Solutions for shipping to meet IMO 2050

Dec-01, 2023

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Outcome of MEPC80 : new strategy

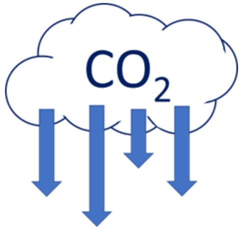
- The revised strategy increases the level of ambition. The new target is a net zero emission state, ***close*** to 2050 (*which cannot be interpreted in a single manner, although it is subject to revision in 2028)*

- The reduction of carbon intensity by 40% in 2030, remains as before

- In order to verify the progress of reduction, two check points have been introduced, in 2030 and 2040. These checkpoints do not address carbon intensity , but total emissions. The target is that, compared to 2008, in 2030 to have a reduction of GHG emissions by 20% and in 2040 by 70%, although striving for 30% and 80% respectively.

- As already known, the CII is subject for review in 2026, and there is no doubt that the reduction factor Z will decrease more sharply in order to arrive us at net zero close to 2050.

Meeting the IMO target for GHG reduction



Alternative Fuels

(i) Availability
(ii) Cost are key concerns

Fossil Fuel & Carbon Capture

- **Post** combustion
- **Pre** combustion

H2 on board

Outcome of MEPC80 : the view on fuels

- Guidelines for the Life Cycle Assessment (LCA) of a fuel were adopted.

This is very important in regards ammonia and methanol. Very rightly IMO wishes that the decarbonization of shipping does not shift emissions to other sectors. Seen under the light of LCA, the *grey* ammonia and methanol will increase sharply the GHG emissions of a ship, because their production is linked with huge emissions of GHG.
Only blue and green ammonia and methanol can be considered for use, which makes their availability and cost much more challenging for shipping.

- The use of *biofuels* will fall under critical observation

Only fuels, certified by international bodies, which succeed a **well-to-wake reduction** of GHG of 65% compared to Marine Gas Oil, can be considered as biofuels, and be assigned a reduced carbon emission factor. In all other cases, they will have the emission factor of the corresponding fossil fuel.
In this regard, the list of possible biofuels that can be used becomes short, with limited availability and very expensive. Also bio-gas cannot be considered as carbon negative.

The case of Bio-fuels

	Bio-Fuel Generations			
	1st	2nd	3rd	4th
Feedstock	Vegetable Oils found in food crops	Agricultural Non-food crop feedstocks, and forest residues	Specially energy source such as algae	Genetically modified (GM) algae to enhance biofuel production
Production Method	Fermentation, Transesterification (FAME), Hydrotreating (HVO)	Fischer Tropsch	Fischer Tropsch	
Common Types	FAME, HVO	FT Diesel		

Emissions reduction potential depends on feedstock, production method and supply chain.
Biofuel must be accompanied with certification issued by ISCC or a similarly approved auditing body (RSB).

- Bio fuels have short "shelf-life" due to very low oxidation stability

The effect of Bio-fuels in combustion & emissions :

- Advance of injection timing
- Modification of ignition timing due to lower LCV
- Shorter Ignition delay due to higher CN
- Effect (+ / -) on NOx emissions : this varies , less NOx usually come at cost for SFOC
- Reduce visible smoke & PM
- Reduced CO and HC emissions

Not enough green energy for green fuels

Annual production of Green energy	**8,300 TWh** [(1)]	
Energy for production of green ammonia	38.2	GJ/MT NH_3 [(2)]
Green Ammonia for shipping	661	Million MT
Green Energy for ammonia for shipping	**7,015**	**TWh**
Power-to-methanol conversion efficiency	48.2% [(3)]	
Energy content of Methanol	23.0	GJ/MT
Green Methanol for shipping	618	Million MT
Green Energy for methanol for shipping	**8,191**	**TWh**

Sources:

1. https://www.iea.org/reports/global-energy-review-2021/renewables
2. https://pubs.rsc.org/en/content/articlelanding/2020/ee/c9ee02873k
3. file:///C:/Users/atr01/Downloads/energies-13-03113-v2.pdf

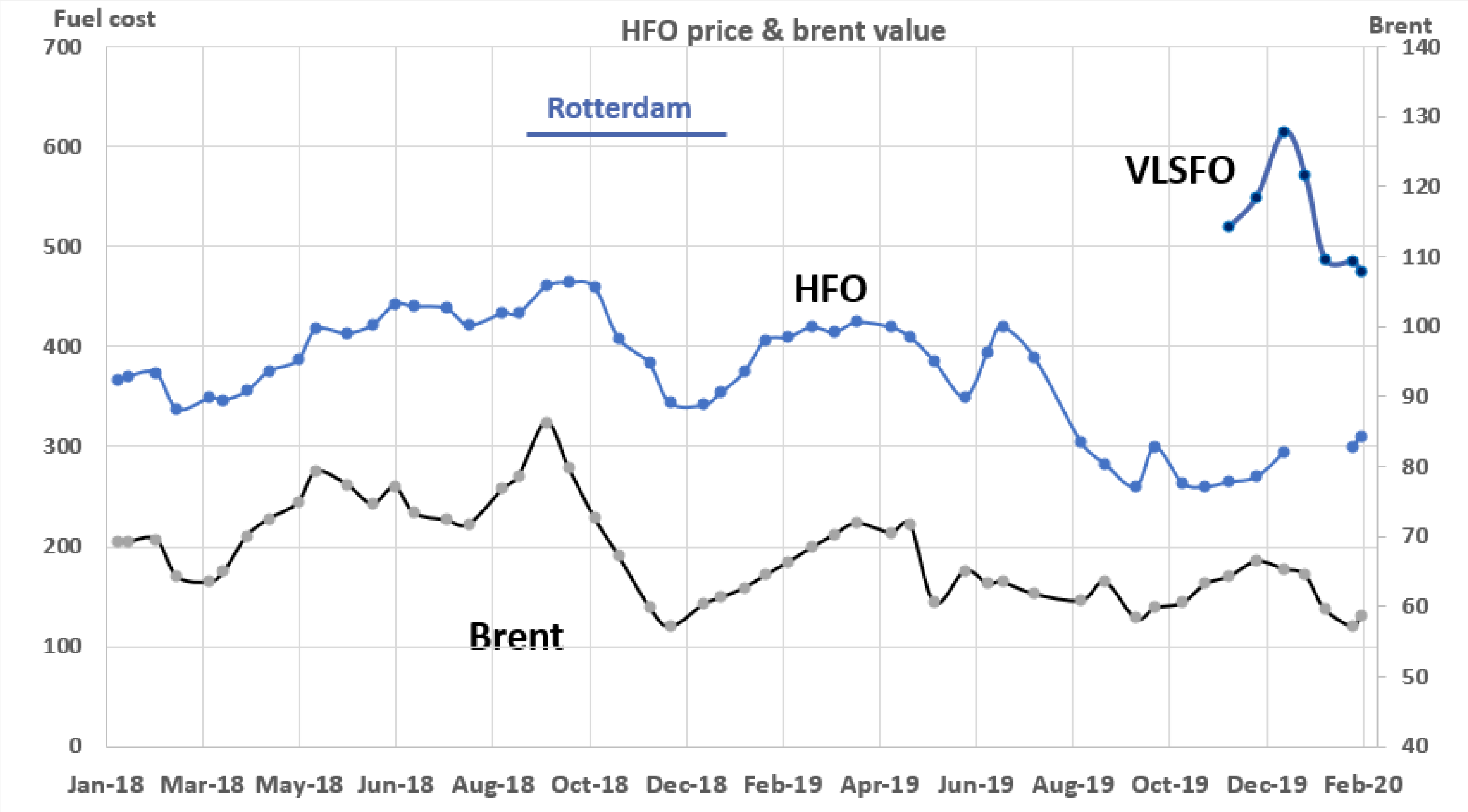
Fuel management on board

	Fuel Oil	LNG	Methanol	Ammonia
Energy content (MJ/kg)	41	50	19.9	18.6
Density (MT/m^3)	0.96	0.45	0.792	0.73

Mass	Ref	-19%	+206%	+220%
Volume	Ref	+73%	+250%	+290%
CO_2 emissions	Ref	-25%	-9%	N/A
With CH_4 slip		-15%		

- Extra mass will have impact on DWT
- Standard arrangement of fuel Tks needs to change

Fuel Price .vs. Fuel Availability



Reduced fuel availability yields skyrocketing prices

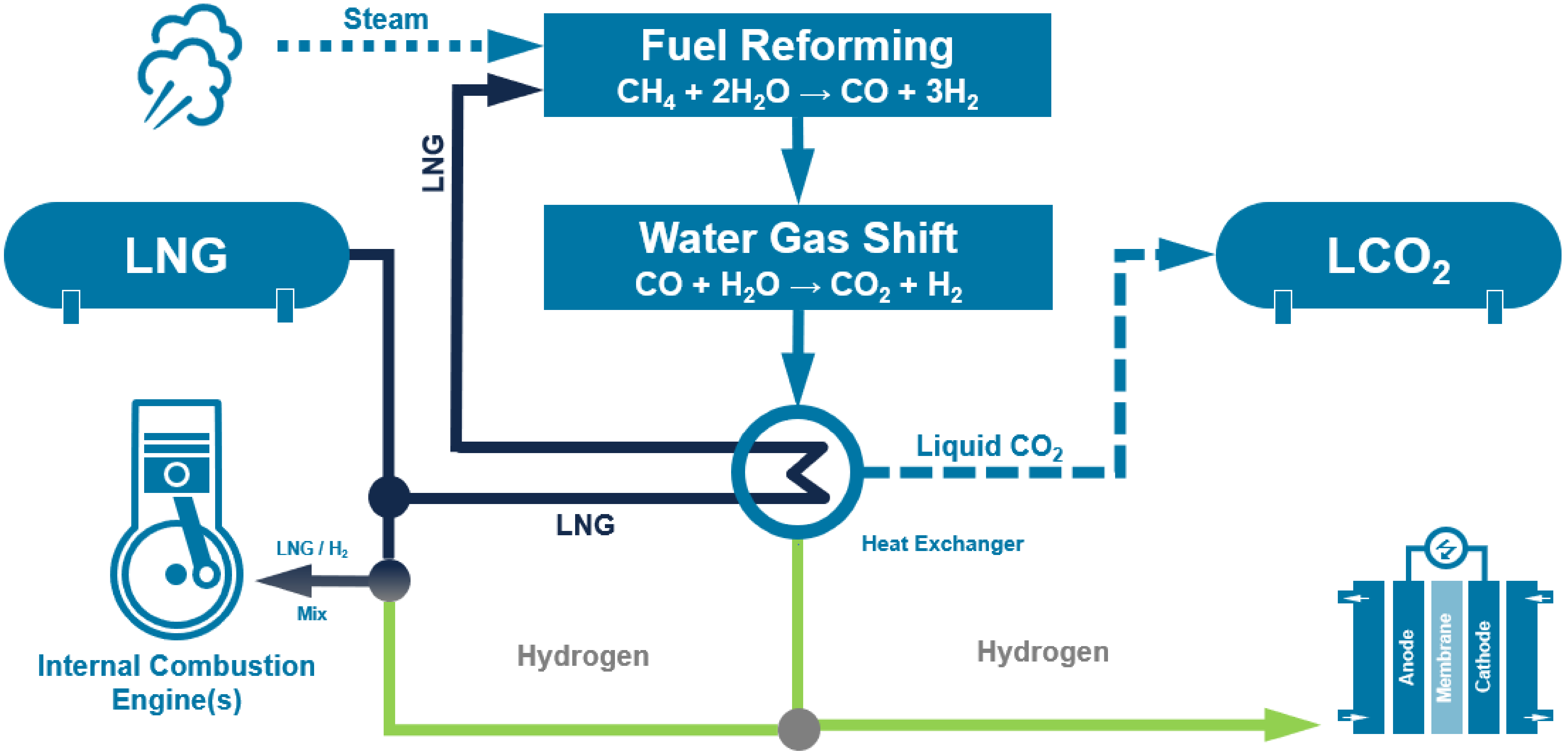
Fuel cost is > 60% of total ship operating costs

Hydrogen is dream fuel

BENEFITS	CHALLENGES
No SOx, PM, CO2 emissions	▪ Very small production globally ▪ No distribution & bunker infrastructure ▪ Very low energy density (1/2.5 of LNG) , very big tank ▪ Great energy loss for liquefaction ▪ Liquid phase temperature interval is only 13oC; Insulation of LH2 tanks is critical ▪ Material challenges , at very low cryogenic temperatures ▪ Little storage time, not very suitable for long voyages

We cannot realistically anticipate that we can solve the problems around production, transportation, delivery and storage of hydrogen.

Steam Methane Reforming



The selection of fuel towards 2050

The fuel is produced on board

Using available and mature technology

- ✓ *Novel application instead of novel technology*
- ✓ *No need for storage & supply of H2*

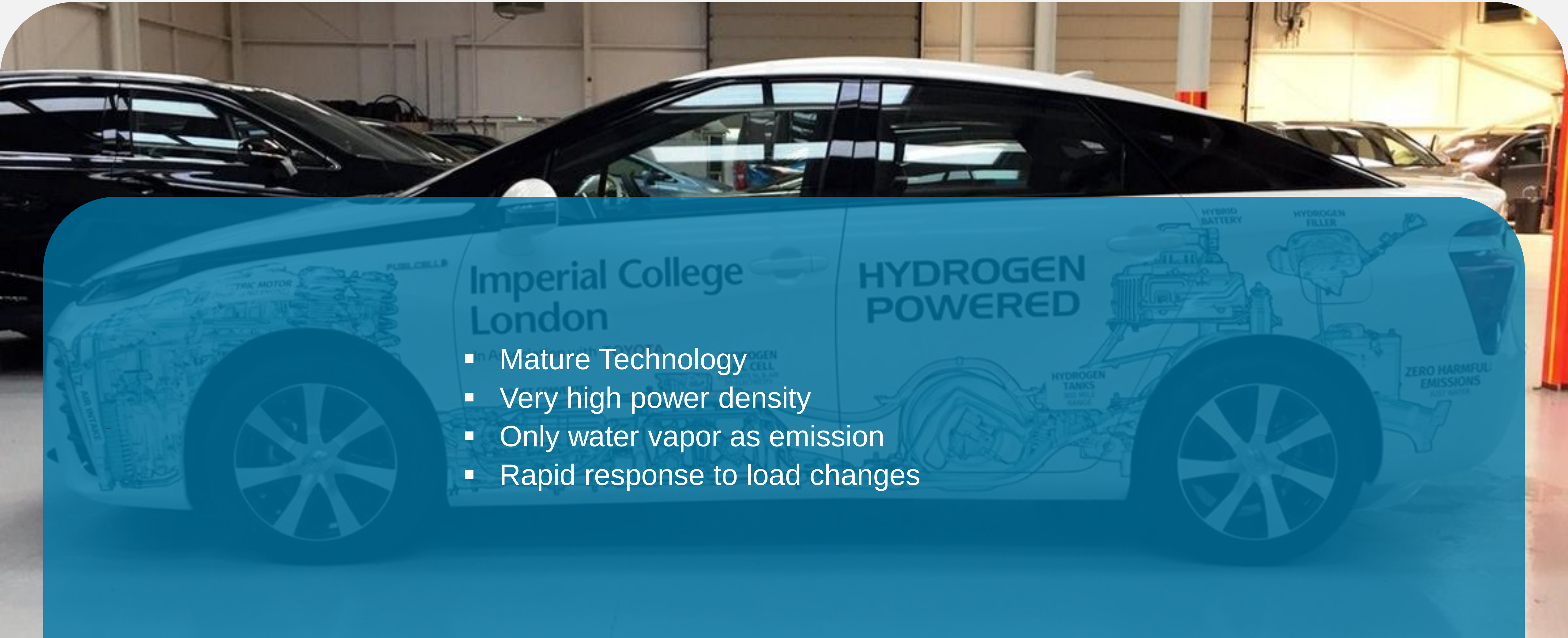
Relying on abundantly available fossil fuel (LNG) which will always be much less expensive than any other alternative fuel

- ✓ *Disconnected from the need to produce and supply/distribute a new fuel*

CO2 is captured before the combustion of fuel, and is liquefied by means of cryogenic temperature of LNG

- ✓ *Less space , cost, and energy consumption*
- ✓ *CCUS is a global solution*

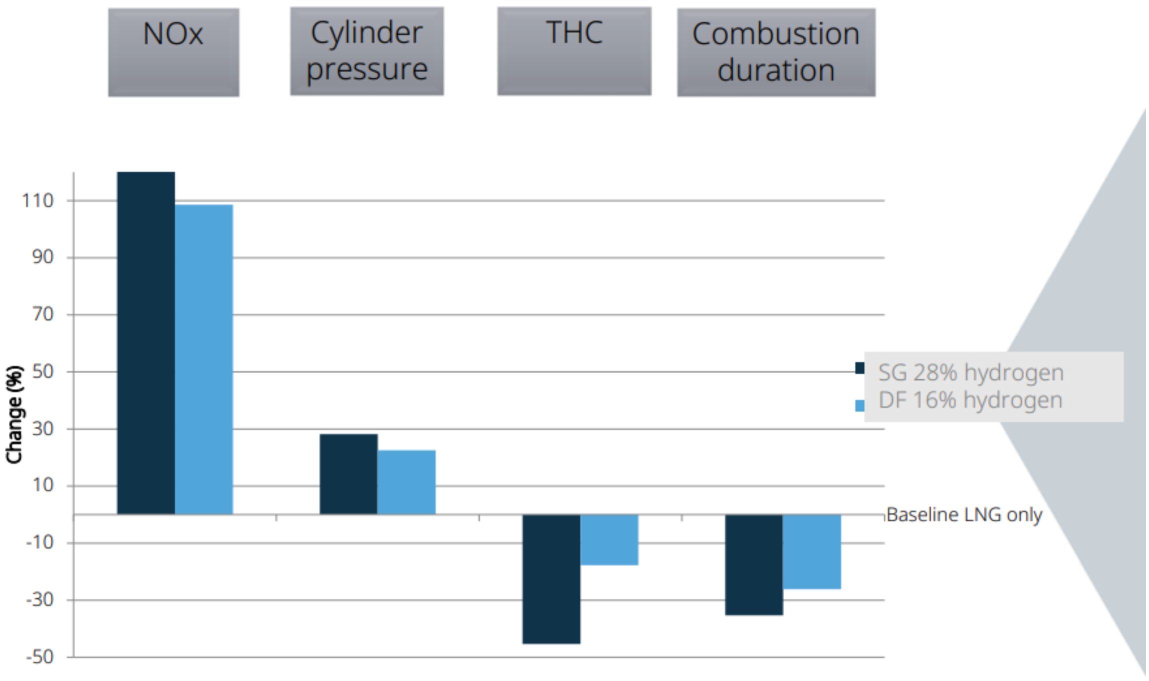
Fuel Cells



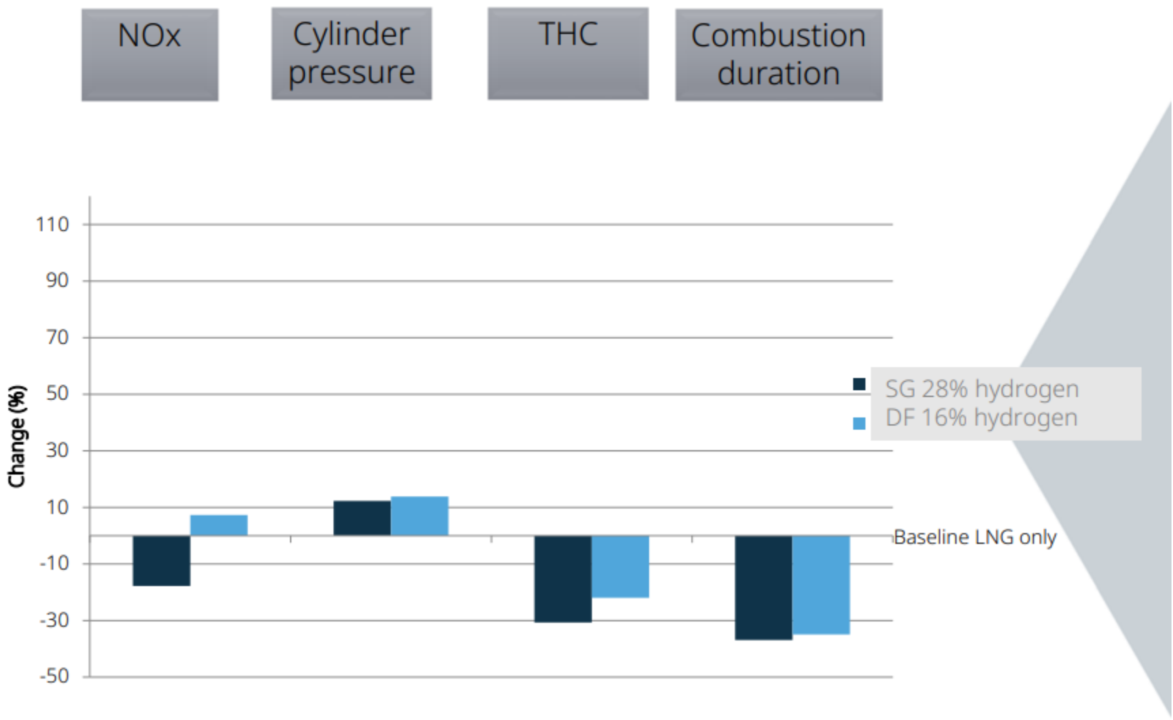
- Mature Technology
- Very high power density
- Only water vapor as emission
- Rapid response to load changes

The benefits of Hy$_{drogen}$+$_{me}$thane

Without Tuning

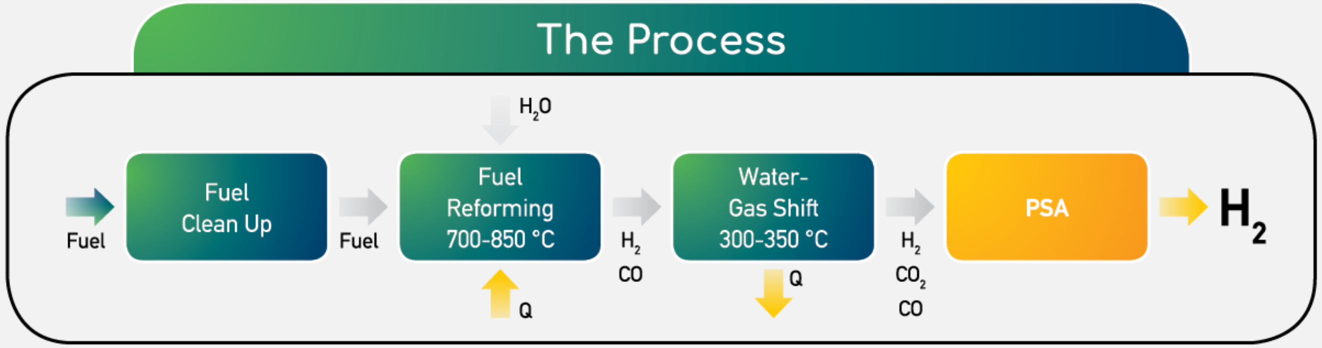


With Tuning

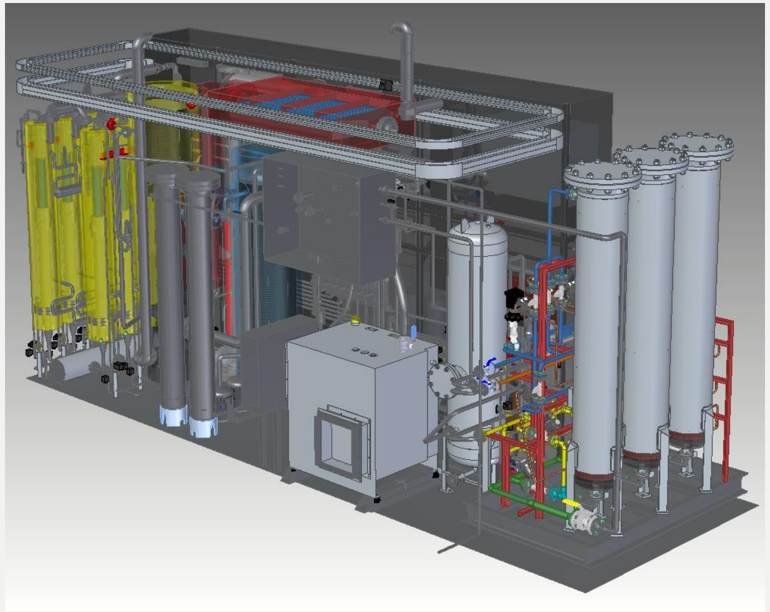


Source : Wärtsilä

Onboard Hydrogen Generators



Helbio
Hydrogen & Energy Systems



Hydrogen as fuel

Property	Unit	Safe fuel/less hazard, when parameter is:	Gasoline	Methane	Hydrogen
Density	kg/m3	Low	4.4	0.65	0.084
Diffusion coefficient in air	cm2/sec	High	0.05	0.16	0.61
Specific heat at const. P	J/gK	High	1.2	2.22	14.89
Ignition limits in air	vol %	Narrow range	1.0-7.0	5.0-17.0	4.0-75.0
Ignition energy in air	mJ	High	0.24	0.29	0.02
Ignition temperature	deg.C	High	228-471	540	585
Flame temperature in air	deg.C	Low	2,197	1,875	2,045
Explosion energy	gTNT/kJ	Low	0.25	0.19	0.17
Flame emissivity	%	Low	34-43	25-33	17-25

- **The risk of hydrogen explosion is minimal**
- Although hydrogen can burn in low concentrations, an explosion of hydrogen is very difficult to occur
- It blazes with little heat radiation, therefore only things immediately next to the flame would burn

COP27 : Solutions for carbon intensive industries

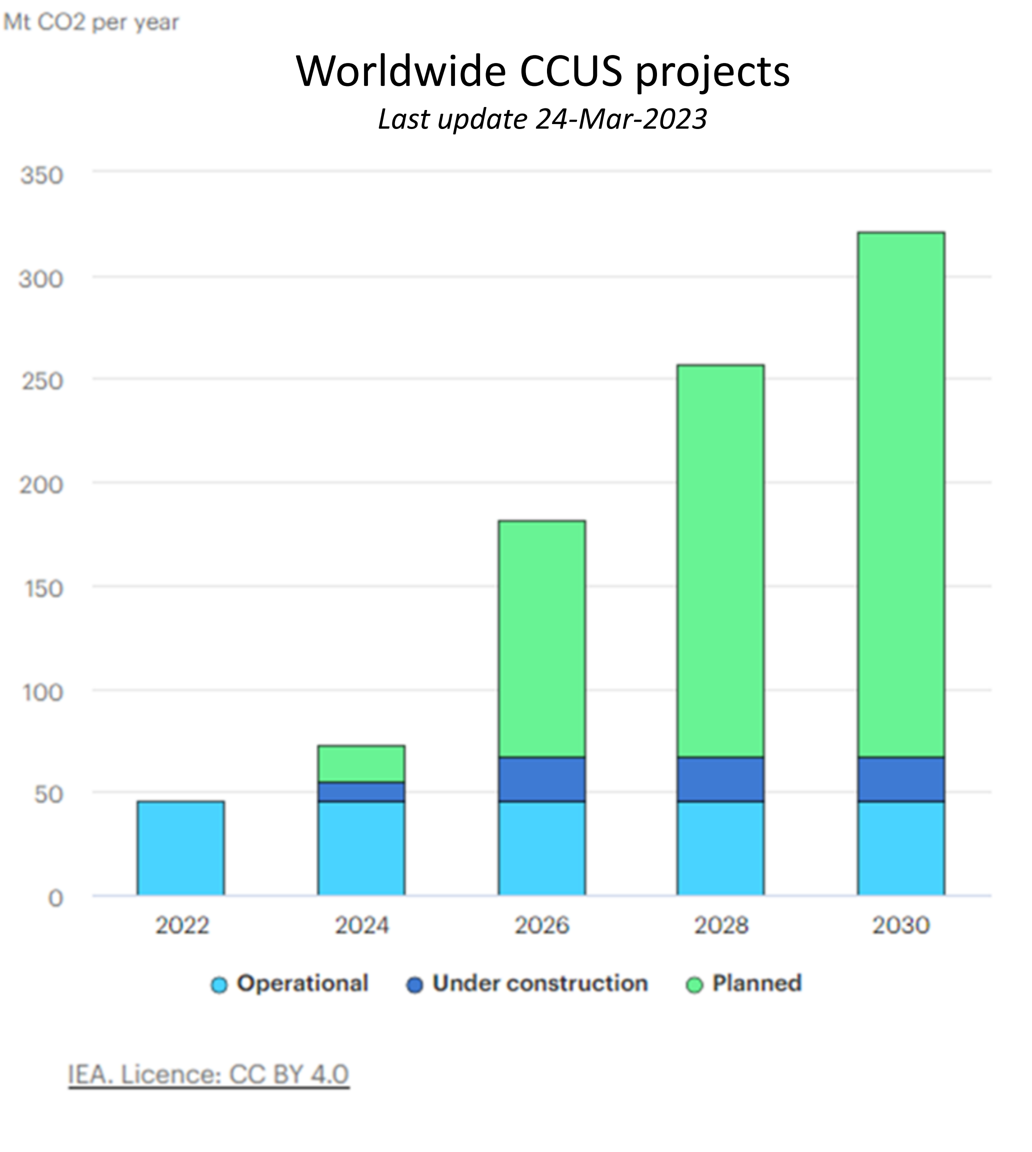
Cement, iron and steel, and chemicals / petrochemicals industries are the most significant industrial CO_2 emitters, accounting for about 25% of total CO_2 emissions globally and 66% of the industrial sector.

Their decarbonization of these industries is a top priority

The solutions presented fall into two categories:

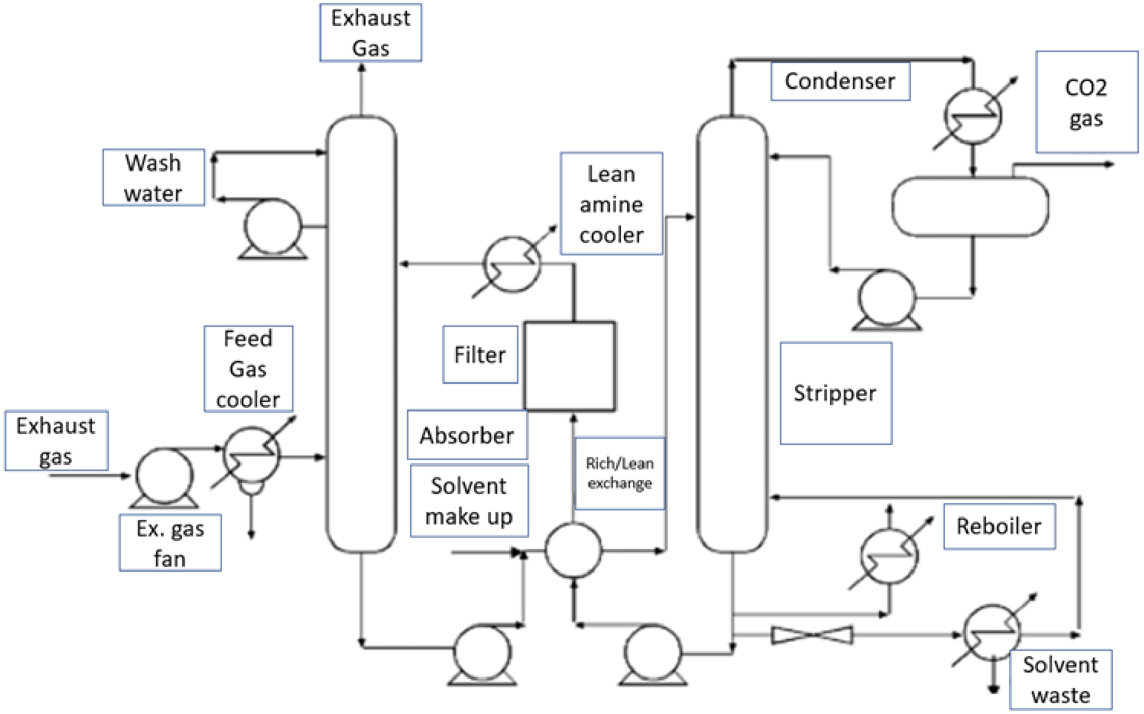
- Technology-based solutions : **carbon capture utilization and storage (CCUS)**; hydrogen; industrial energy efficiency; nuclear power and heat; electrification coupled with increased renewables
- Concept-based solutions : Circular Carbon Economy (CCE) and Industrial Clusters approach

It is reasonable that shipping shares solution with other industries (CCUS)



Reformer .vs. Post combustion capture

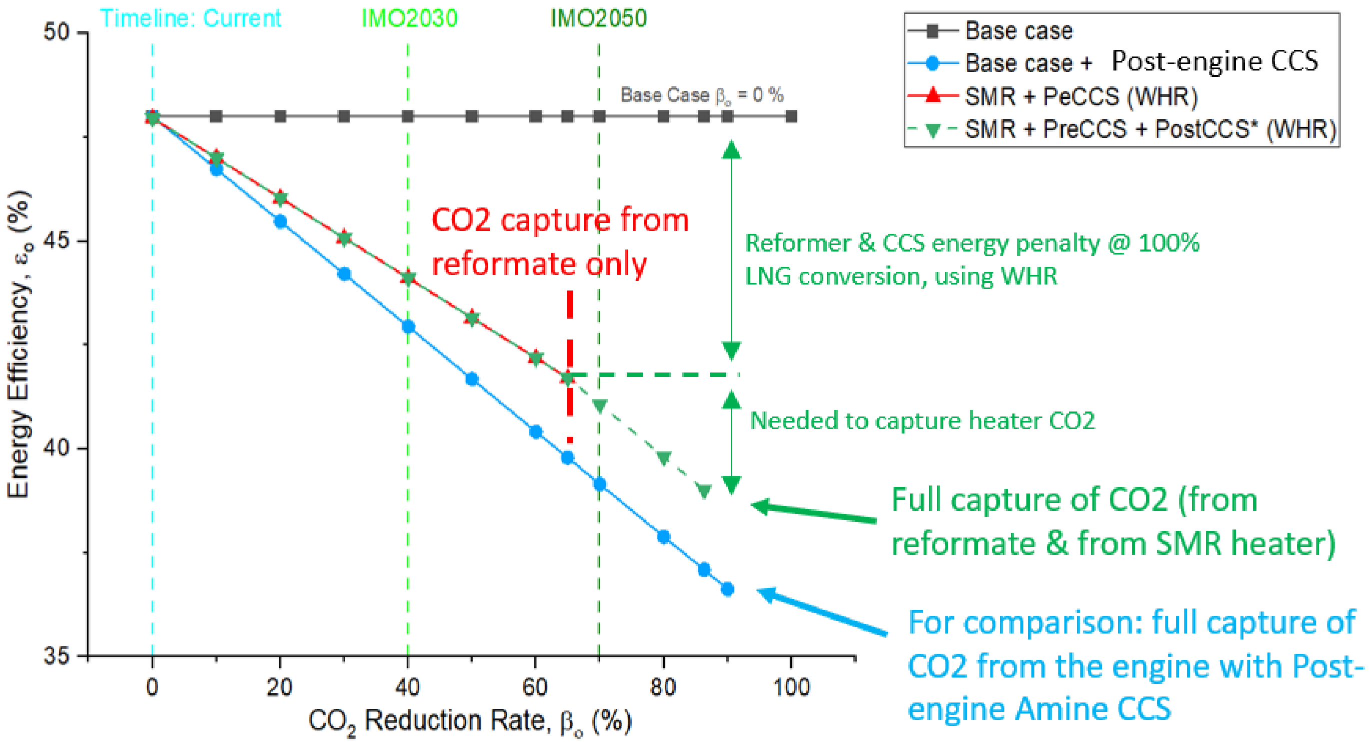
	Post-	Pre-
Process	Chemical	Physical
Hazardous Materials	!	✓
Purity of CO2	!	✓
CO2 concentration	!	✓
Flow rate	!	✓
Extra logistics & purchasing	!	✓
Scalable	!	✓
Energy consumption	!	✓
Space required	!	✓
Sensitive to vibrations	!	✓
Sensitive to impurities	!	✓



- The removal of CO2 from reformed gases is a physical process and does not involve or require the use of chemicals
- Due to its very complex nature (heat & mass transfer process sensitive to hydromechanic and thermodynamic factors), the post combustion is very sensitive to vibrations and it is highly unlikely that it will perform on bord a ship
- The post combustion is very sensitive to impurities (NOx, SOx, PM) : their presence will rapidly degrade the chemical solvent, while their removal needs higher standards that catalysts and scrubbers

Validation of concept from Cambridge

On-board partial LNG reforming: overall efficiency vs CO2 removal



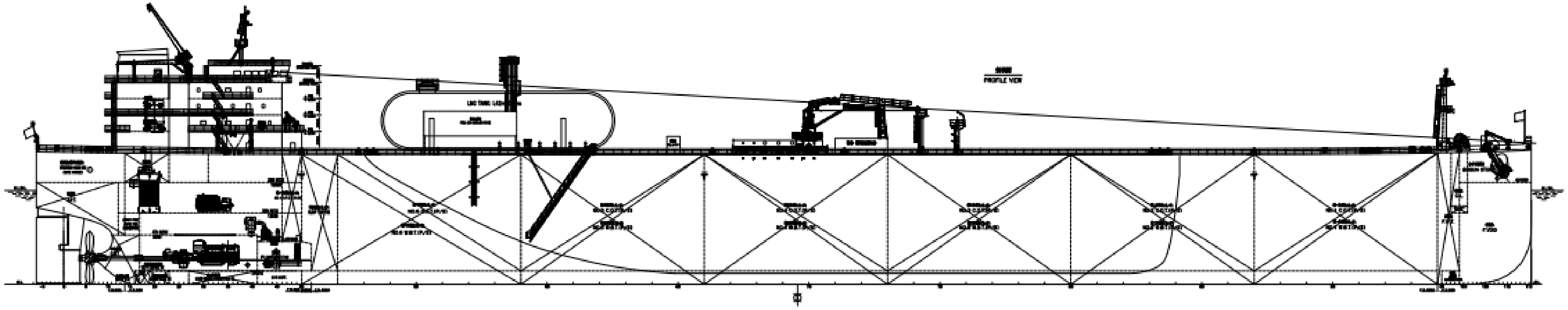
Better overall efficiency than post-engine CO2 capture.

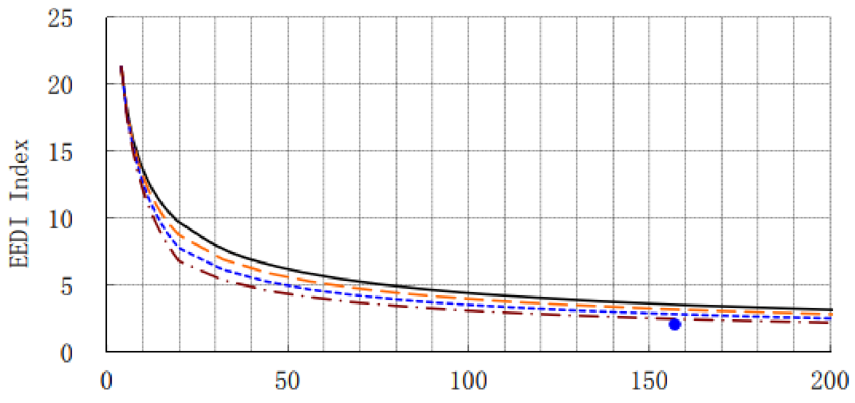
Advantages:

- Efficiency: Allows Waste Heat Recovery, hence overall efficiency improved.
- H&S: Higher CO2 concentrations than Post-combustion CCS makes PSA possible; no amine issues.
- H&S: No on-board H2 storage; physical H2 path from production to consumption very short.
- Financial: On-board SMR+PSA Pre-combustion CCS probably less bulky than Post-combustion Amine CCS; no large LH2 boil-off; likely to have smaller cargo loss compared to LH2 option.
- Gradual decarbonization: if engine can use variable LNG+H2 mixtures, IMO trajectory can be met progressively; easier for shipowners to invest (less risk).
- Methane slip: likely to be improved (even small amounts of H2 can have drastic effect on CH4 slip)

The case of Suezmax tanker

New Partner:





41% reduction of EEDI

IMO2030 compliant !

OUTLINE SPECIFICATION

FOR

156,000DWT CRUDE OIL TANKER
(MEGI LNG DUAL FUEL)

REF NO. : TK-2059-OS-Rev.I1

BUILDER: NEW TIMES SHIPBUILDING CO., LTD

December 2020

The development of CII

Depending on : **operating speed & accepted rate of CII**

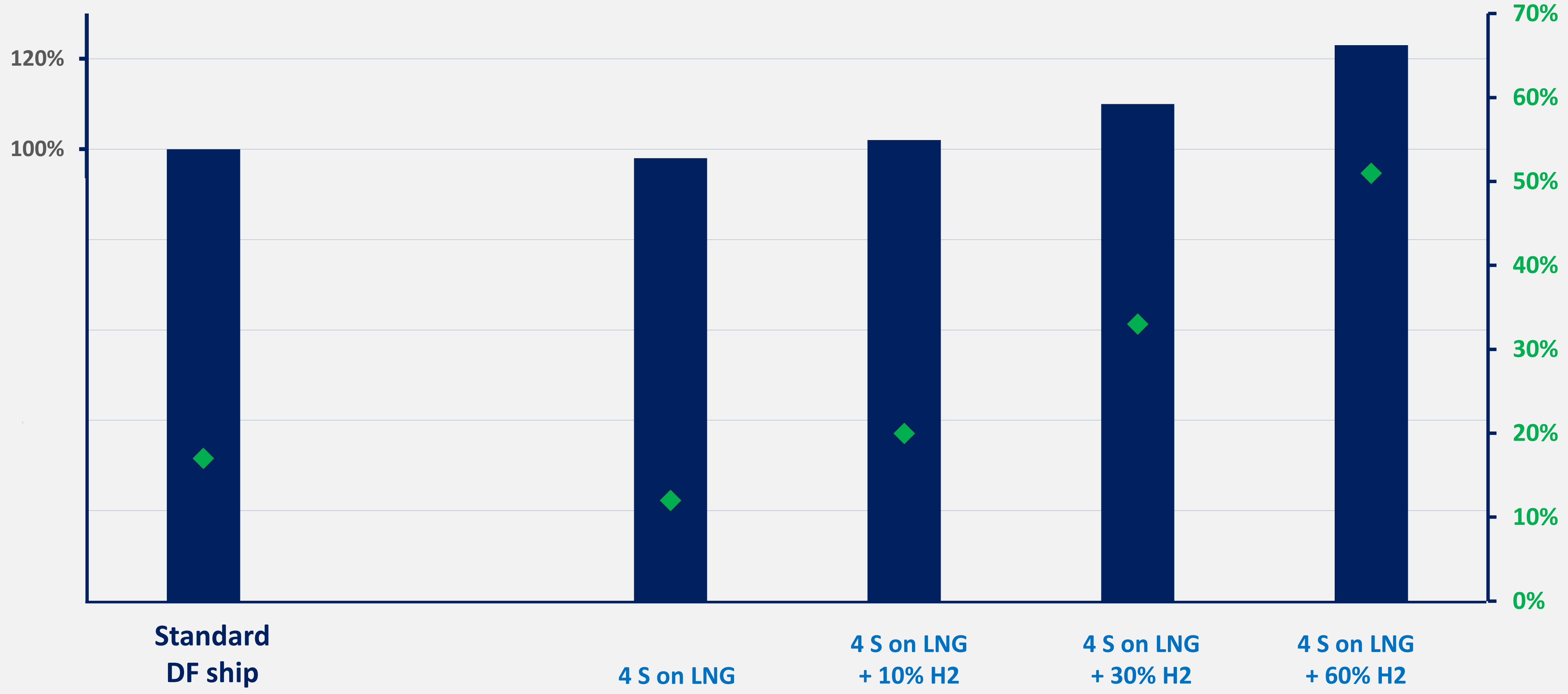
different options are available to Owner for compliance

@ 12 kn	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046
LNG	A	A	A	B	B	B	B	B	C	C	C	C	D	D	D	D	E	E	E	E	E	E
10% H2	A	A	A	A	A	A	A	B	B	B	B	C	C	C	D	D	D	D	E	E	E	E
30% H2	A	A	A	A	A	A	A	A	A	A	A	A	B	B	B	C	C	C	D	D	D	E
60% H2	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	B	B	C

@ 11 kn	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046
LNG	A	A	A	A	A	A	B	B	B	B	C	C	C	C	D	D	D	D	E	E	E	E
10% H2	A	A	A	A	A	A	A	A	A	A	B	B	B	C	C	C	D	D	D	D	E	E
30% H2	A	A	A	A	A	A	A	A	A	A	A	A	A	A	B	B	B	C	C	C	D	D
60% H2	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	B	B

@ 12 kn	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046
LNG	A	A	A	B	B	B	B	B	C	C	C	C	D	D	D	D	E	E	E	E	E	E
10% H2	A	A	A	A	A	A	A	B	B	B	B	C	C	C	D	D	D	D	E	E	E	E
30% H2	A	A	A	A	A	A	A	A	A	A	A	A	B	B	B	C	C	C	D	D	D	E
60% H2	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	B	B	C

The cost for CO2 reduction



Proposal accepted by major Greek Owner

Lloyd's List

Angelicoussis Group advances first bulk carrier design to exceed IMO 2050

Dual-fuel, LNG/hydrogen, newcastlemax is being developed in conjunction with Rina and Shanghai Design & Research Institute

18 Nov 2022 | **NEWS**

Maria Angelicoussis is CEO of the Angelicoussis Group. Photo: FT

Angelicoussis Group developing bulker that produces hydrogen on board

Greek owner's Maran Dry Management teaming with Rina and SDARI for innovative dual-fuel newcastlemax

European Regulations

- **Fit for 55** *(All ships > 5,000 GT)*

Pay the cost for :

100% of the GHG emissions within EU ports and from voyages between EU ports

50% of the GHG emissions from voyages to or from EU ports

Emissions to be considered :

CO_2 from 1 January 2024

Methane (CH_4) and nitrous oxide (N_2O) from 1 January 2026

Phase-in : 40% of the verified aggregated emissions reported for 2024;
70% of the verified aggregated emissions reported for 2025;
100% of verified aggregated emissions reported for 2026 and each year thereafter

- **Fuel EU** *(All ships > 5,000 GT)*

The yearly average GHG intensity of the energy used on-board by a ship shall not exceed the reference value, which is reduced by an increasing % from 2% in 2025 up to 80% in 2050

Implications by EU regulations

EU allowance	ANNUAL		EMISSIONS COVERED BY ETS			
100 EUR/MT	Consumption	CO2 emissions	25%	50%	75%	100%
FUEL OIL	9,305	28,976	724,394	1,448,789	2,173,183	2,897,577
LNG	7,777	25,847	646,175	1,292,350	1,938,525	2,584,700
30% H2	9,040	20,271	506,775	1,013,550	1,520,325	2,027,100

							AVERAGE
COST BENEFIT OVER 10 YEARS	LNG	782,193	1,564,385	2,346,578	3,128,770		1,955,481
	30% H2	2,176,193	4,352,385	6,528,578	8,704,770		5,440,481
						TOTAL	**7,395,963**

EU allowance	ANNUAL		EMISSIONS COVERED BY ETS			
150 EUR/MT	Consumption	CO2 emissions	25%	50%	75%	100%
FUEL OIL	9,305	28,976	1,086,591	2,173,183	3,259,774	4,346,366
LNG	7,777	25,847	969,263	1,938,525	2,907,788	3,877,050
30% H2	9,040	20,271	760,163	1,520,325	2,280,488	3,040,650

							AVERAGE
COST BENEFIT OVER 10 YEARS	LNG	1,173,289	2,346,578	3,519,866	4,693,155		2,933,222
	30% H2	3,264,289	6,528,578	9,792,866	13,057,155		8,160,722
						TOTAL	**11,093,944**

Aside from cost benefit of ETS, and regardless who will pay this (Owner or Charterer),
As pr FuelEU, the need to reduce the carbon intensity of energy consumed on board , ***REMAINS***

Thank you for your attention

Giosuè Vezzuto
Executive Vice President, Marine