HD HYUNDAI EUROPE R&D CENTER

HD Hyundai Europe R&D Center and SOFC Development in HD Hyundai



HD Hyundai Europe R&D Center

Mission Statement

We drive **groundbreaking**, **result-driven research** by fostering **collaboration across multi-disciplinary partners**.

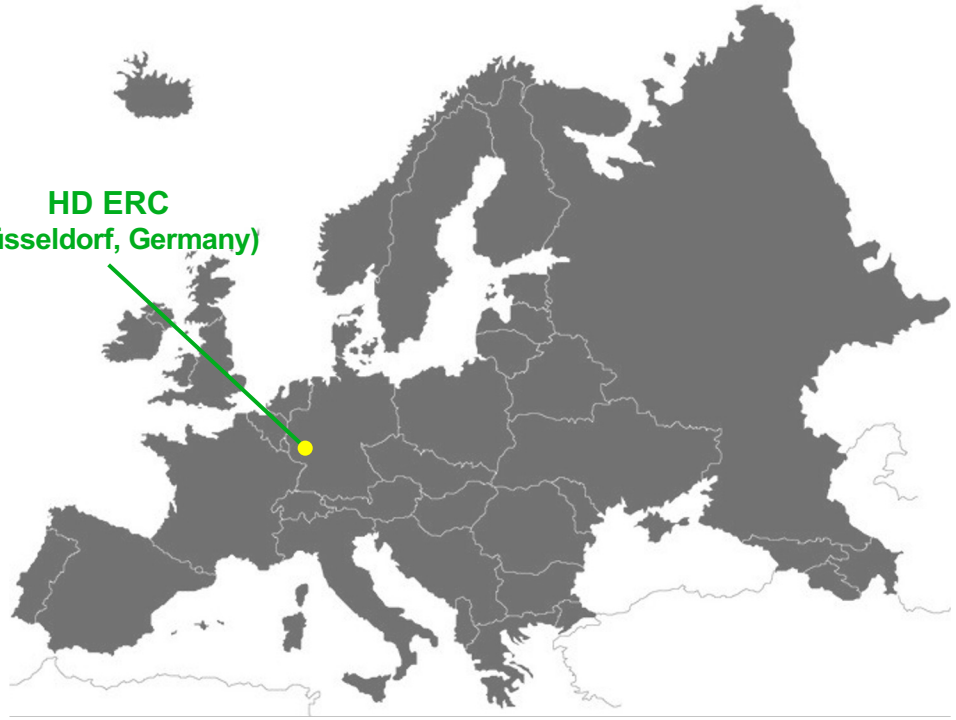
We aim to deliver fast development and transformation, working closely with our customers while staying at the forefront of innovation through continuous updates to our methodologies.

Europe Research & Development Center (ERC)

Newly established R&D Center in Germany

Corporation	HD Hyundai Europe Research & Develop Center GmbH
Managing Director	Dr. Kwang-Pil Chang (CTO of HD KSOE)
Location	Peter-Müller-Straße 14, Düsseldorf, Germany
Date of incorporation	22th of Mar. 2023
Business Sector	Co-development of R&D projects

※Parent Company: HD Korea Shipbuilding & Offshore Engineering Co., Ltd. (HD KSOE)



Press release

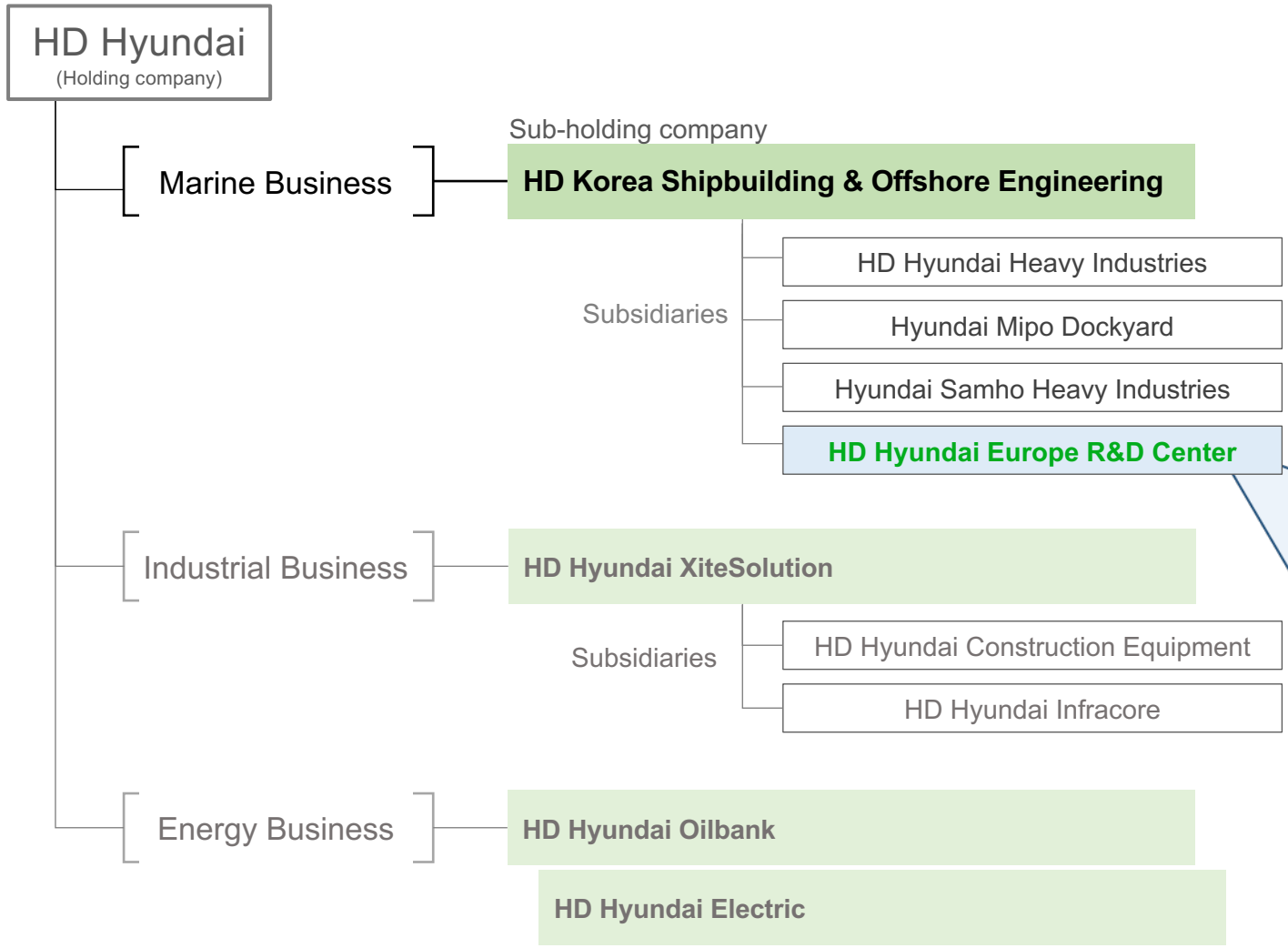
HD Korea Shipbuilding to invest 15 mln euros in Europe

All News · 11:18 April 28, 2023

SEOUL, April 28 (Yonhap) — Major South Korean shipyard HD Korea Shipbuilding & Offshore Engineering Co. said Friday it will expand its research and development (R&D) spending in Europe to secure future shipbuilding and maritime technologies.

To that end, HD Korea Shipbuilding will spend 15 million euros (US$16.5 million) on its European research institute in Dusseldorf, Germany, and other R&D projects, including one for onboard carbon dioxide (CO2) capture and storage (OCCS), over the next five years.

HD Hyundai Overview and HD ERC



R&D Division

- Green Energy Technology Lab.
- Decarbonization Ship Research Lab
- Digital Technology Lab.
- Manufacturing Innovation Lab.
- Maritime & Engine Lab..

abt. 600 Researchers

€ 115 mil. R&D Budget (annually)

Europe R&D Center's Role

- Co-development R&D project
- Participation in EU R&D Program
- Technology promotion to client
- Global R&D platform of HD Hyundai Group

ERC R&D interests

Electric Power Technology

- Power Control Solution
- Hybrid Propulsion System
- Electric Power Propulsion
- System Integration



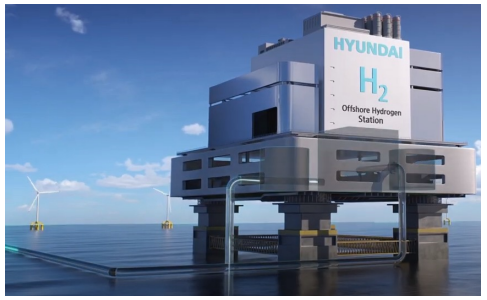
Carbon Neutral Technology

- Green Fuel Technology
  - Electrolysis
  - Methanol Synthesis
- Catalyst Technology
- CCUS
  - Onboard-CCS
  - Direct Air Capture (DAC)



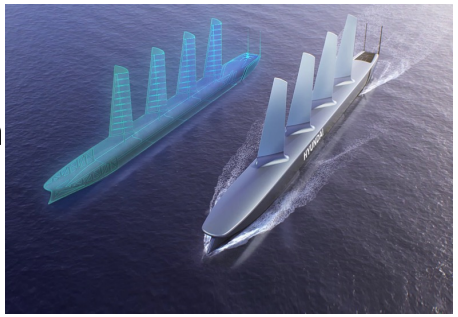
Hydrogen Value Chain

- Floating Wind Turbine
- Floating H_2 Production Platform
- LH_2 Storage system
- Hydrogen Carrier/Fueled Vessel



AI & Data technology

- Machinery Automation
- Long-distance Big data transmission
- Real-time Remote Control
- Sensor Fusion based Perception



ERC focuses on decarbonizing / digital technologies for the future

R&D Collaboration Project 2024

HD Hyundai Funding projects

1) Advanced future energy/system mix model
   - Advanced Modelling

SINTEF

2) High-efficient MVDC power distribution
   - Electric Propulsion

RWTH AACHEN UNIVERSITY

3) MMC VFD commercialization
   - Electric Propulsion

KIT Karlsruher Institut für Technologie

4) Co-SOEC based e-methanol production
   - e-Fuel

AVL

5) Safety of Ammonia Propulsion System
   - Green fuel

NTNU

Europe funding projects

1) Hydrogen release experiment
   : German Funding
   7+ Consortium members

DLR, RINA, BAM, Dräger, Air Liquide

2) reSail project
   : Norwegian Funding
   consortium in progress

SINTEF

3) EMSA project
   : EU funding
   consortium in progress

RINA

4) OptiStress project
   : Norwegian Funding
   5+ Consortium members

SINTEF, norwegian electric systems, HAV design

5) ECO2FleeT project
   : Horizon Europe
   consortium in progress

SINTEF, VARD a Fincantieri company, LR, THENAMARIS

ERC's Other Activities

Technology Scouting & Partnering

- Conferences & Trade Fairs
- Networking Events
- Visiting of Companies and Institutes
- Industrial Working Groups
- Investment to Start-up & Venture



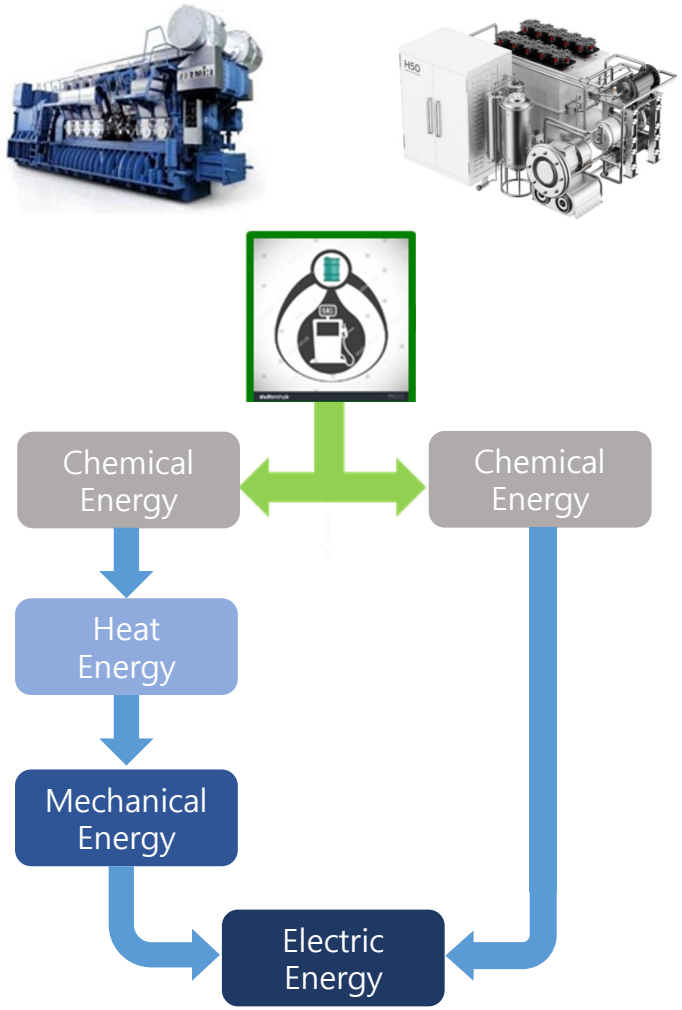
Recruiting

- Campus Recruiting
- Co-R&D Project with University
- Scholarship Program
- Summer Job & Internship Program
- Co-Recruiting with HD KSOE



SOFC Development in HD Hyundai

In theory



Type	Electrolyte	Anode	Charge Carrier	Cathode	Temperature
PEMFC	Polymeric Membrane	H_2 →	H^+ →	← O_2, → H_2O	80
PAFC	Phosphoric Acid	H_2 →	H^+ →	← O_2, → H_2O	100 - 250
MCFC	Molten Carbonate	H_2 →, H_2O ←, CO_2 ←	← CO_3^{2-}	← O_2, ← CO_2	600 - 650
SOFC	Solid Oxide	H_2 →, H_2O ←	← O^{2-}	← O_2	700 - 1000

LT

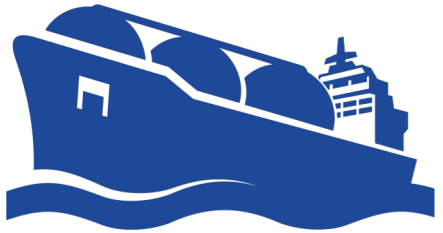
HT

Fuel

Air

Key enabling technology for hydrogen value chain





Fuel Cell

Electrolysis Cell





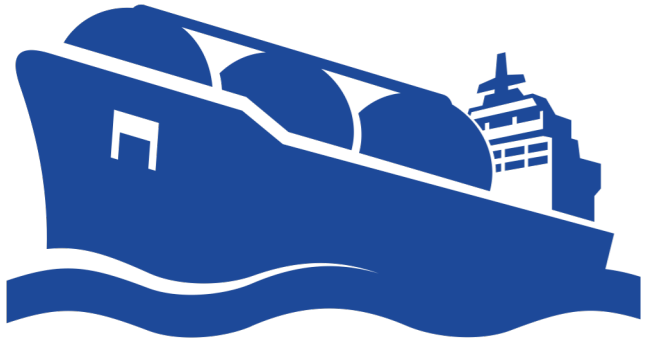
Why SOFC?

Fuel Flexibility

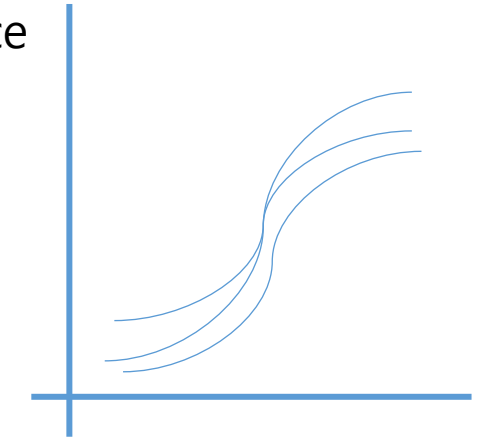
- LSFO / MGO
- X-LNG
- H2
- NH3
- X-Methanol

Enhanced operation

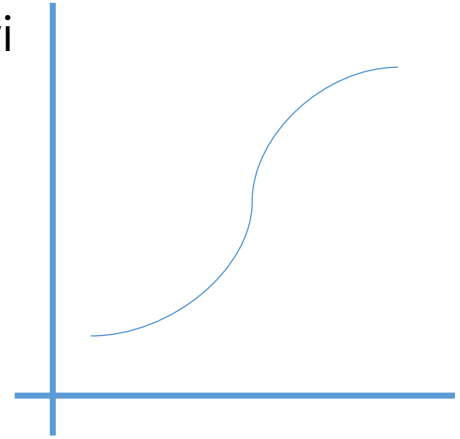
- Reduced Manning
- Autonomous
- Increased Efficiency



Fuel Price

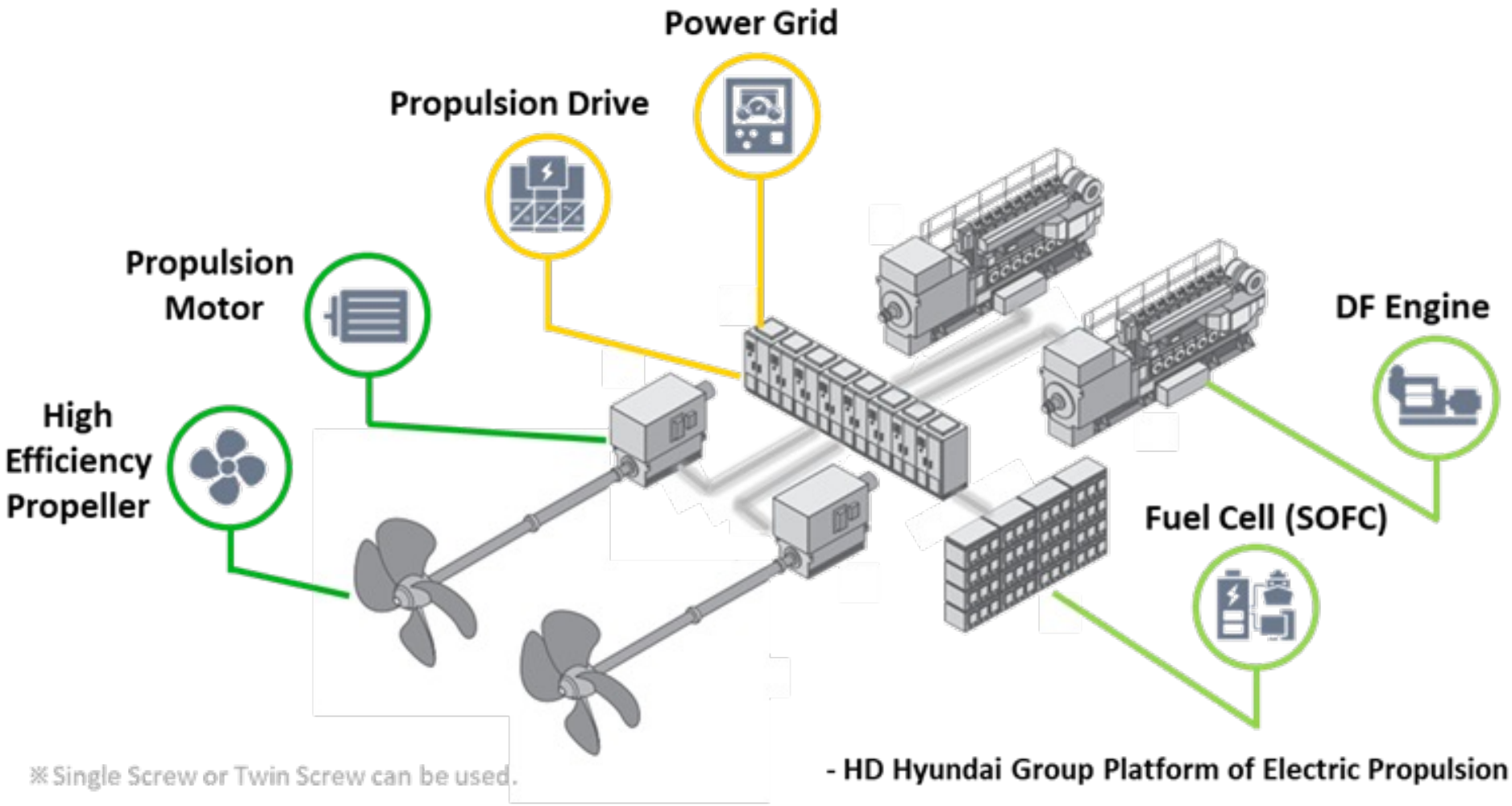


Carbon Levi



SOFC can achieve lower TCO, fuel flexibility and increased autonomy for maritime application

SOFC and Electrification of Large Commercial Vessels



- HD Hyundai Group Platform of Electric Propulsion Solution -

Simple case study - VLCC

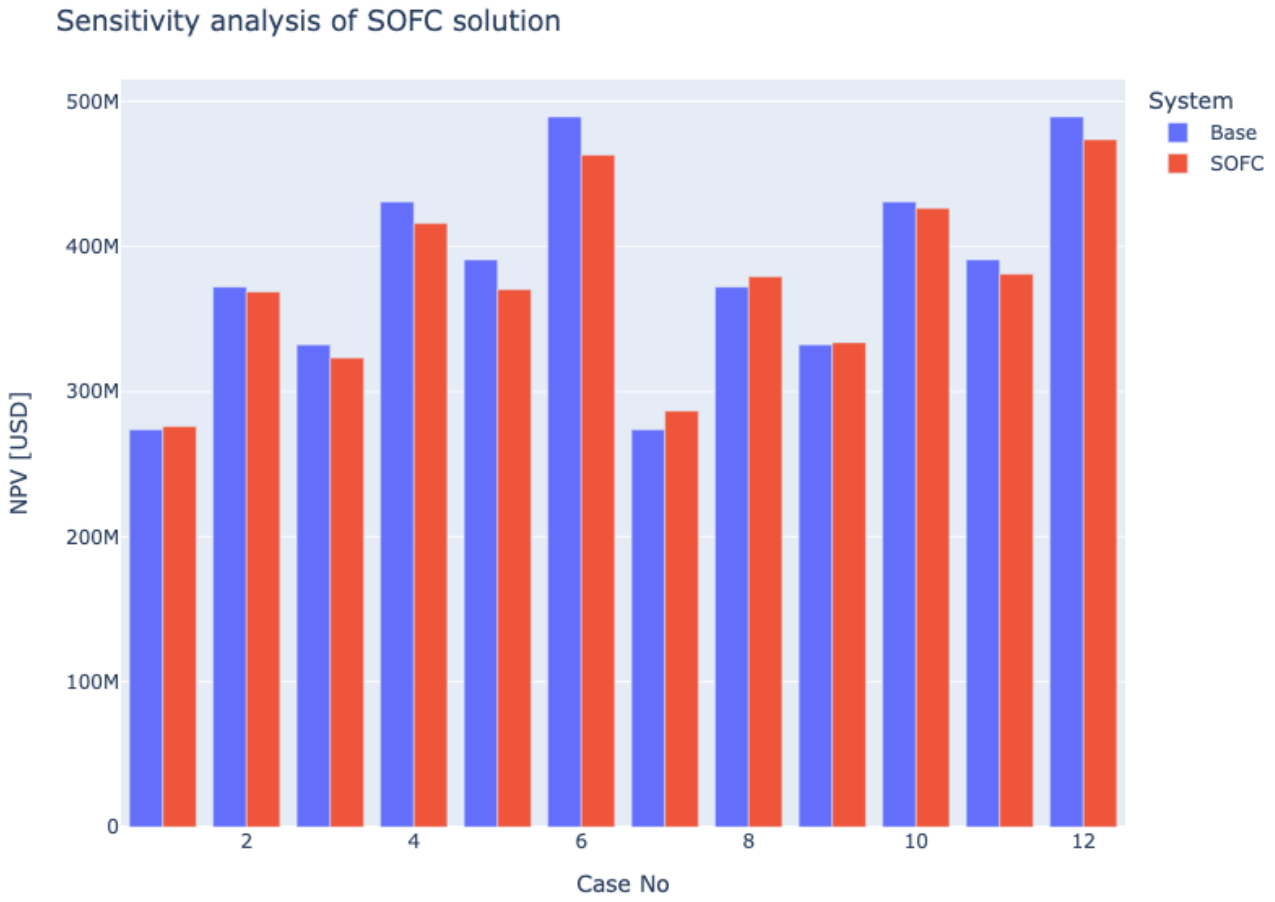
Assumption
- Annual Energy Requirement: 247 TJ
- Fuel cell efficiency: 60%
- Wake to genset / SOFC efficiency: 93%
- Main engine efficiency: 51%
- Aux engine efficiency: 30 ~ 39%
- Average power split (SOFC : Gensets): 7 : 3
- Fuel: LNG(main), MGO(pilot)
- LHV value, GHG factor: FuelEU Maritime
- No methane slip for fuel cell

Conventional system – 2 stroke engine + 3 Gensets
- Annual fuel consumption: 528 TJ
- Annual GHG emission: 44146 ton
- System efficiency: 46.8%

SFOC Hybrid – SOFCs + Gensets + Battery
- Annual fuel consumption: 513 TJ (2.9% saving)
- Annual GHG emission: 41537 ton (5.9% saving)
- System efficiency: 48.2% (1.4% gain)
  => 5-7% additional improvement possible

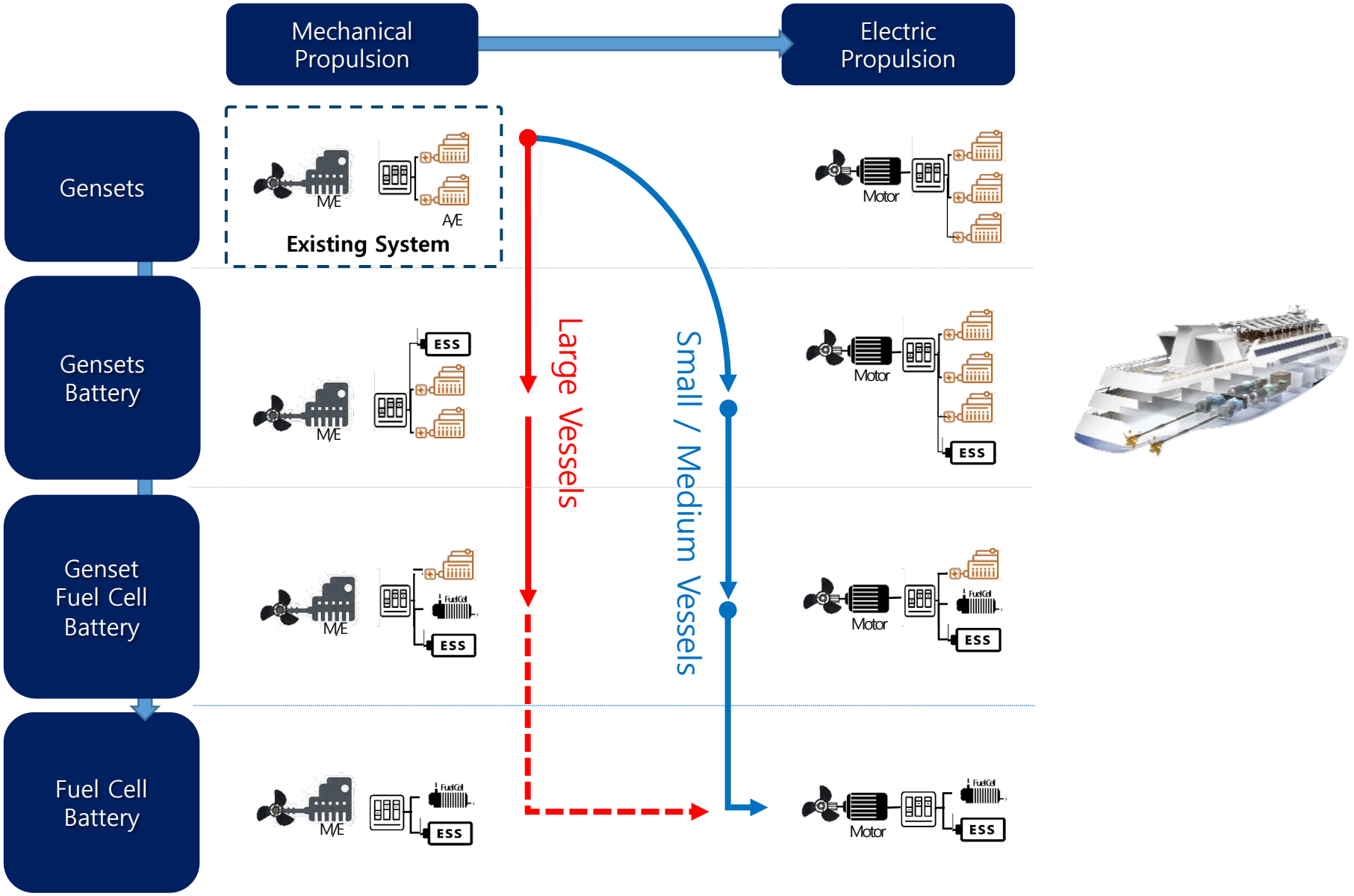
Simple case study - VLCC

Annual Energy Requirement: 247 TJ
Ship cost without machinery: 120mUSD
Discount rate: 7.5%
Engine price: 700 (M/E), 400 (A/E) USD/kW
Battery: 1000 USD/kWh



Case	Fuel cell price [US$/kW]	Fuel price [US$/GJ]	CO2 Levy [US$/ton]	%TCO
1	2000	15	100	100.9
2	2000	15	300	99.1
3	2000	25	100	97.3
4	2000	25	300	96.6
5	2000	35	100	94.8
6	2000	35	300	94.6
7	3000	15	100	104.7
8	3000	15	300	101.9
9	3000	25	100	100.5
10	3000	25	300	99.0
11	3000	35	100	97.5
12	3000	35	300	96.8

Various pathways



Collaboration

- **50kW SOFC Module Development**

HD KOREA SHIPBUILDING & OFFSHORE ENGINEERING

- Packaging / a large power platform
- Maritime application
- Stationay power plant application

Fraunhofer IKTS

- Collaboration on the development of the module
- Large stack and BOP core

SOFC

Fuel cell technology elcogen

- Stack provider, technology support
- Collaboration for domestic production
- Investment Agreement (30m€)





It will be a rough road



Conclusion

- HD ERC aims “open innovation” to solve global challenges in decarbonization and digitalization of heavy industries with European partners.
- SOFC technology with electrification for large commercial vessels will enhance the system efficiency while providing fuel flexibility and reduced manning.
- Our hybrid SOFC solution has a potential to lower TCO than conventional system for the large ocean-going vessels.

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