Techno-Economic Assessment of H2-Propulsion

Dr. Hyunchun PARK

HD Hyundai Heavy Industries | Engine Research Institute

25 June 2026

Co-authors
B.Thaler[1], M.Wohlthan[1], N.Wermuth[1], L.Kistner[2], K.K.Yum[2], Y.Yu[3], H.Kim[3], S.Moon[3], A.L.Keil[3]
1: LEC, Austria / 2: HD ERC, Germany / 3: SNU, Korea

General Notice

DISCLAIMER

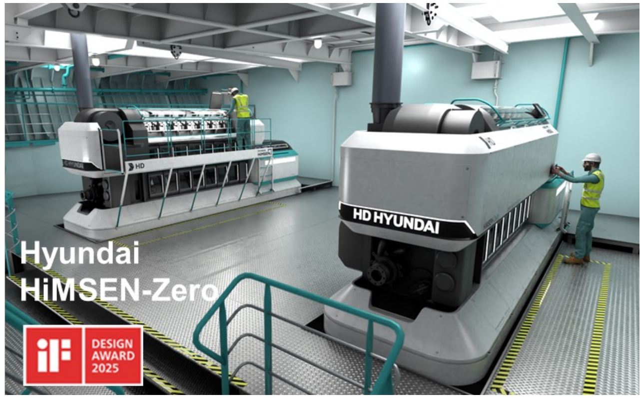
All information provided in this document is for informational purposes only. Therefore, it is not a definitive binding document and may be changed without prior notice. In addition, there are no guarantees or guarantees for any particular content. Depending on the requirements of the specific project in the future, related data and documents may be changed, and specifications should be determined after evaluation by specific project. This should be determined according to each individual project, that is, the specifications required for the specific area and specific operating conditions.

CONFIDENTIAL

Contents

Power Creator, Innovative Leader
ECO MOBILITY DYNAMICS

1. Project & Consortium Overview
2. Motivation & Questions
3. Methodology & Assumptions
4. Case1: RoPax Ferry (short-sea)
5. Case2: LH2 Carrier (ocean-going)
6. Summary
7. Acknowledgement

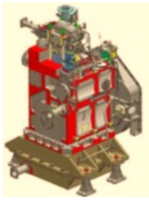


HD HYUNDAI HEAVY INDUSTRIES

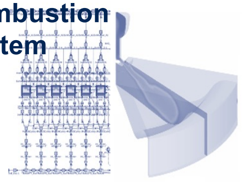
Project & Consortium Overview

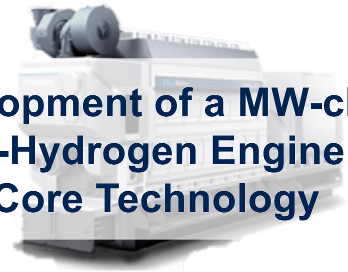
Power Creator, Innovative Leader
ECO MOBILITY DYNAMICS

WP1: Engine Test



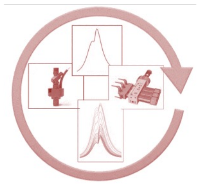
WP2: Combustion System





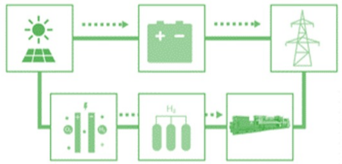
Development of a MW-class K-Hydrogen Engine Core Technology

WP3: Adaptive Control



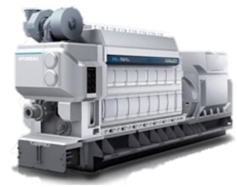
WP4: Fuel System

WP5: System Integration



H2 ICE oriented hybrid power generation system's LCA / TEA simulation tool development

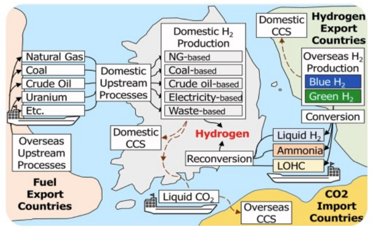
HD HYUNDAI HEAVY INDUSTRIES



HD HYUNDAI EUROPE R&D CENTER

LEC

서 울 대 학 교
SEOUL NATIONAL UNIVERSITY



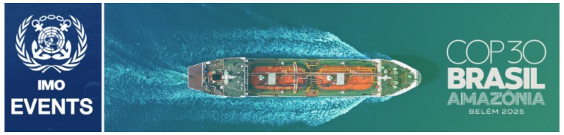
HD HYUNDAI HEAVY INDUSTRIES

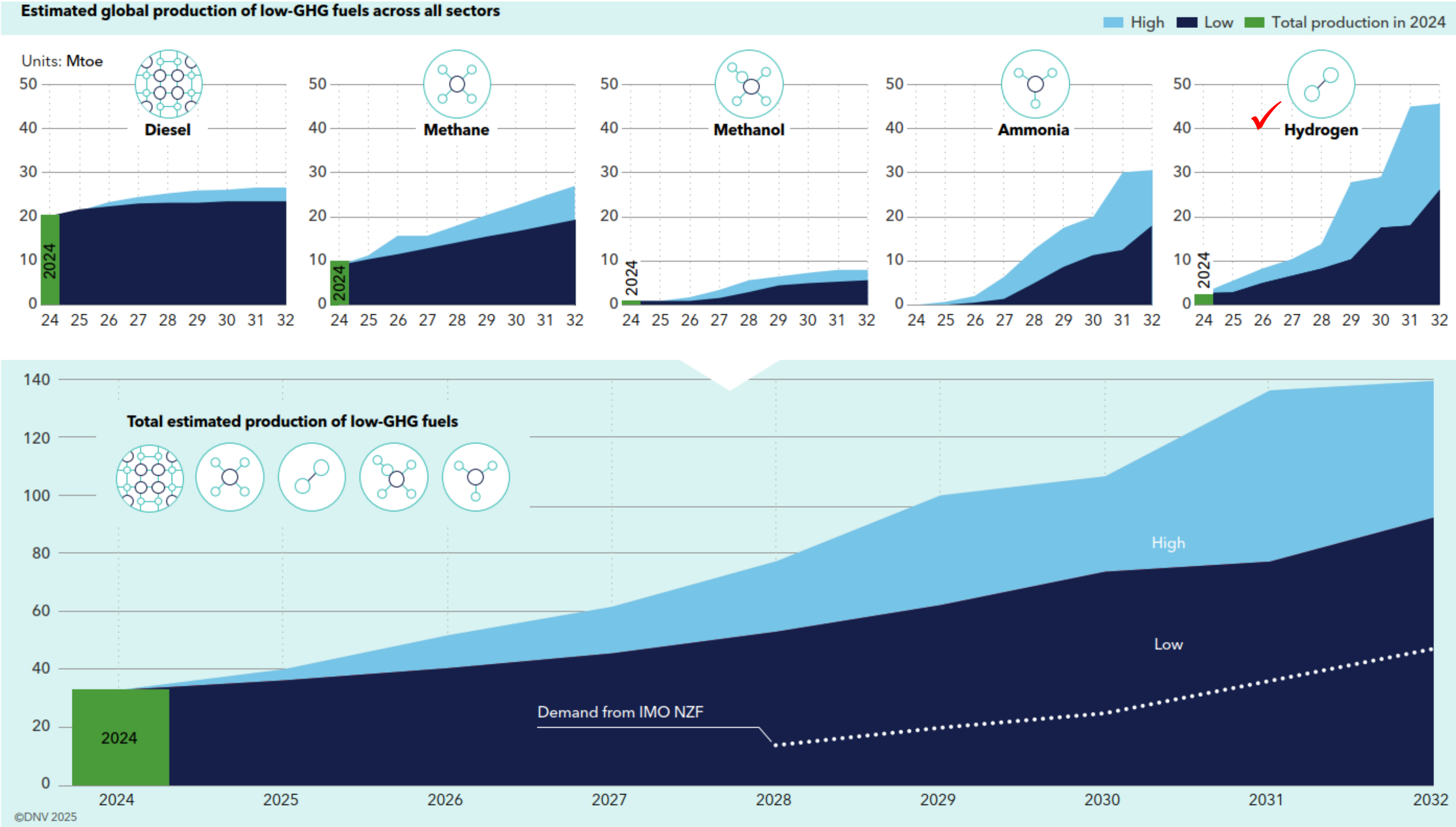
Motivation : Regulation & Fuel

Power Creator, Innovative Leader
ECO MOBILITY DYNAMICS

E-Fuel is emerging, and H2 is expected to be produced the most

“ Don’t think the IMO stops there, because we don’t. ”
- IMO Sec-Gen, A.Dominguez -





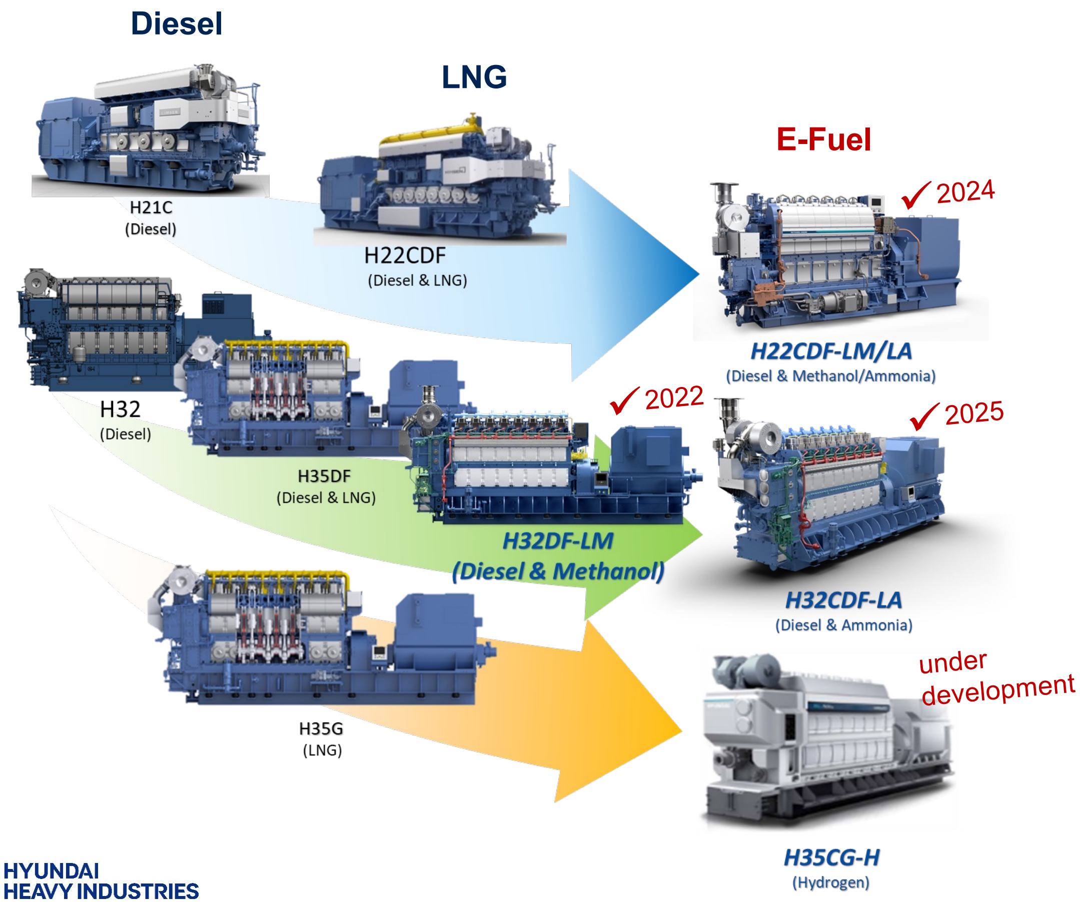
Source: DNV, Maritime Forecast to 2050, 2025

HD HYUNDAI HEAVY INDUSTRIES

Motivation : Technology

Power Creator, Innovative Leader
ECO MOBILITY DYNAMICS

E-Fuel technology is already in the market



Methanol Container ship (2024)

Ammonia Gas Carrier (2026)

HD HYUNDAI HEAVY INDUSTRIES

Questions to be investigated

Power Creator, Innovative Leader
ECO MOBILITY DYNAMICS

Can “Hydrogen” propulsion be chosen in terms of TCO for 2035 ?

Economic Viability

Can H_2 propulsion compete with fossil fuels or batteries under IMO NZF in 2035?

Technology Choice

PEMFC vs. H_2 ICE - which achieves lower Total Cost of Ownership?

Supply Impact

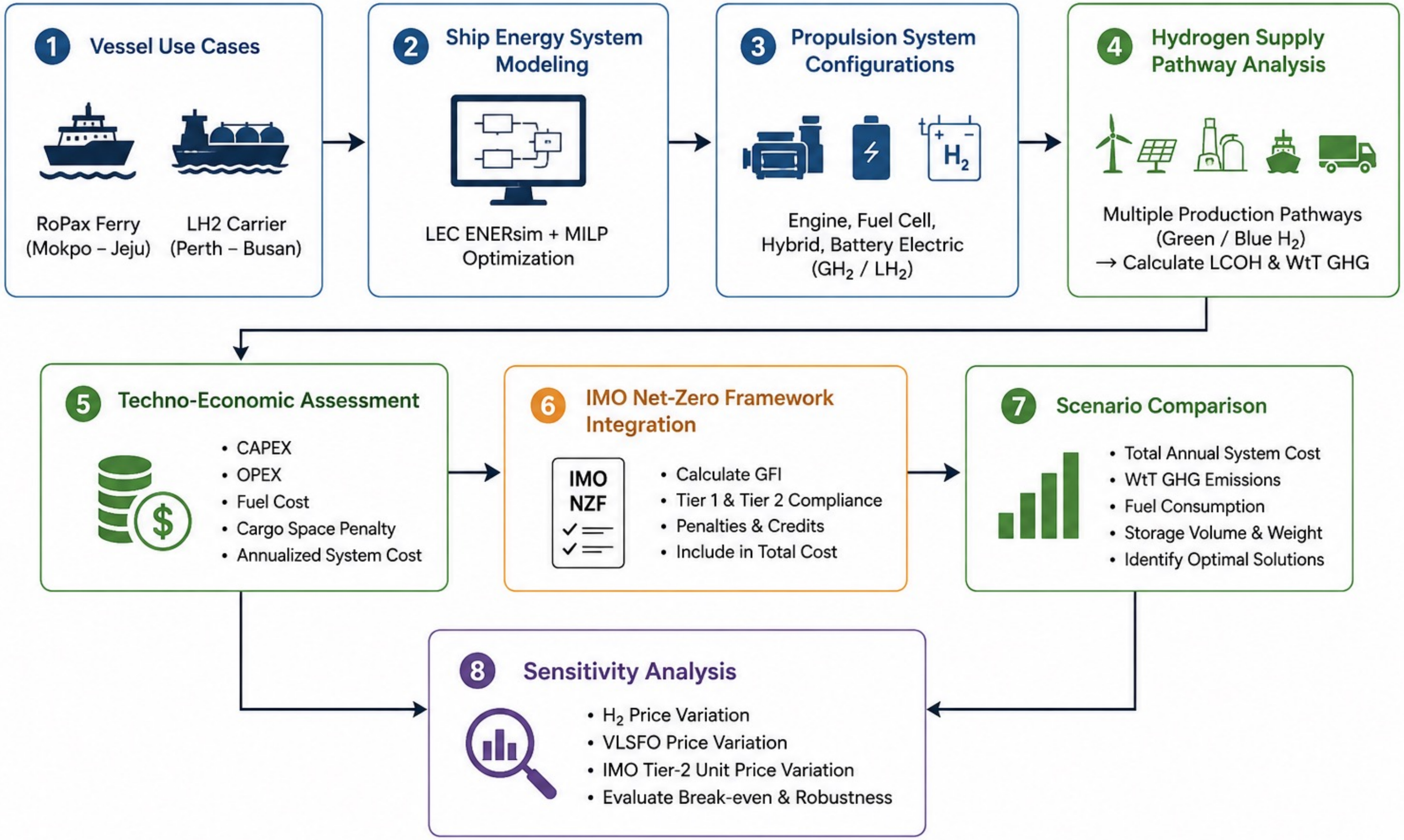
How do Green vs. Blue H_2 and import pathways affect ship economics?

Regulatory Role

How do IMO penalties and surplus credits reshape the landscape?

HD HYUNDAI HEAVY INDUSTRIES

Methodology : LCA / TEA for H2 powered vessels



Power Creator, Innovative Leader
ECO MOBILITY DYNAMICS

Assumptions : Target year 2035

1. Baseline

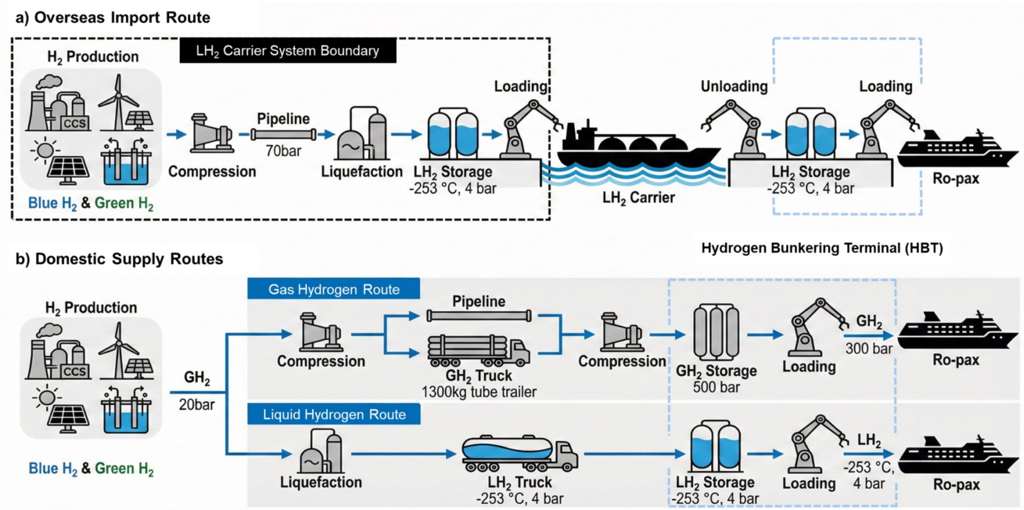
Category	Value
Discount Rate	7.5 %
Diesel Price	600 USD/ton
Hydrogen Price (Korea)	pathway-dependent
Electricity Price (Korea, Renewable)	106 USD/MWh
Battery Energy Density	230 Wh/kg
IMO Tier-1 or 2 Penalty	100 or 380 USD/tCO_2e

2. Propulsion Components

Technology	Efficiency*	CAPEX	OPEX	Lifetime
Main Engine	~50%	250-300 USD/kW	5 %/yr	25 yr
Diesel Genset	~45%	300 USD/kW	5 %/yr	25 yr
H_2 Genset	~40%	1,200 USD/kW	5 %/yr	25 yr
PEMFC	~45%	1,400 USD/kW	8 %/yr	25 yr
Battery	94%	500 USD/kWh	0.5 %/yr	10 yr
Electric Motor	96%	60 USD/kW	1 %/yr	25 yr

3. Hydrogen Pathways

Category	Options Considered
Production Method	Electrolysis (Green), SMR/ATR+CCS (Blue)
Production Region	Korea, Saudi Arabia, India, USA, Australia
Electricity Source	Grid (Gray), Renewable (Green)
Transport Method	Pipeline, GH_2 Truck, LH_2 Truck, LH_2 Carrier
End Use	RoPax Ferry, LH_2 Carrier



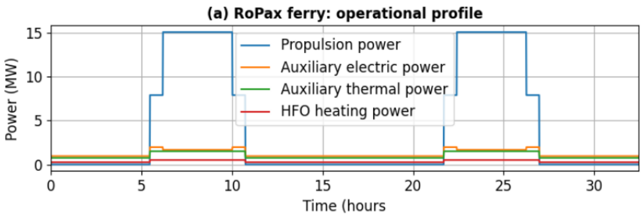
HD HYUNDAI HEAVY INDUSTRIES

Case1 : RoPax Ferry (short-sea)

Power Creator, Innovative Leader
ECO MOBILITY DYNAMICS

Vessel Specification

Case	Target
Name	Queen Jenuvia
IMO No.	9867475
Tonnage	27,391 ton
Cargo	1,284 passengers + 3,695 ton
Route (one-way)	Mokpo – Jeju (5 hr)
Speed	Max. 24 kts

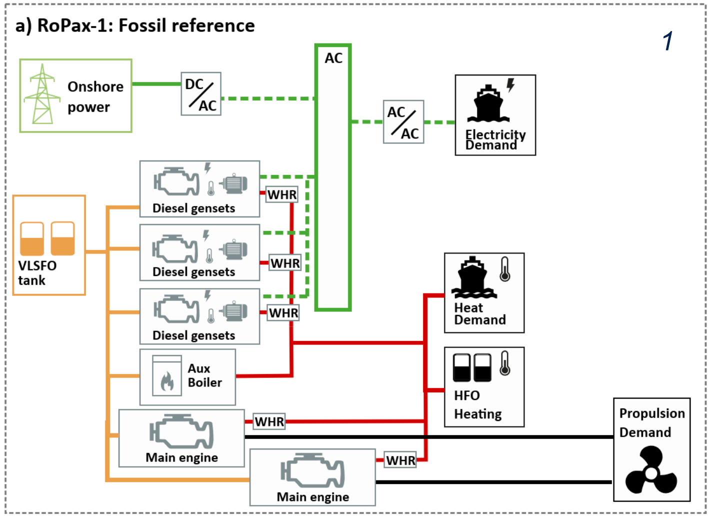


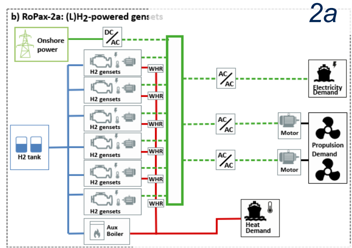
Source: Operational Management Regulation for Ro-Pax, Queen Jenuvia, Seaworld High-speed Ferry co., 2020

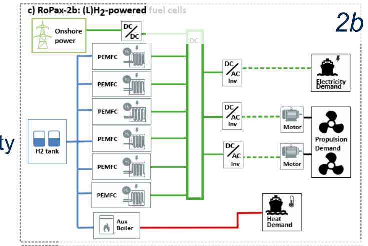
Propulsion Systems (5 Cases)

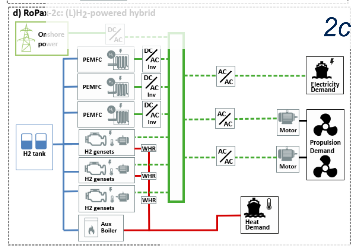
Case	Propulsion System	Fuel
1	2*Diesel ME + 3*Diesel GE	Diesel
2a	6*H2 GE (Elec.Prop.)	H2
2b	6*PEMFC (Elec.Prop.)	
2c	3*H2 GE + 3*PEMFC (Elec.Prop.)	
3a	Battery (Elec.Prop.)	RE (2 charge/day)
3b		RE (1 charge/day)

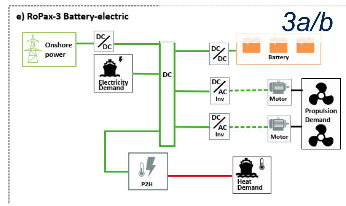
ME: Main Engine, GE: Genset Engine, PEMFC: PEM Fuel Cell, RE: Renewable Electricity











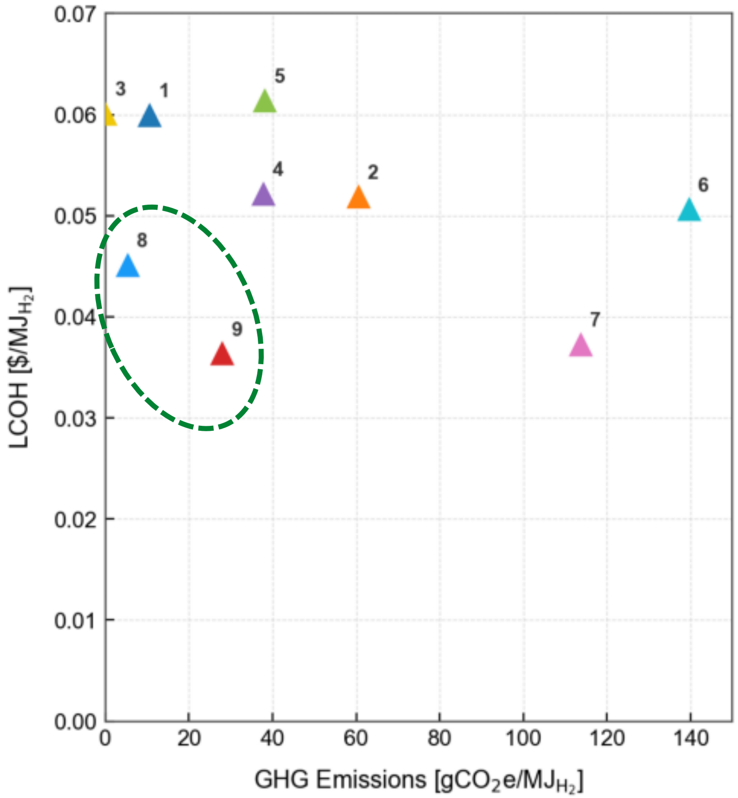
HD HYUNDAI HEAVY INDUSTRIES

Case1 : RoPax Ferry – H2 supply pathways (WtT)

Power Creator, Innovative Leader
ECO MOBILITY DYNAMICS

Imported H2 (+T&D by RE) are the most optimal (PW-8,9)

- All H2 transported & distributed through grid electricity are fail to meet GHG limit



Pathway Scenario	GHG Compliance	Reasoning / NZF Impact
Dom./Import T&D by Grid (PW-2, 6, 7)	FAIL	Grid T&D electricity mix raises WtT GHG above fossil baseline.
Most H_2 Pathways	PASS	Compliant with GFI direct targets; generates surplus Tier-2 credits.
Import T&D by RE (PW-8, 9)	OPTIMAL	Eligible for high NZF rewards, narrowing the cost gap with fossil fuels.

1. Domestic - Green - T&D(GRID) - Pipeline - GH2 loading
2. Domestic - Blue(ATR 94.5%, GRID) - T&D(GRID) - GH2 Truck 1300kg - GH2 loading
3. Domestic - Green - T&D(RE) - Pipeline - GH2 loading
4. Domestic - Blue(ATR 94.5%, RE) - T&D(RE) - GH2 Truck 1300kg - GH2 loading
5. Domestic - Blue(ATR 94.5%, RE) - T&D(RE) - LH2 Truck - LH2 loading
6. IN - Green - T&D(GRID) - LH2Carrier - LH2 loading
7. SA - Blue(SMR 90%) - T&D(GRID) - LH2Carrier - LH2 loading
8. IN - Green - T&D(RE) - LH2Carrier - LH2 loading
9. SA - Blue(ATR 94.5%, RE) - T&D(RE) - LH2Carrier - LH2 loading

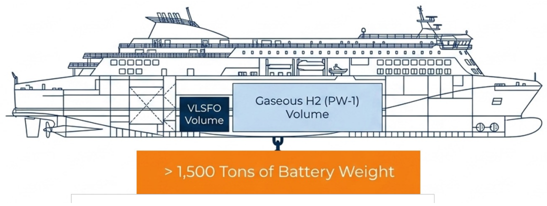
HD HYUNDAI HEAVY INDUSTRIES

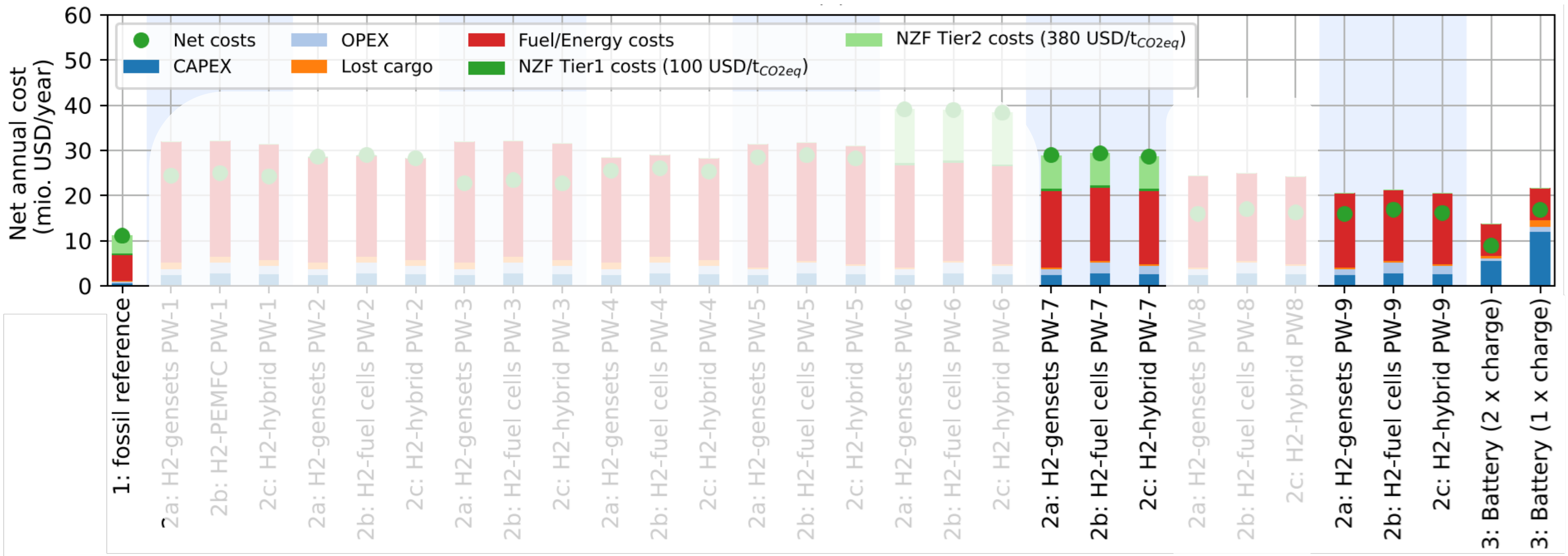
Case1 : RoPax Ferry – Annual Cost Comparison

Power Creator, Innovative Leader
ECO MOBILITY DYNAMICS

Fuel cost dominates economics (Fuel >> NZF penalty > CAPEX/OPEX)

- Battery & Diesel are economic (but, battery sacrifices ~20% of payloads in weight)
- In case of H2, fuel pathway is dominant, and technology becomes minor
- H2 becomes economic if fuel cost 25%↓, and battery loses economic if NZF penalty is decreased to 200 USD/tCO2eq.



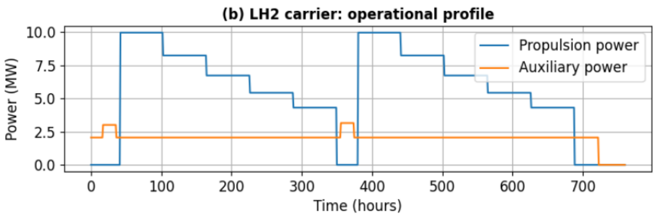


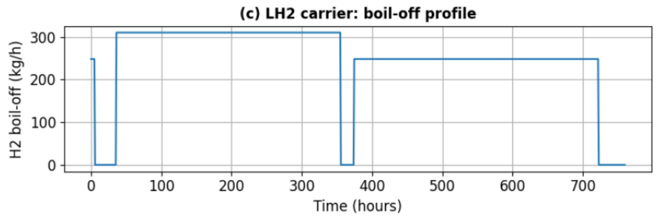
HD HYUNDAI HEAVY INDUSTRIES

Case2 : LH2 Carrier (ocean-going)

Vessel Specification

Case	Target
Cargo	80000 m³ (LH2 Refrig.)
BOG	~0.26 %/day
Route (one-way)	AUS–KOR (13.5 days)
Speed	15 kts

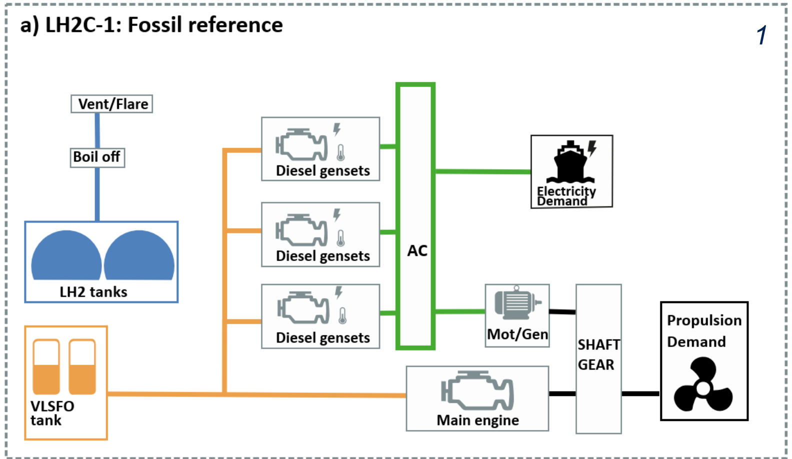




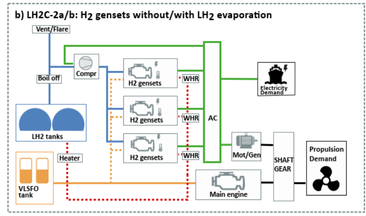
Propulsion Systems (5 Cases)

Case	Propulsion System	Fuel
1	1*Diesel ME+ 3*Diesel GE	Diesel
2a	1*Diesel ME + 3*H2 GE	Diesel + H2 (BOG only)
2b		Diesel + H2 (BOG&Evap.)
3a	4*H2 GE (Elec.Prop.)	Diesel + H2 (BOG only)
3b		H2 (BOG&Evap.)
3c	2*H2 GE + 2*PEMFC (Elec.Prop.)	H2 (BOG&Evap.)

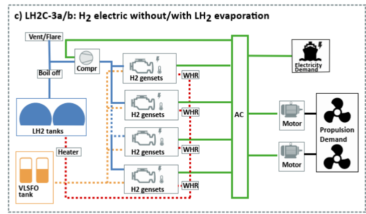
ME: Main Engine, GE: Genset Engine, PEMFC: PEM Fuel Cell (H2)



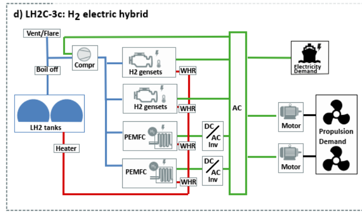
2a/b



3a/b



3c

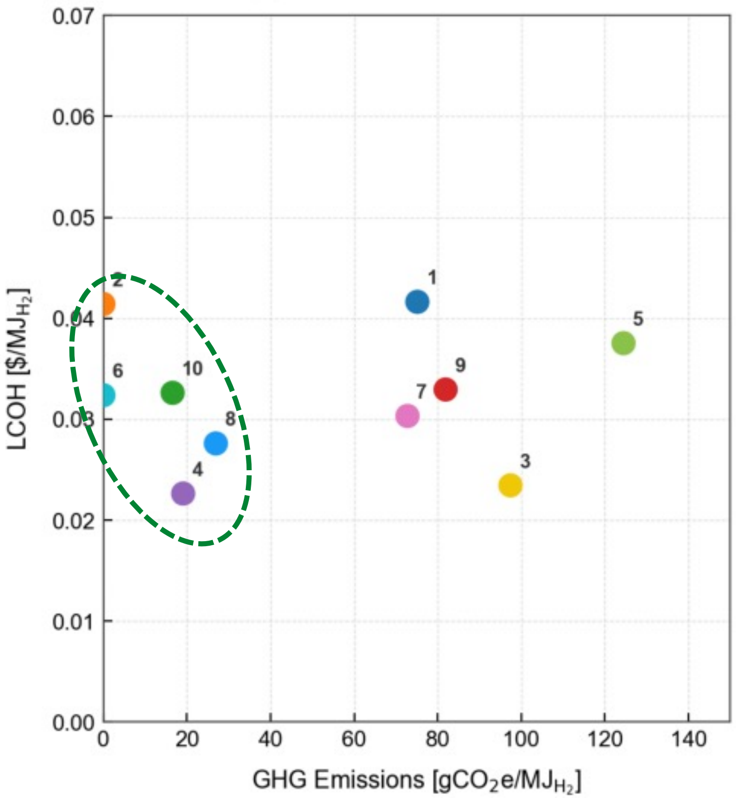


Case2 : LH2 Carrier – H2 supply pathways (WtT)

Power Creator, Innovative Leader
ECO MOBILITY DYNAMICS

Imported H2 (+T&D by RE) are the most optimal (PW-2,4,6,8,10)

- All H2 transported & distributed through grid electricity are fail to meet GHG limit



Pathway Scenario	GHG Compliance	Reasoning / NZF Impact
T&D by Grid (PW-1,3,5,7,9)	FAIL	Grid T&D electricity mix raises WtT GHG above fossil baseline.
T&D by RE (PW-2,4,6,8,10)	Pass	Eligible for high NZF rewards, narrowing the cost gap with fossil fuels.

1. SA - Green - T&D(GRID) - LH2Carrier - LH2 loading
2. SA - Green - T&D(RE) - LH2Carrier - LH2 loading
3. SA - Blue(SMR 90%) - T&D(GRID) - LH2Carrier - LH2 loading
4. SA - Blue(ATR 94.5%, RE) - T&D(RE) - LH2Carrier - LH2 loading
5. IN - Green - T&D(GRID) - LH2Carrier - LH2 loading
6. IN - Green - T&D(RE) - LH2Carrier - LH2 loading
7. US - Blue(SMR 90%) - T&D(GRID) - LH2Carrier - LH2 loading
8. US - Blue(ATR 94.5%, RE) - T&D(RE) - LH2Carrier - LH2 loading
9. AU - Blue(SMR 90%) - T&D(GRID) - LH2Carrier - LH2 loading
10. AU - Blue(ATR 94.5%, RE) - T&D(RE) - LH2Carrier - LH2 loading

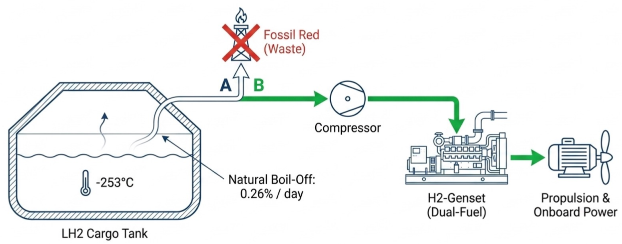
HD HYUNDAI HEAVY INDUSTRIES

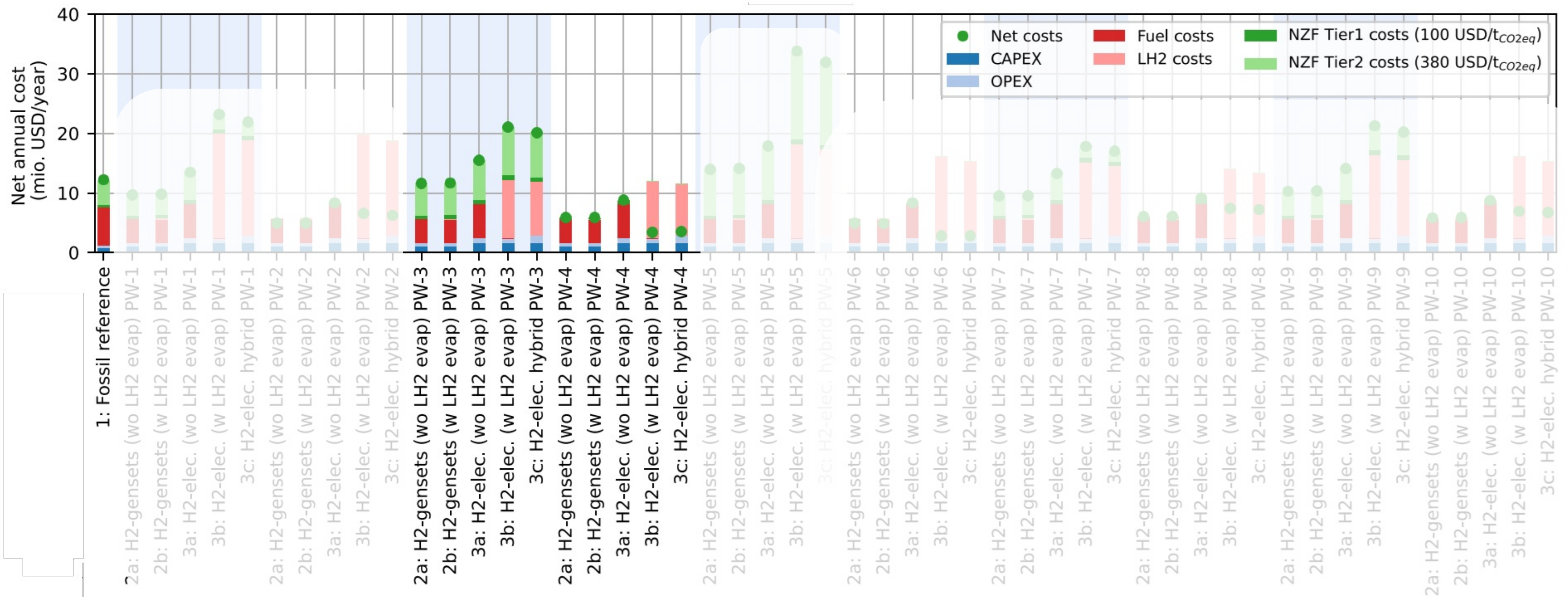
Case2 : LH2 Carrier– Annual Cost Comparison

Power Creator, Innovative Leader
ECO MOBILITY DYNAMICS

H2 BOG used as a fuel is always beneficial

- H2 becomes more economic if diesel usage is minimized
- In case of H2, fuel pathway is dominant, and technology becomes minor
- NZF penalty should be under consideration as it determines the diesel fuel ratio

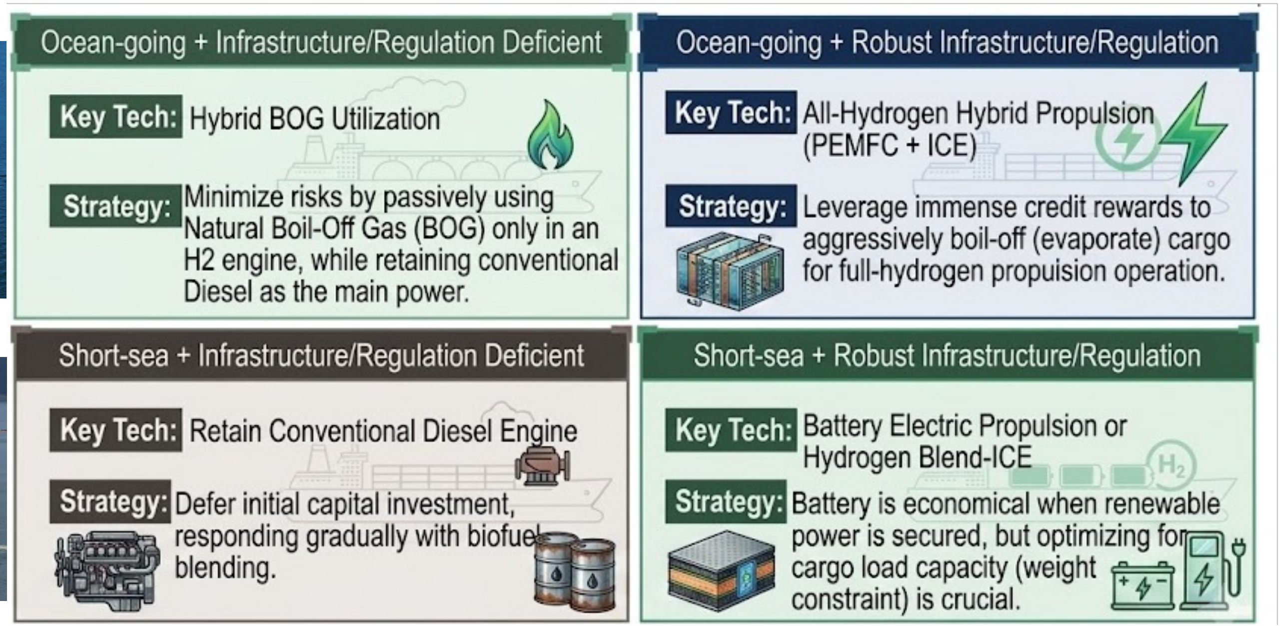




Summary & Conclusion

Technology is ready, but Fuel pathway & Policy should be clear

- Hydrogen economy is very sensitive to fuel pathway and policy rather than technology
- There is no best technology for all vessel. It will be diversified for individual vessels.



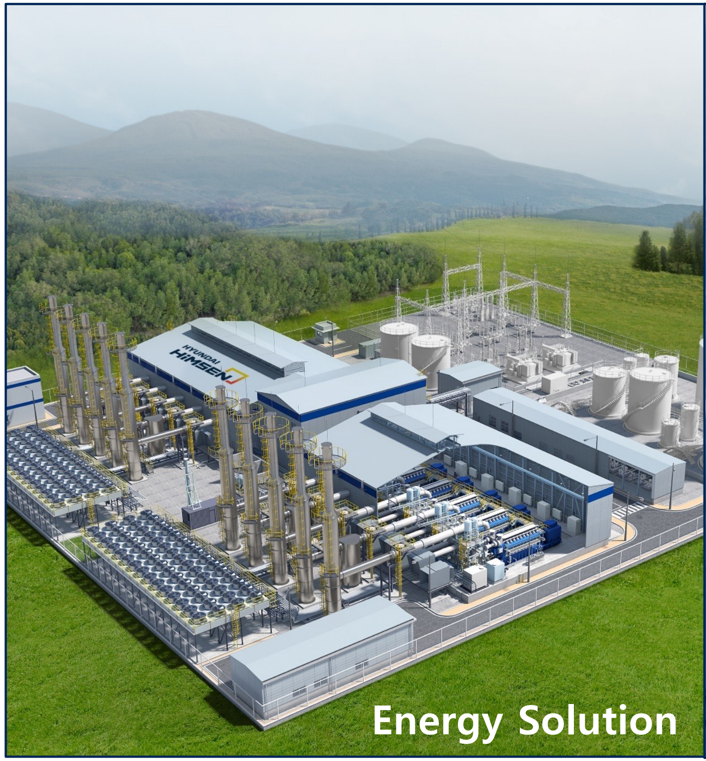
Optimization can be done through LCA / TEA - Cooperation is essential !

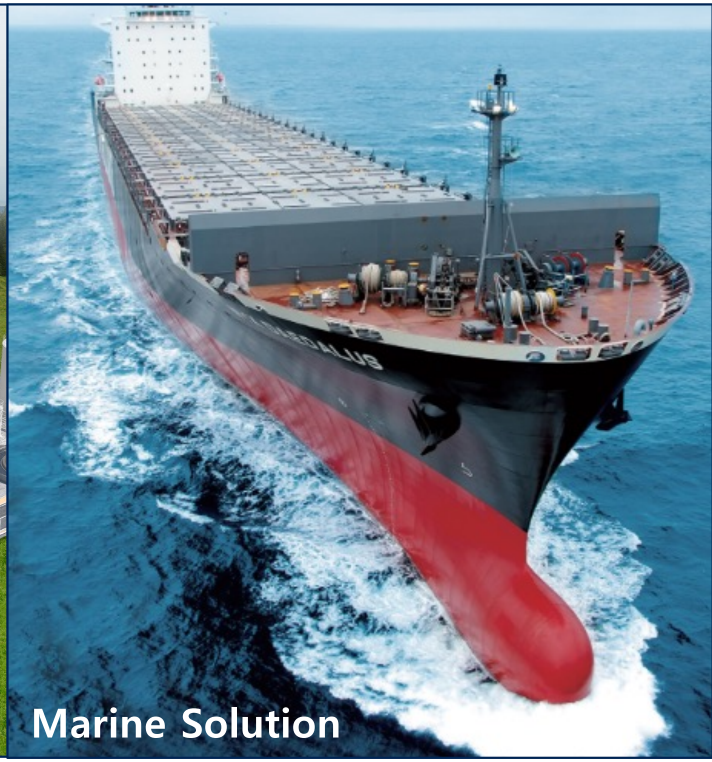
Acknowledgement

This research was financially supported by
the Ministry of Trade, Industry, and Resources (MOTIR), Korea,
under the “Global Industrial Technology Cooperation Center(GITCC) program” supervised by
the Korea Institute for Advancement of Technology (KIAT). (Task No. P0028457)

This presentation is the short version of the original paper under submission for review :
Berhard et al., “Evaluation of Hydrogen-based Ship Propulsion for Short- and Deep-sea Shipping in Light of Future Regulatory Environments”, Applied Energy, 2026

THANK YOU FOR YOUR ATTENTION!





c.50 AD	Hero's Engine (Wood)
1769	James Watt's Steam Engine (Coal)
1877	Nicolaus Otto's Engine (Gasoline, Natural Gas)
1892	Rudolf Diesel's Engine (Diesel)
2022	**HD HHI's HiMSEN MeOH Engine**
2024	**HD HHI's HiMSEN NH_3 Engine**
202X	**HD HHI's HiMSEN H_2 Engine**

HD HYUNDAI HEAVY INDUSTRIES

Power Creator, Innovative Leader
ECO MOBILITY DYNAMICS