Fuel Cell Solutions: Hydrogen, Alternative Fuels and CCS

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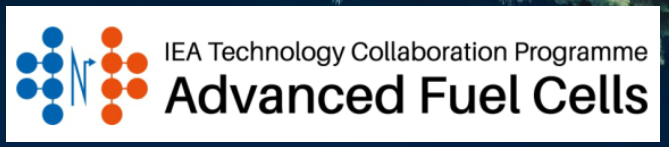


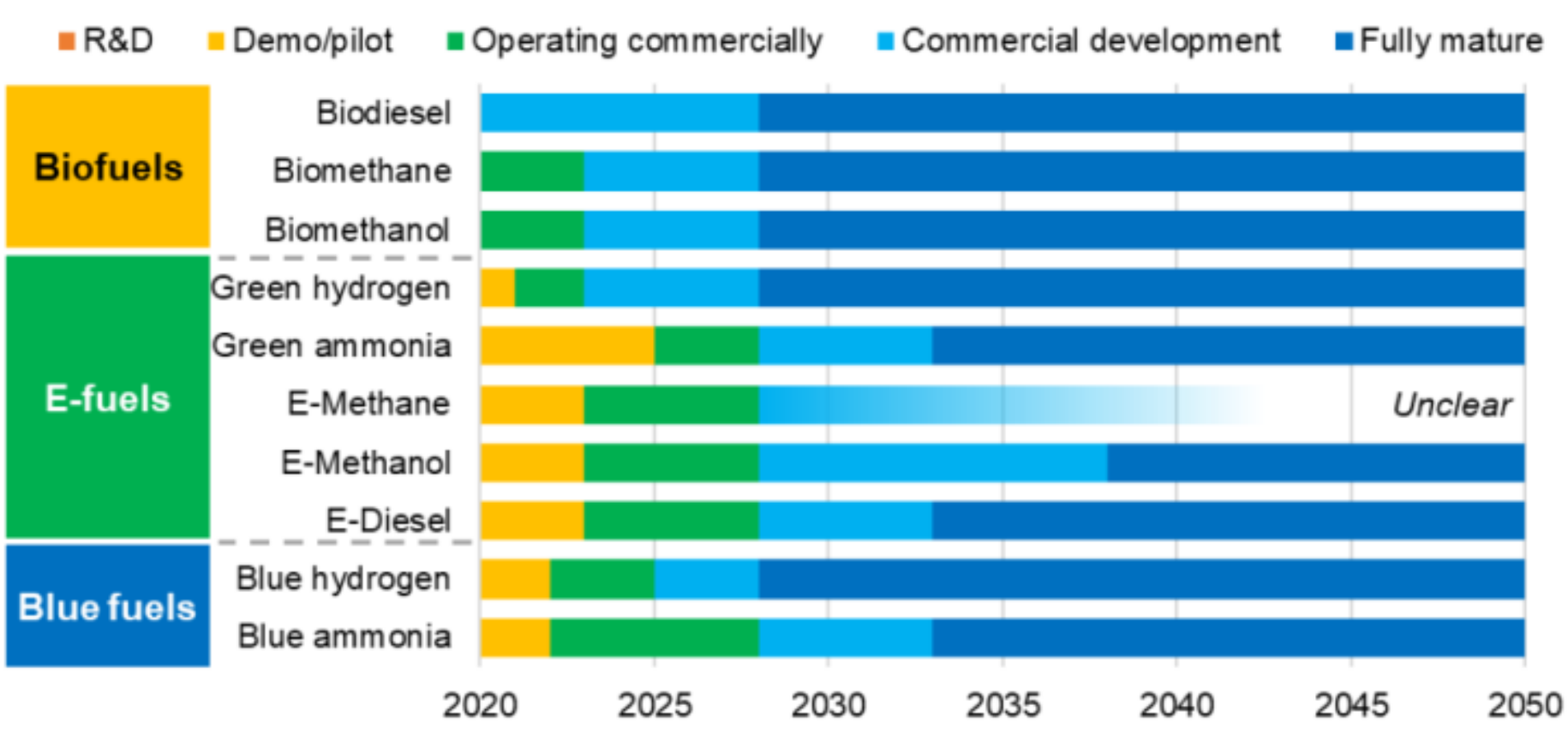
Fuel Cell Applications for Maritime Sector

RINA View

Decarbonization Mission

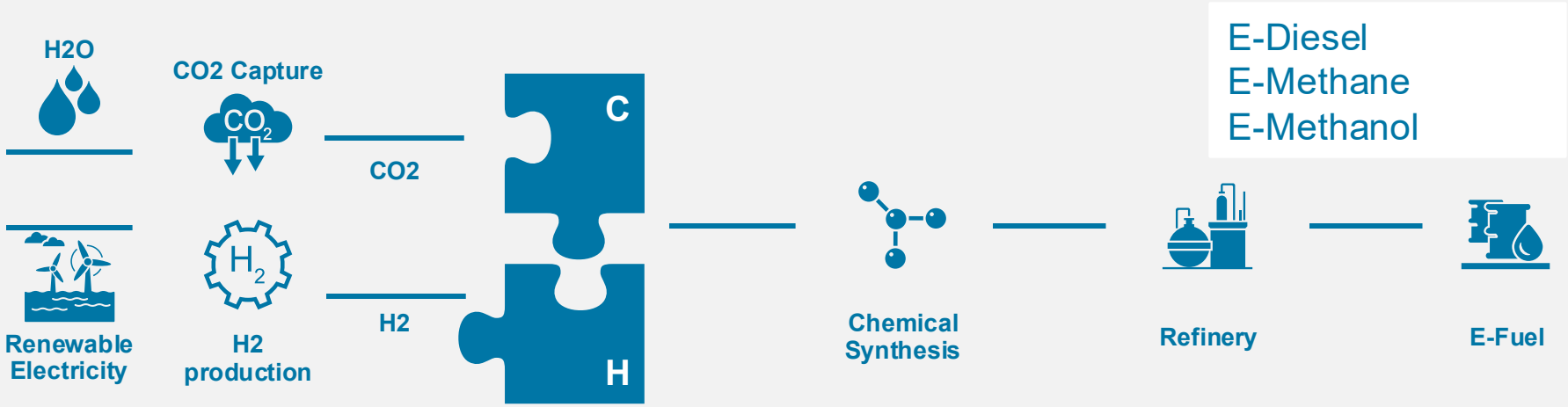
Awareness of **alternative fuels** and **novel technology** is crucial in the shipping industry and understanding the benefits and drawbacks of such fuels is equally important. **RINA supports** shipowners and other industry players to make informed decisions and achieve their goals through its expert know-how in **green fuels** -hydrogen, electrification (**battery**, DC grid, shore power, **fuel cell**), novel **energy efficiency solutions** (Wind, Air Lubricating, Coating, waste heat recovery, propeller/rudder optimization) and CO2 abatement systems (**Carbon Capture**)

Forecast of Alternative Fuels Availability



CO_2 for E-Fuel Synthesis

POWERFUELS - ELECTRO-FUELS (E-FUELS) - SYNTHETIC FUELS (SYNFUELS) - RFNBO (RENEWABLE FUELS OF NON-BIOLOGICAL ORIGIN): gaseous or liquid NON-BIO fuels that draw their energy content from renewable electricity and are obtained through a synthetic process.

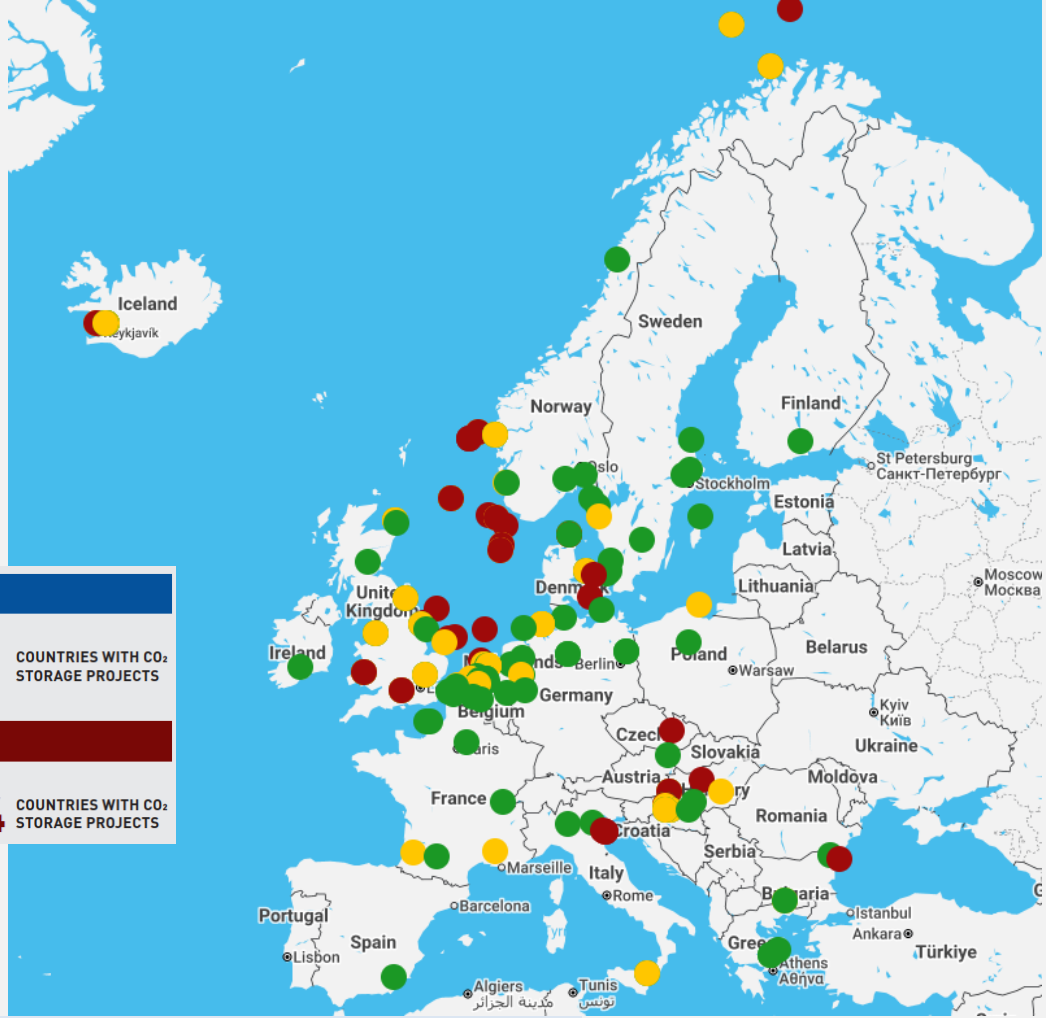


CCUS – Europe

Project type
Capture
Storage
Transport

European Union			
0,67 Mt CO_2 / YEAR IN OPERATION 0,025 ELIGIBLE UNDER NZIA	2,9 Mt CO_2 / YEAR IN FID	24 CO_2 STORAGE PROJECTS	11 COUNTRIES WITH CO_2 STORAGE PROJECTS

Europe			
3,96 Mt CO_2 / YEAR IN OPERATION	14,9 Mt CO_2 / YEAR IN FID	53 CO_2 STORAGE PROJECTS	14 COUNTRIES WITH CO_2 STORAGE PROJECTS



International Association of Oil & Gas Producers

Source: www. iogpeurope.org/european-ccs-projects-map/

CO_2 Post Combustion Capture BAM Project

Retrofit Project on ships:

- BAM Despina Bulk Carrier
- BAM Proteus General Cargo
- BAM Triton Bulk Carrier
- BAM Arion Bulk Carrier

Langh Tech's onboard carbon capture system uses a post-combustion technique. In short, the ship's exhaust gases containing CO2 are directed into a capture unit. CO2 dissolves into the liquid phase through a counter-currently flowing aqueous NaOH solution. A maximized surface area ensures *"the highest possible"* carbon capture rates. As a result of several consecutive reactions, CO2 is chemically bound into a thermodynamically stable product of sodium carbonate.

A REAL CASE STUDY

GAMMA Research Project

A REAL CASE STUDY

TOPIC Fleet

60,000 tonnes dead weight.
That is how much cargo the bulk carrier from TOPIC Fleet which is used as the case study in the new EU project GAMMA, can carry across the world's oceans.

UNIQUE TECHNOLGIES

Ammonia and green methanol will be bunkered on-to the ship and then converted into hydrogen with cracker and reformer technologies. The hydrogen will be purified and then converted into electricity with a fuel cell, which will be providing electric energy to the vessel and thus replacing the use of the auxiliary generators running on fossil fuel.

The energy to convert to hydrogen will be supplied by PV panels.

Co-funded by the European Union

Approval in Principle for Fuel Cell Power Module

RINA

CERTIFICATE OF APPROVAL IN PRINCIPLE

PemGen 3.0 Fuel Cell Power System

AiP- MAC337724XG

This is to declare that the Approval in Principle (AiP) of the following design concept:

Concept:	**Fuel Cell Power System**
Applicant:	**Carbon Technology Energies Bv** **Zandbergweg 167** **4818 LL** **Breda, The Netherlands**
Description:	**Fuel Cell Power System with an Electrical DC output of 700kW (Nominal)**

Has been carried out in compliance with the process described in the "RINA Guide for Approval in Principle Processes" (2014), on the basis of the below listed technical criteria.

RINA Rules	**RINA Rules, Pt C, Ch 2, App 3 (Fuel Cell Powered Ships)** **RINA Rules for the Type Approval of Fuel Cell Power Modules – NCC96**
IMO interim Guidelines	**MSC.1/Circ.1647 – Interim Guidelines for the Safety of Ships Using Fuel Cell Power Installations**

Issued in **HAMBURG** on **May 26, 2025**

RINA Services S.p.A.

Murat Kurt, Patrizio Di Francesco

RINA

CERTIFICATE OF APPROVAL IN PRINCIPLE

PemGen 3.0 Fuel Cell Power System

AiP- MAC337724XG

Annex 1 [Page 1/1]

The following submitted documentation, provided by the Client allowed the Approval in Principle Certificate issuance:

- FSM_ASM Piping classification_R01
- P24001-DSP-006-R01-System Overview
- P24001-EFA-001-R00 Single Line
- P24001-EQL-003-R01-Key Components for Approval (incl. key component library)
- P24001-PDS-003-R01-General Safety Concept
- P24001-PRE-00X-R01-Explanatory notes_PemGen RINA
- P24001-PID-001-R05-FCM
- P24001-PID-002-R04-ASM
- P24001-SCH-001-R02-Interface Diagram
- P24001-SCH-002-R01-Block Diagram
- PemGen 3 Automation components_R01

It is intended that the general conditions and requirements listed and detailed in RINA Doc:

- " PemGen 3.0 Fuel Cell Power System" RINA Approval in Principle Report

have to be fulfilled in the detailed design phase, with the possible addition of further measures introduced by the Flag and State Administrations.

Type Approval for Fuel Cell Power Module

RINA

TYPE APPROVAL CERTIFICATE
No. **MAC278620XG**

This is to certify that the product identified below **satisfies** the **requirements of the standard quoted under "Reference standard"**

Description	**Fuel Cell Power Module**
Type	**MeOH100 Fuel Cell**
Applicant	**Freudenberg Fuel Cell e-Power Systems GmbH** **Bayerwaldstrasse 3** **81737 München** **GERMANY**
Manufacturer *Place of manufacture*	**Freudenberg Fuel Cell e-Power Systems GmbH** **Bayerwaldstrasse 3** **81737 München** **GERMANY**
Reference standards	**RINA Rules for the Type Approval of Fuel Cell Power Modules** **NCC/93; RINA Rules Part C Chapter 1 Appendix 15** **Methyl/ethyl alcohol fuelled ships**
Reference documents	**RINA Type approval system**

Issued in **Hamburg** on **August 30, 2022**. *This Certificate is valid until* **August 29, 2027**

RINA Services S.p.A.
Giuseppe Russo

This certificate consists of this page and 1 enclosure

TYPE APPROVAL CERTIFICATE
No. **MAC278620XG**
Enclosure - Page 1 of 3
MeOH100 Fuel Cell

Product Description

The MeOH-100 System is a fuel cell system that consists of one hydrogen supply module, three fuel cell stack modules and one electronic module. The system allows to convert the chemical energy of hydrogen into electrical power and heat.

The Hydrogen supply module of the MeOH-100 System is the part of the system that, by steam reforming, converts the methanol into a hydrogen-rich reformate stream, provides the CO cleaning of the reformate stream and catalytically converts the H_2 that is not used in the fuel cell into heat for the reforming process and evaporation of the methanol and water.

The methanol and water (gas/vapour phase) are fed to the REFORMER where the methanol/water mixture is catalytically converted at 250°C into a hydrogen-rich mixture (reformate) which contains approximately 1% of CO. Because the LTPEM fuel cell can only cope with CO in the ppm range, the reformate is fed into a CO clean-up section containing a water-gas SHIFT reactor, where CO is converted to chemical equilibrium with H_2, CO_2 and H_2O. In the next step the reformate is fed to 2 selective oxidation SELOX reactors where small air flows are added to selectively convert the CO with the oxygen in the air to CO_2. This will reduce the CO content of the reformate into the ppm range. For temperature control of these SELOX reactors and removal of the heat from the oxidation reaction, heat exchangers are used that cool down the reformate streams by evaporation of water and methanol in addition to the evaporation heat exchangers after the burner.

The fuel cell stack module converts the hydrogen from the reformate stream and oxygen from air into electrical power and heat. The reformate produced in the hydrogen supply module is then fed to the anode side of the fuel cell, air is compressed and fed to the cathode side of the fuel cell. In the fuel cell part of the hydrogen and oxygen are converted to electrical power, heat and water vapour. The fuel cell is cooled with a water-cooling circuit in order to maintain the system in its required operating range.

The depleted reformate and air stream are then fed to the BURNER, where the rest of the hydrogen is catalytically oxidized to provide the energy for the steam reforming reaction in the reformer.

The electronic module contains the control system, the safety system and is connected to the high voltage DC line where the electrical power is transformed into the required AC line.

Components and Materials

Hydrogen Supply Module

- Reformer/Burner Reactor - Material 1.4571 (AISI 316Ti)
- Shift Reactor – Material 1.4571 (AISI 316Ti)
- Selox Reactor – Material 1.4571 (AISI 316Ti)
- Heat Exchangers – Material 1.4571 (AISI 316Ti) , 1.4404 (AISI 316L), AISI 319 or similar
- Fittings / Connectors/ Piping – Material 1.4571 (AISI 316Ti) , 1.4408 or similar

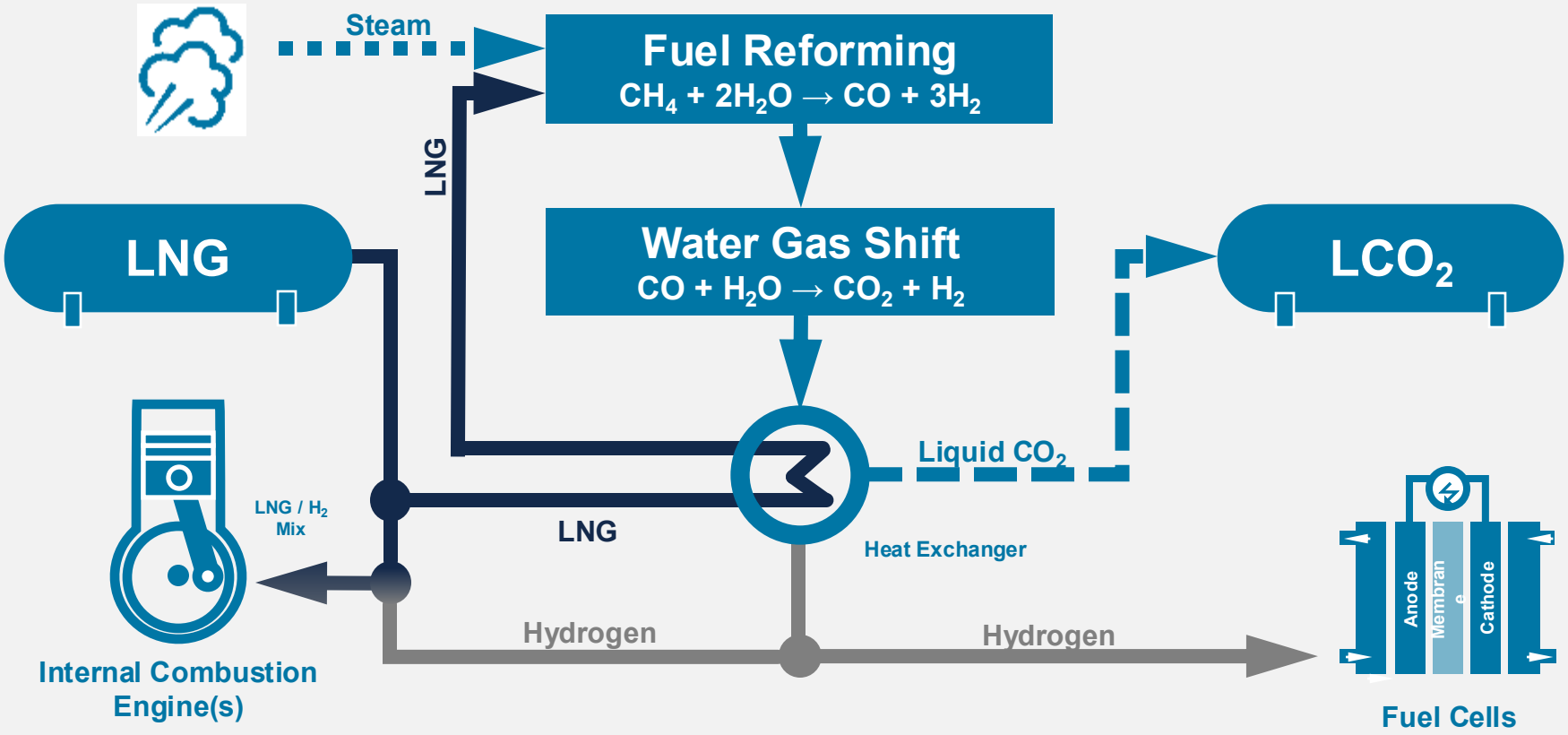
Fuel Cell Stack Module

- Stack Box – Material 1.4301 / 1.4462
- Cells – HD Graphite Bipolar Plate (BPP) + HD Membrane Electrode Assembly (MEA)

Control, Monitoring and Safety System

- Electronic Module (ELMO) as control cabinet including Disconnect Unit (DCU), Low Voltage Distribution Unit (LVDU), Fuel Cell Gateway (FCG), Fuel Cell Safety System (FCS), Fuel Cell System Control Unit
- Hydrogen Supply Module (H2MO) including Module Control (MOC), High Voltage Distribution Unit (HVDU) and Heater Control Unit (HTC)
- Fuel Cell Module (FCMO1, FCMO2, FCMO3) including Module Control (MOC), High Voltage Distribution Unit (HVDU).

Gas Fuelled Ship - Steam Methane Reforming



For more info:

Thank you!