liquid
- Possible co-combustion with different liquid fuels
- Already applied to UEC-LSJ with **Water**
- Can be applied to UEC-LSJA with **Ammonia**

## Advanced combustion control

- **Suitable for Ammonia fueled engine**
- **Optimized stratified (layered) Injection** with easily flammable pilot fuel (ignitor), hardly flammable Ammonia (sandwiched) and easily flammable post fuel (assist)
- **Minimize fuel consumption and N<sub>2</sub>O production**

## CFD sample

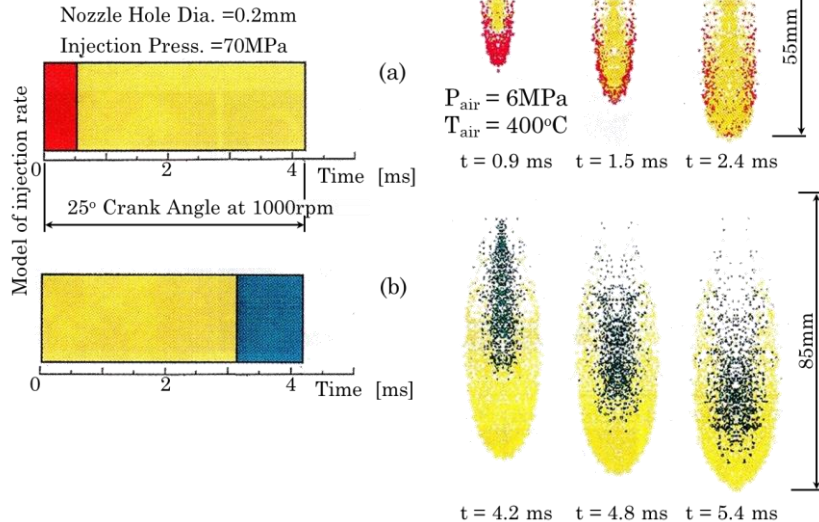


Bild 5: Computersimulation der Strahlbildung  
 Fig. 5: Numerical results of the spray characteristics

Source: Prof. Takasaki, Kyushu Univ.

## Ignite Ammonia fuel spray and keep Ammonia fuel flame combustion

The first sprayed MGO (red) envelops the ammonia spray (yellow) during the spray formation process

## Reduction of unburned Ammonia and $\text{N}_2\text{O}$

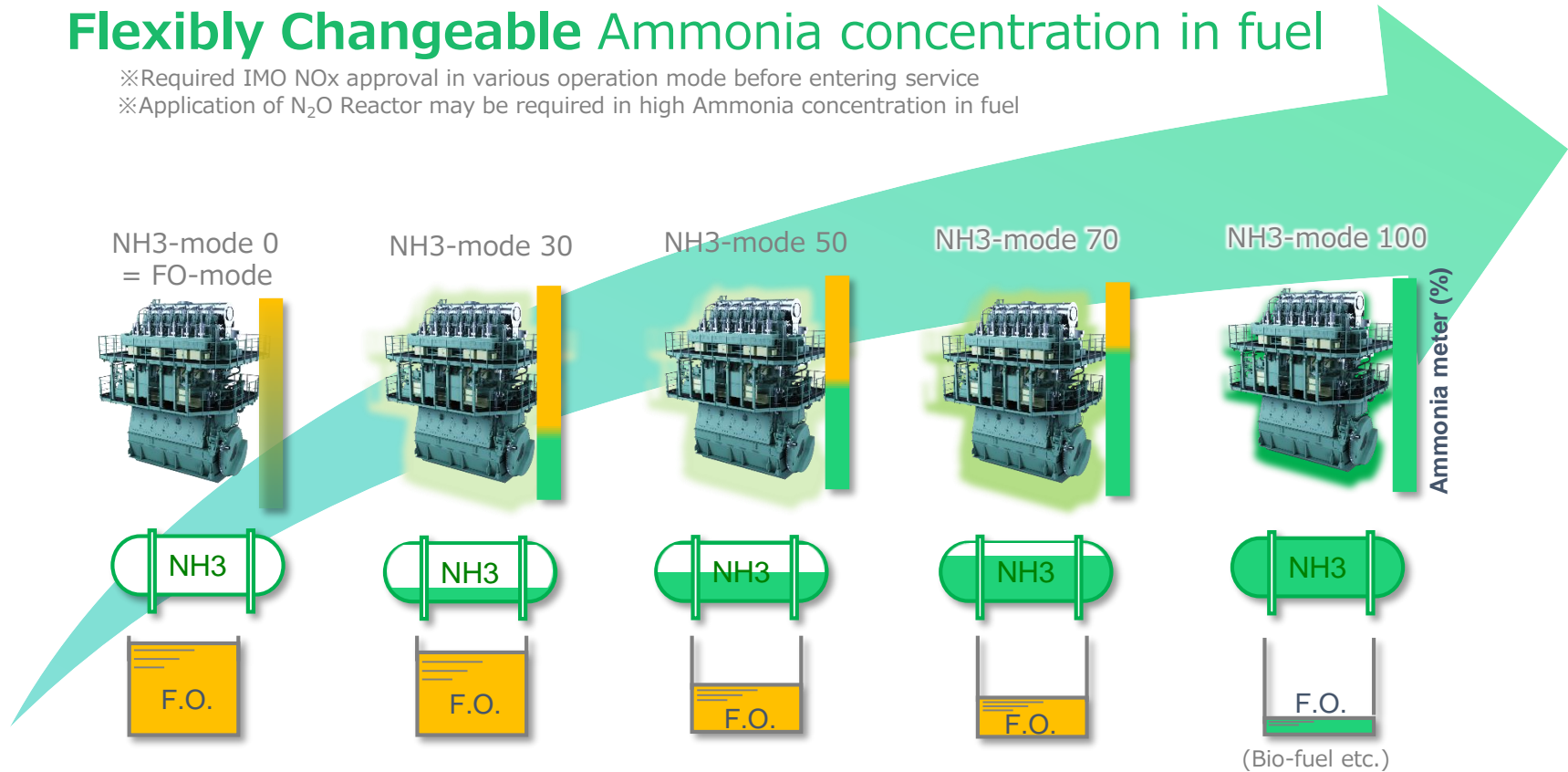
The last sprayed MGO (blue) pushes the ammonia spray (yellow) around the hot flame and activates combustion.

## Enable stable combustion over the entire combustion period.



## Flexibly Changeable Ammonia concentration in fuel

- ※Required IMO NOx approval in various operation mode before entering service
- ※Application of N<sub>2</sub>O Reactor may be required in high Ammonia concentration in fuel



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## **GHG reduction**

UEC-LSH/LSJ engine

Ammonia fueled engine

**Hydrogen fueled engine**

## Towards GHG zero-emission, **Hydrogen fuel conversion in sea transportation is essential**



Hydrogen fueled ship (Container ship, bulk carrier)  
(Source: MLIT Roadmap to Zero Emission from International Shipping)



The use of Hydrogen fuel has already begun in many fields to reduce GHG



FC Truck



FC Bus



Hydrogen gas turbine



Commercial or industrial fuel cell



Liquefied hydrogen carrier



FCV



Fuel-cell forklift



Hydrogen power plant



Hydrogen station

Source: Website of agency for natural resources and energy

Press release on Oct. 26, 2021

October 26, 2021

**Demonstration Project Begins for Commercialization of Vessels Equipped with Domestically Produced Ammonia-Fueled Engine**

**-- Utilizing the Japanese Government's Green Innovation Fund --**

NYK Line  
Japan Engine Corporation

NYK Line, Japan Engine Corporation, IH Shipyard Co., Ltd. (i.e., "the Companies") and the Japanese Government's Green Innovation Fund approved the Companies' participation in the demonstration project for the commercialization of vessels equipped with ammonia-fueled engine as part of the Green Innovation Fund.

Press release  
On Nov. 9, 2021

November 9, 2021

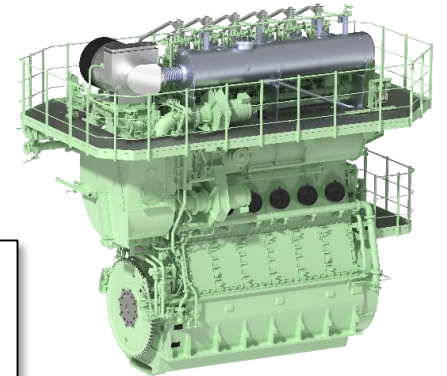
**MOL, MOL Drybulk, J-ENG Sign Agreement for Trial of Hydrogen-fueled Engine equipped Onboard**  
~ Aiming to Realize a Zero Emissions Vessel ~

Mitsui O.S.K. Lines, Ltd.  
MOL Drybulk, Ltd.  
Japan Engine Corporation

TOKYO—Mitsui O.S.K. Lines, Ltd. (MOL), MOL Drybulk, Ltd., and Japan Engine Corporation (J-ENG) today announced the signing of a basic agreement to cooperate in a trial of hydrogen-fueled engine equipped on an in-service vessel. The ship will be operated by MOL and MOL Drybulk, and the engine—the world's first low-speed, two-stroke hydrogen-fueled marine engine—will be developed by J-ENG.

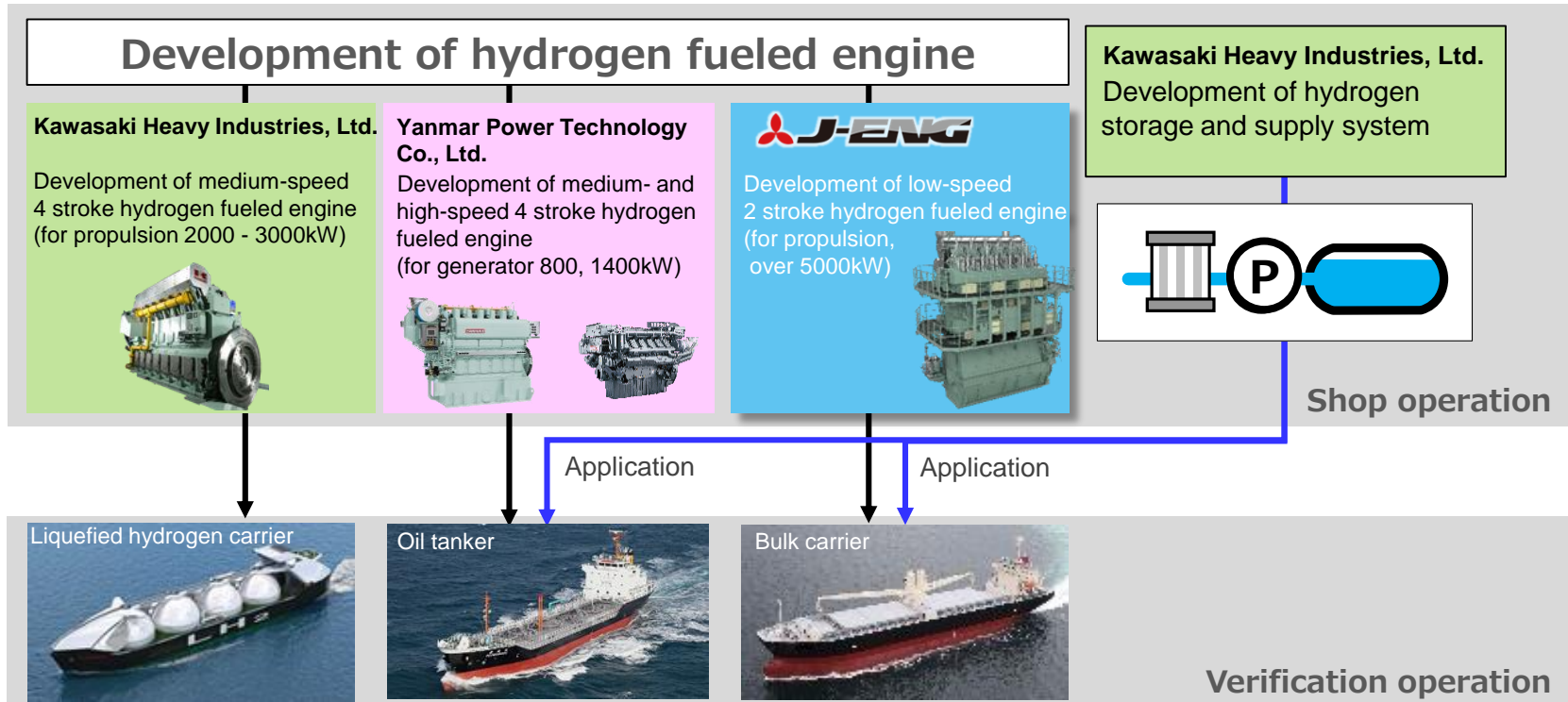
While accelerating efforts to reduce greenhouse gas (GHG) emissions as measures to address climate change, the ocean shipping industry has also

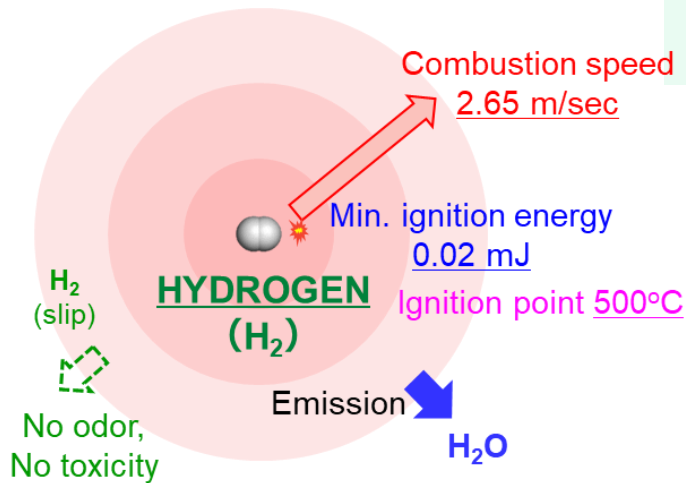
## Development of hydrogen fueled Bore 35cm class engine



[https://www.j-eng.co.jp/news/2021/141e6t000002cj5-att/J-ENGPRESSRelease20211109\\_JP.pdf](https://www.j-eng.co.jp/news/2021/141e6t000002cj5-att/J-ENGPRESSRelease20211109_JP.pdf)

Hydrogen fueled engine will be completed around the end of FY2026, and verification operation on bulk carrier is planned





## Easily-flammable

**Very fast** Combustion speed : 2.65 m/s

**Low** minimum self-ignition temp : 500 degC

**Wide** flammable air-hydrogen ratio

- Establish **Stable combustion technology**
- Apply **Safety measures** (double wall pipe, purge etc.,)

**Hydrogen embrittlement** may be concerned

- Apply **Proper materials**

**Easy to leak** because of Small molecular weight

- Establish **Sealing technology**

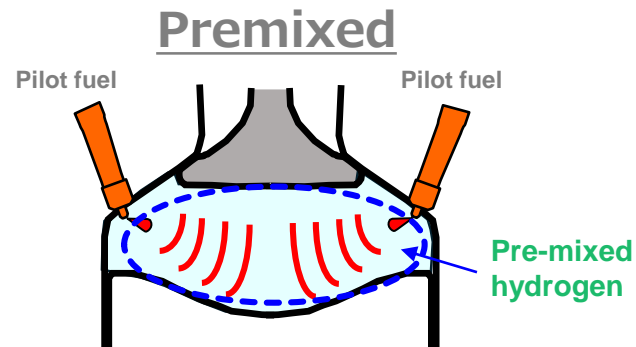
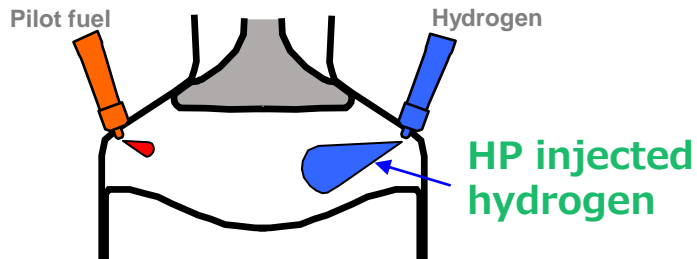
International standards are not yet in place

- Japan leads the making of international standards

For stable combustion and 100% Hydrogen

## Apply HP Gas Injection

### High Pressure Gas Injection



#### Pros

- **Secure stable combustion**  
→ High efficiency and **High output** are possible with high compression ratio (keep **same output with same engine size**)

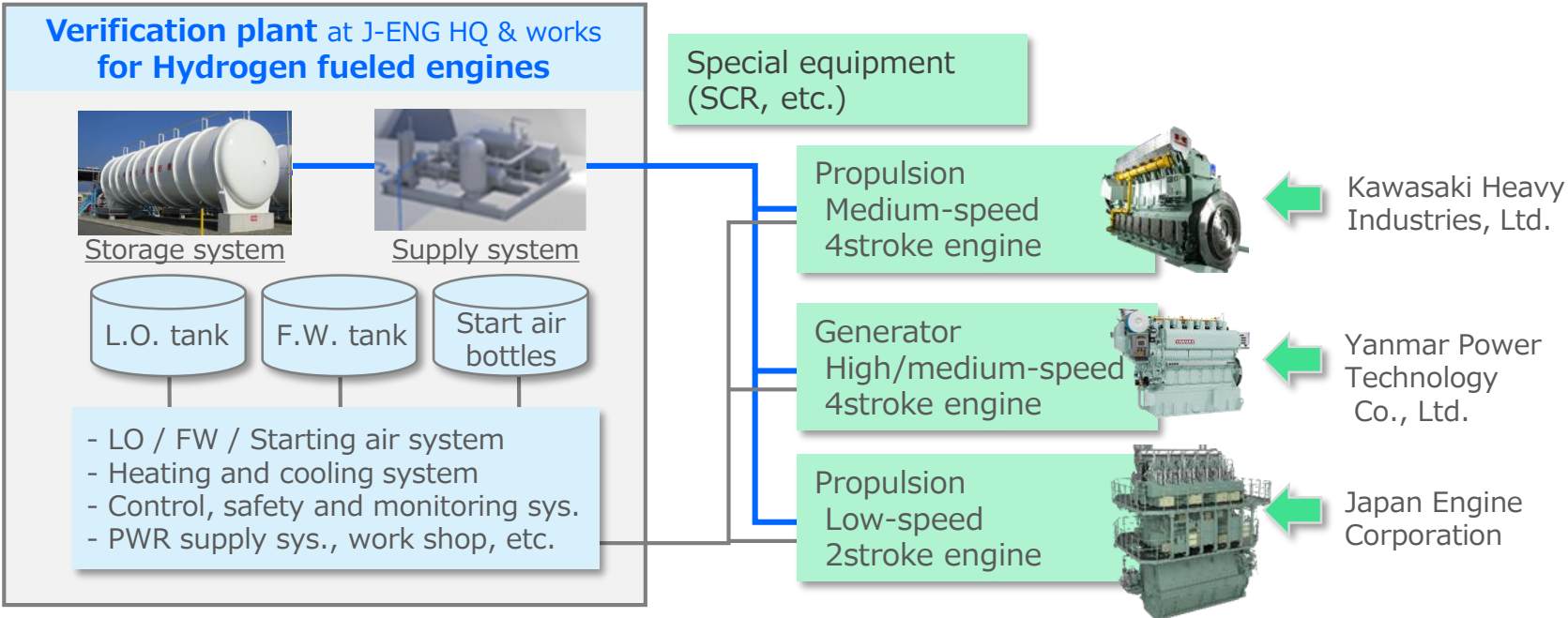
- Low press gas supply (e.g. 1MPa)
- Low NOx emission

#### Cons

- High press gas supply (e.g. 30MPa)
- High NOx emission

- **Abnormal combustion possible** (pre-ignition, knocking)  
→ Alleviation of high temp and high press conditions by low compression ratio  
→ **Reduction of efficiency and output** (necessary to **apply larger engine size**)

- Common element technology development, Standardization, Rule creation
- Installation and use of shared facilities for shop operation with hydrogen
- Development and system integration of Hydrogen storage / supply system





Japan Engine Corporation

Technology to move  
the next generation

UE Engine

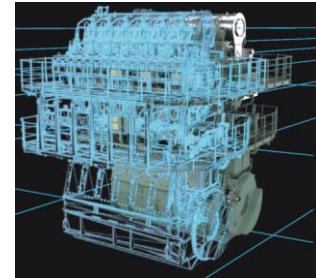
GHG reduction

**Digitalization**

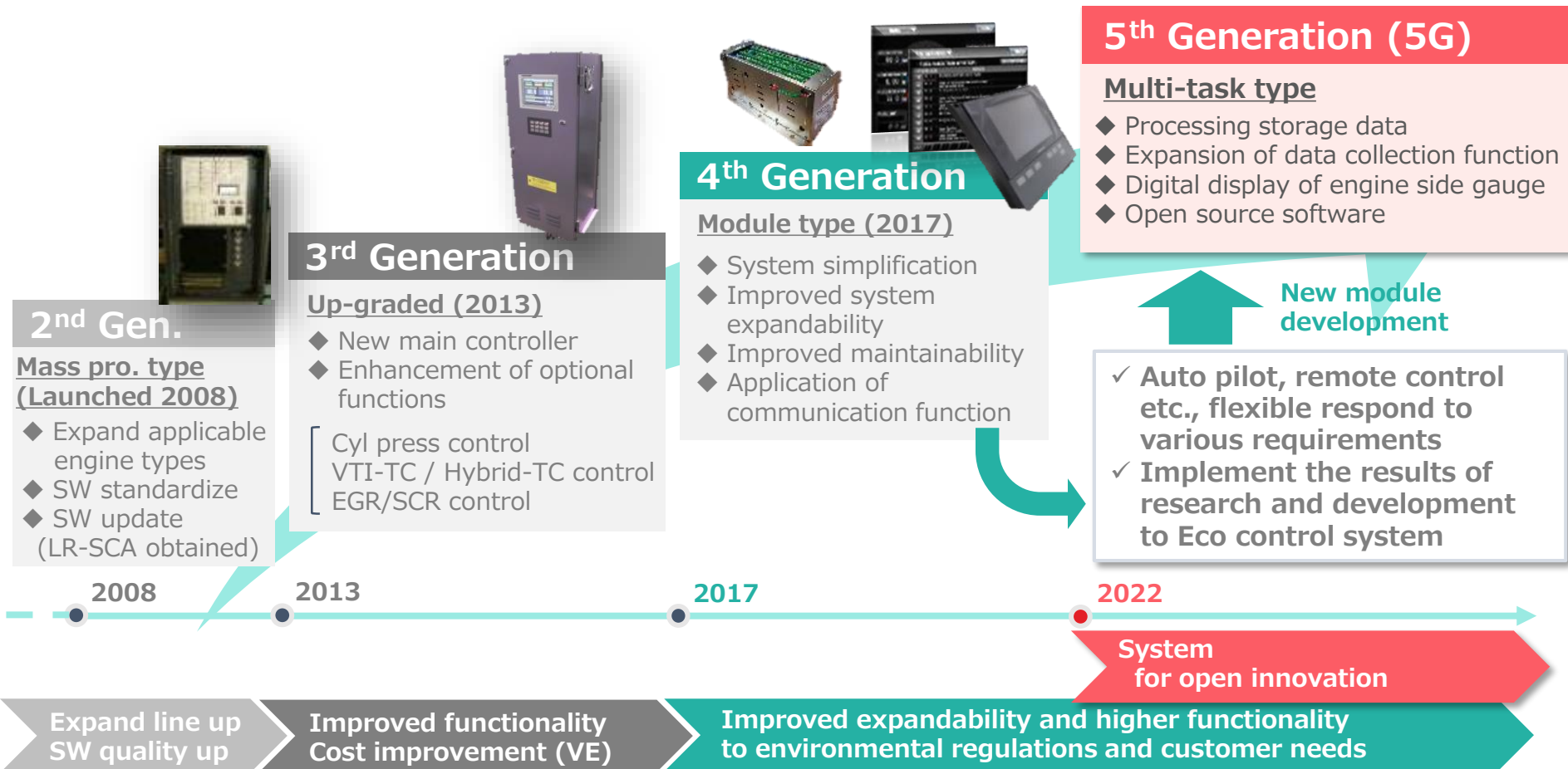
Conclusion

VISION : **Supply engines that support safe operation and crew**

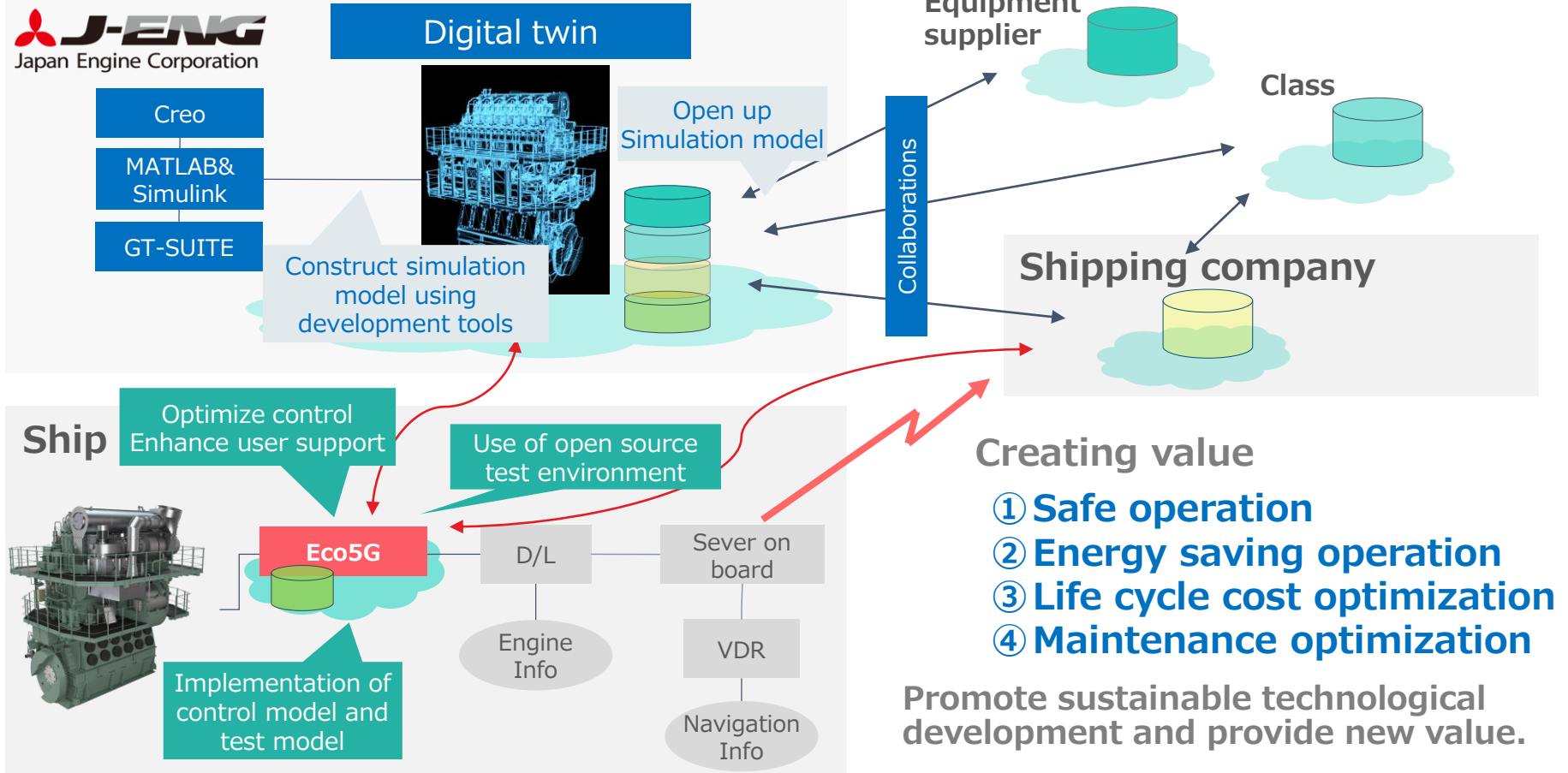
- **Development of Next generation Eco control system**  
**“Fifth generation (5G)”**
- **Engine monitoring, control and diagnosis by “Digital twin”**
  - Autonomous, auto pilot
  - Always automatic diagnosis ⇒ Failure prediction and detection  
⇒ Accident prevention
  - Operation optimization
  - Maintenance optimization (CBM)
- **Promote digitalization** through joint research with Class and other companies
- New engine will be developed as a **digitalization promotion model**



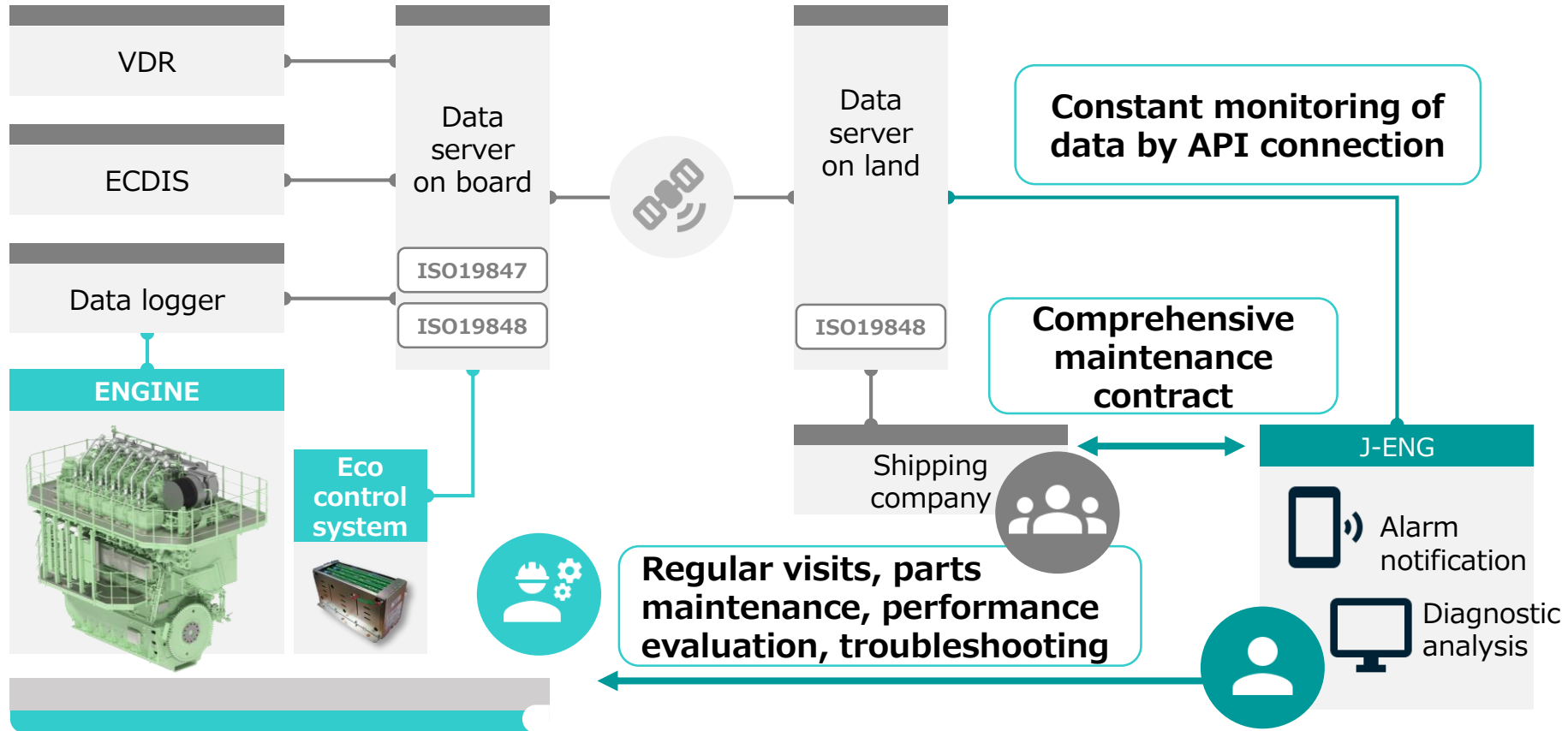
# Development of 5G Eco control system



# Future vision of J-ENG's digital architecture



# Toward the realization of after-sales service utilizing data



# Engines for MLIT/Advanced Ship Safety Management System (ASMS) for coastal ship

MLIT: Ministry of Land, Infrastructure and Transport

## Approval scheme of ASMS

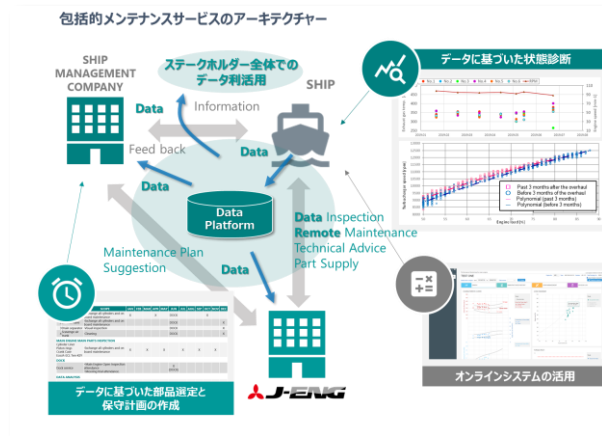
- ① Apply required sensors (Cylinder pressure, Cylinder liner temp etc.)
- ② Remote monitoring of sensor data and status diagnosis
- ③ Comprehensive maintenance contract



## Currently working on a construction project for coastal shipping companies

- ✓ Link onboard server and Eco control system, Monitor engine data on land
- ✓ Use of onboard server(ISO19847) and data linkage according to ISO19848
- ✓ Planning comprehensive maintenance menu including status diagnosis

**We operate comprehensive maintenance utilizing data and aim to increase the added value of services.**



# Additional Sensors for MLIT/ASMS

Cylinder pressure



Cylinder liner temperature



Oil mist analog output

C/R



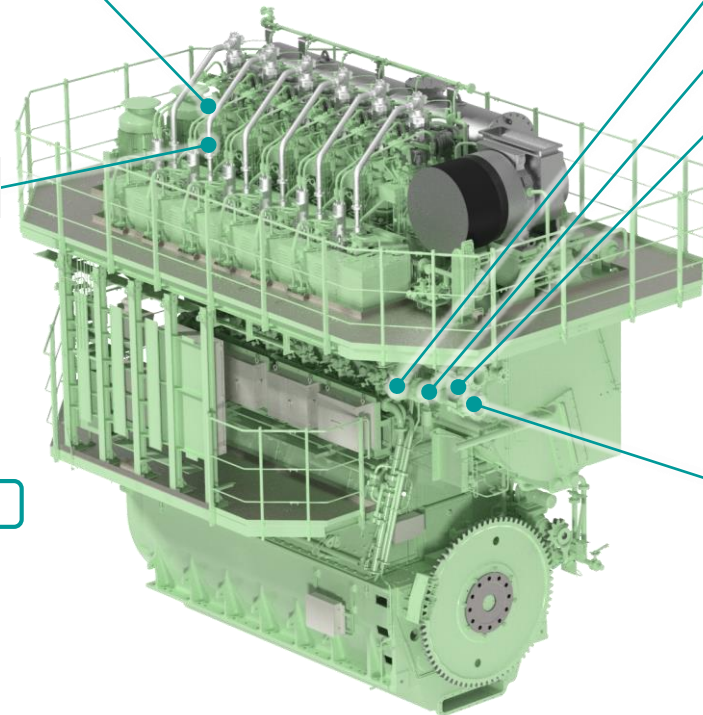
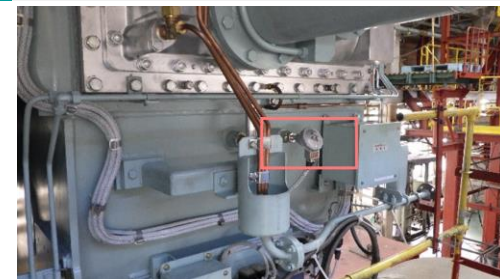
Air cooler inlet water temp

Air cooler outlet water temp

Air cooler inlet air temp



Air cooler outlet air temp



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Technology to move  
the next generation

UE Engine

GHG reduction

Digitalization

**Conclusion**



- As the movement toward **carbon neutrality in 2050** accelerates, it is an urgent task to develop an internal combustion engine that can use decarbonized fuel as a solution for reducing GHG in international shipping.
- J-ENG is promoting the development of **Ammonia-fueled engine** and **Hydrogen-fueled engine**, which are promising options for carbon neutrality.
- In addition, **SFOC reduction** of the base engine and **expansion of the Tier III technology line up** are on going.
- Towards safe operation, energy-saving and life cycle cost optimization, we have developed a **next-generation Eco control system** that supports open innovation, **expanded the monitoring system** required for CBM, and **improved the accuracy of diagnostic logic**. We will also promote digitization.

Thank you for your attention

