Greener Shipping Summit
Nov.2021

A scalable and sustainable proposal for meeting IMO2050 targets

Antonios Trakakis, Tech Director, Marine RINA Greece

Issues around green fuels

- **Annual fuel consumption of shipping : 250mtoe**
- **Annual production of :**
  - **Ammonia : 135mtoe**
  - **Methanol : 50mtoe**

Green fuels :

- Health and safety issues, emission of very potent GHG (ammonia)
- are not to be expected during this decade
- will be 2x or 3x more expensive than today's fossil fuels
- require different amount of energy for their production, and have different needs in terms of infrastructure and storage; is unlikely that deep sea shipping to be provided with many fuel options, all @ same price

- **It is very risky today to select a fuel & engine technology**
- **A ship running on fuel oil is clearly an investment with very limited penetration in the future.**

Hydrogen as fuel

BENEFITS	CHALLENGES
No SOx, PM, CO_2 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 13°C; Insulation of LH2 tanks is critical - Material challenges , at very low cryogenic temperatures - Little storage time, not very suitable for long voyages

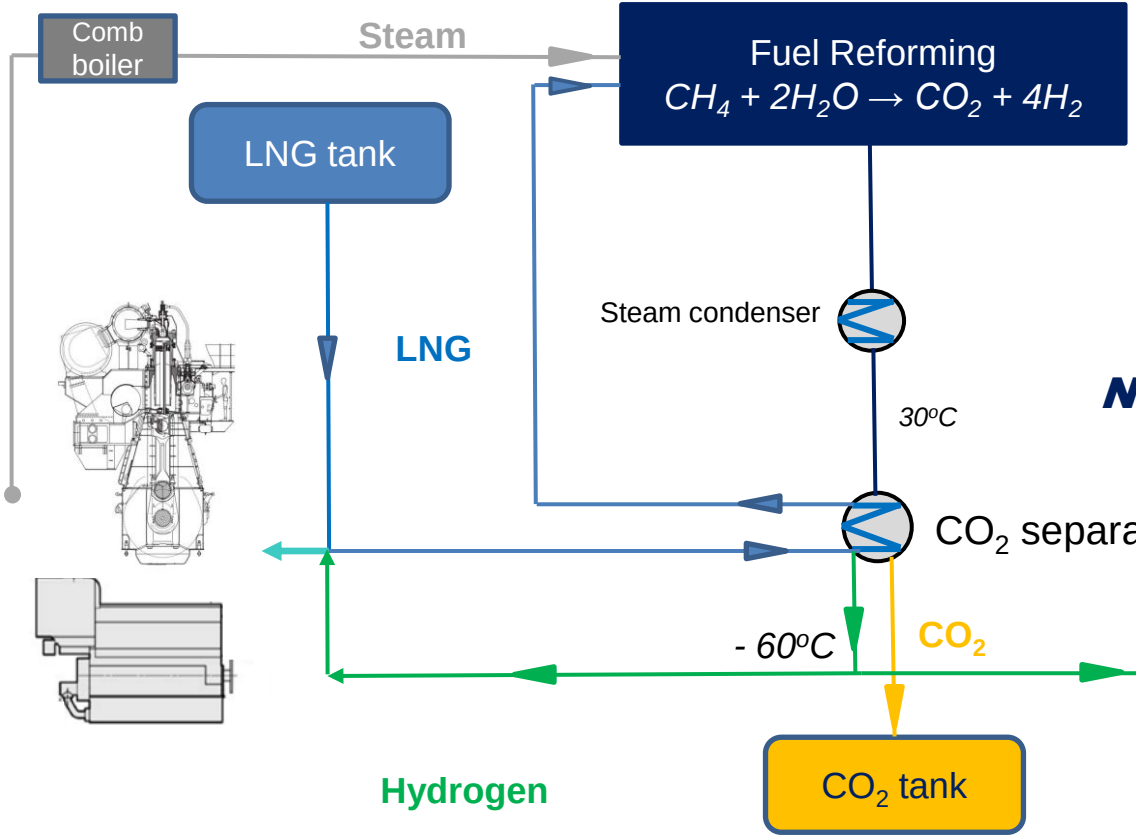
The energy yield of land area is much higher when it is used to capture wind or solar energy (H2 .vs. biofuel)

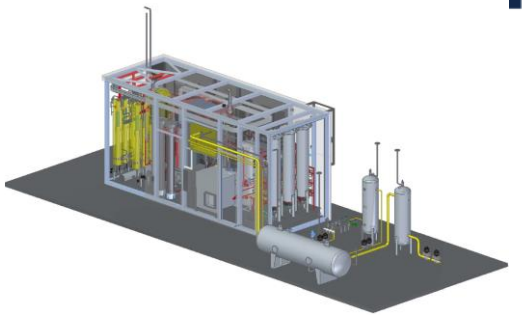
It is very difficult to solve the problems around production, transportation/delivery and storage of hydrogen

But it is possible to tackle them, by producing H_2 on board ***an LNG fueled ship***!

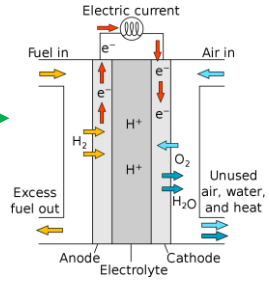
With Steam Methane Reforming process

Steam Methane Reforming





No storage of H_2 on board !



The importance of CCUS

- **Tackling emissions from existing energy infrastructure:** CCUS can be retrofitted to existing power and industrial plants that could otherwise emit 600 billion tonnes of CO_2 over the next five decades - almost 17 years' worth of current annual emissions

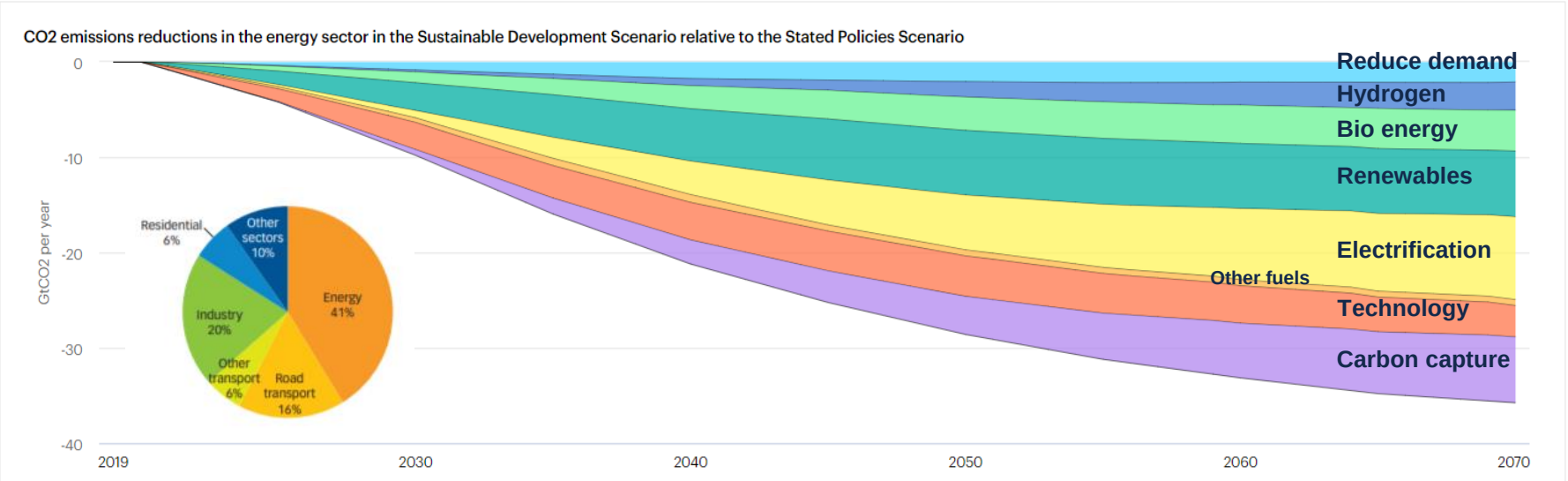
- **A solution for some of the most challenging emissions:** Heavy industries account for almost 20% of global CO_2 emissions today. CCUS is virtually the only technology solution for deep emission cuts from cement production. It is also the most cost-effective approach in many regions to curb emissions in iron and steel and chemicals manufacturing

- **Production of syn-fuels:** Captured CO_2 is a critical part of the supply chain for synthetic fuels from CO_2 and hydrogen - one of a limited number of low-carbon options for long-distance transport, particularly aviation

- **A cost-effective pathway for low-carbon hydrogen production:** CCUS can support a rapid scaling up of low-carbon hydrogen production to meet current and future demand from new applications in transport, industry and buildings

- **Removing carbon from the atmosphere:** For emissions that cannot be avoided or reduced directly, CCUS underpins an important technological approach for removing carbon and delivering a net-zero energy system

The role of CCUS



Source: *https://www.iea.org/reports/ccus-in-clean-energy-transitions/ccus-in-the-transition-to-net-zero-emissions*

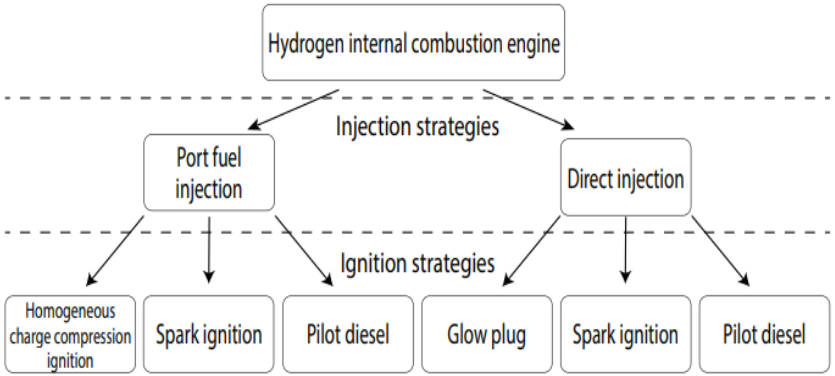
CCUS will have a special role in reducing global GHG emissions

Combustion of H_2 in ICE's

Although H_2 has high auto-ignition temperature, its resistance to knocking (MN) is low due to its very low ignition energy, which indicates that hydrogen can be easily ignited by hot spots or residues in combustion chamber.

- A small amount of H_2 is accelerating the combustion and creates efficiency gains, with lower NOx emissions

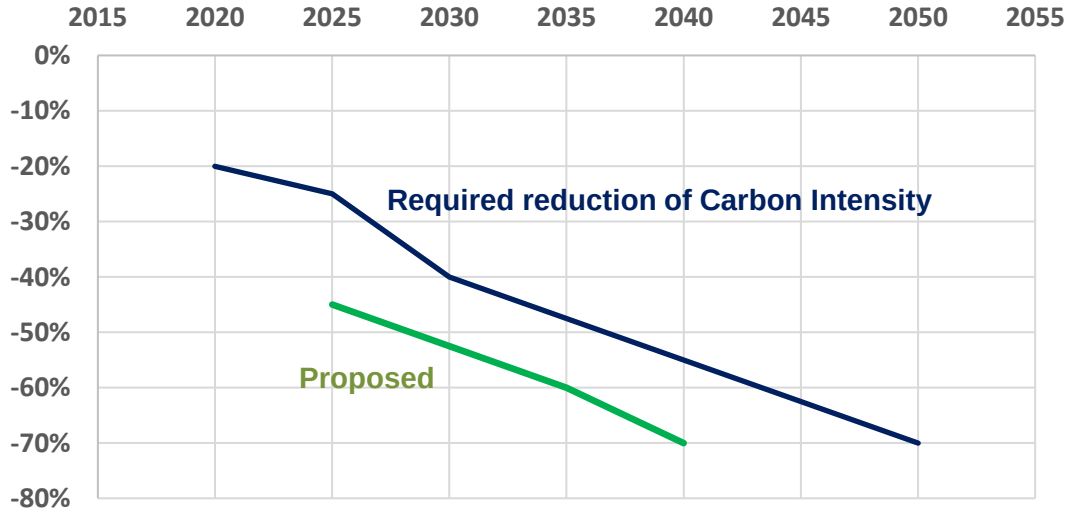
- As the H_2 content increases, t**he main driver for a stable H_2 combustion is the combustion strategy**



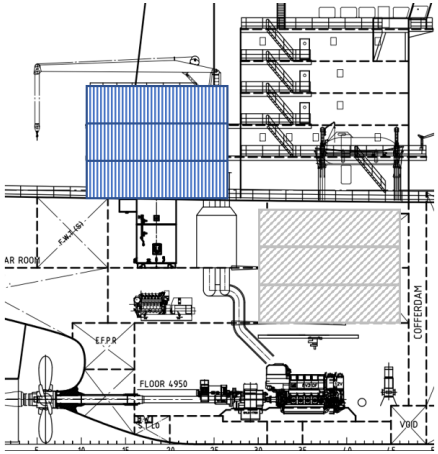
Meeting IMO2050 with H_2 & engine technology

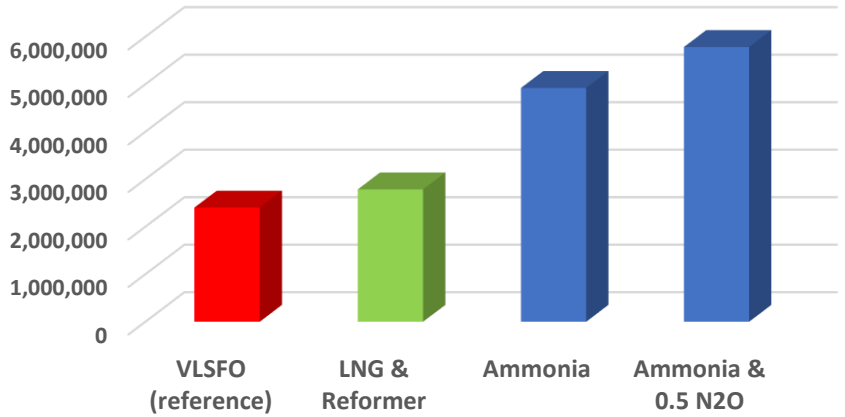
	Year	Carbon Intensity	% H2	Fuel Cost (compared to VLSFO)
Delivery	2025	-45%	0	-10%
1st SS	2030/**35**	-60%	30%	0%
2nd SS	2035/**40**	-70%	60%	10%

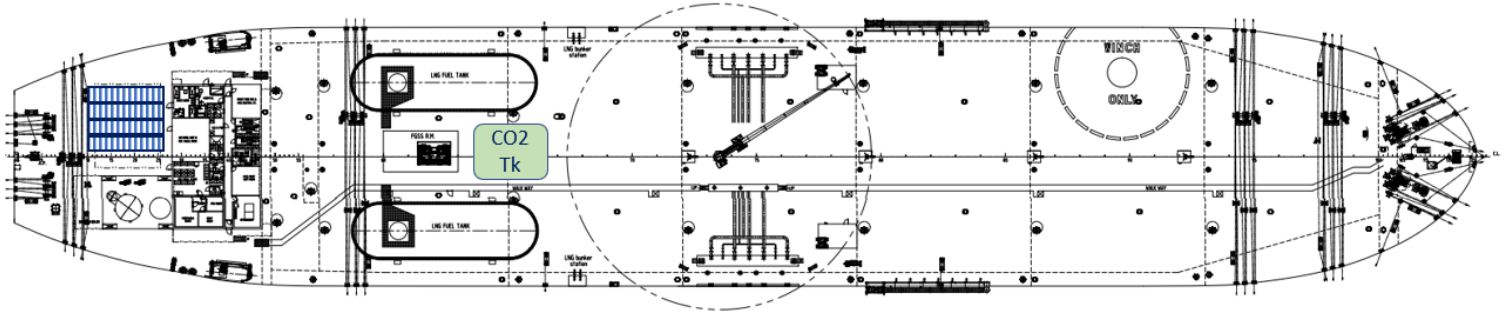
An LNG fueled ship will require corrective action for CII after ~10 years



Space & cost considerations







The case of Fuel cells

Fuel Cell Technology	Abbreviation	Fuel	Operating Temperature (°C)	Efficiency
Proton Exchange Membrane	PEM	H2	50-70	40-60%
Solid Oxide Fuel Cells	SOFC	Hydrogen rich	600-900	45-55%

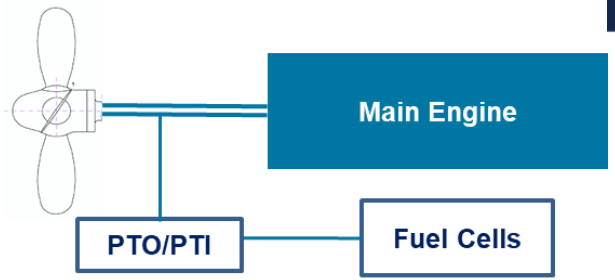
	PEM	SOFC	ICE
CO2 emissions	☺		
Efficiency	☺		
CAPEX			☺
OPEX	☺		
Dimensions	☺		
Lifetime			☺
Operating T	☺		
Fuel Flexibility			☺
Start up Time	☺		
Cargo capacity	☺ ☺		

If H_2 is available, PEM FC is a valid choice

Solutions with Fuel Cells

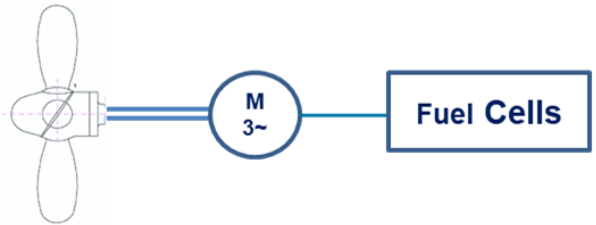
Hybrid : Power share between engine/FC's

- Engine can burn progressively higher H_2% to meet IMO 2050
- Install additional modules of FC's



Fuel Cells only

- Great opportunities to increase cargo capacity
- IMO2050 compliant from delivery
- Easy to become zero carbon



Power distribution		Hydrogen % in engine	
Engine	PEMFC	30%	60%
100%		**30%**	**50%**
90%	10%	**35%**	**55%**
50%	50%	**63%**	**70%**
	100%	**80%**	

Reduction of CO2 emissions (MT)

refer.2008

CO_2 reductions for Kamsarmax bulker

								CO2 emissions									
			Conventional (*refer.2008*)		PROPOSAL			0% Hydrogen					25% Hydrogen				
Speed	Propulsive Power	Total Power	FOC	CO2 emissions	Engine		FC	Engine	CH4 slip	Reformer	Reduction	Refer. 2008	Engine	CH4 slip	Reformer	Reduction	Refer. 2008
kn	kW	kW	kg/h	kg/h	% MCR	kW	kW	kg/h					kg/h				
11.5	4,500	5,200	915	2,849	85%	4,080	1,120	1,783	183	122	**27%**	**57%**	1,388	137	241	**38%**	**63%**
12	5,050	5,750	1,014	3,156	85%	4,080	1,670	1,783	183	182	**32%**	**55%**	1,388	137	300	**42%**	**62%**
12.5	5,700	6,400	1,130	3,519	85%	4,080	2,320	1,783	183	252	**37%**	**54%**	1,388	137	371	**46%**	**61%**
13	6,400	7,100	1,256	3,910	85%	4,080	3,020	1,783	183	328	**41%**	**52%**	1,388	137	447	**50%**	**59%**
13.5	7,150	7,850	1,390	4,329	85%	4,080	3,770	1,783	183	410	**45%**	**51%**	1,388	137	528	**53%**	**57%**
14	8,000	8,700	1,543	4,804	85%	4,080	4,620	1,783	183	502	**49%**	**49%**	1,388	137	621	**55%**	**55%**

Engine selection : 1 x 8V Wartsila 31DF, MCR = 4,800 kW
Fuel cells installed power = 5,000 kW
Total installed power : 10% less than conventional vessel

>50% ✓ IMO2050

CO_2 storage volume @ 12 kn, **30 days**
0% H_2 = 600 m^3
25 % H_2 = 1,000 m^3
Total volume (LNG+CO_2) < NH_3

Retrofitting options

Applied on a **supramax (57k DWT) bulk carrier vessel**

Normal sea going condition @ 12kn		**Main Engine**	**Diesel Generator**	**Fuel Cells**
Power	% / kW	55%	450	
Daily Fuel Consumption	MT/day	22.7	2.3	
LNG consumption	MT/day			2.2
CO2 emissions	MT/day	71	7.2	1.2
TOTAL	MT/day	**78.2**		72.2
CO2 reduction		**8%**		

Required Tks for 50 days:

- LNG ~ 250 m^3
- CO_2 Tk = 55 m^3

A scalable & sustainable proposal

CAN START NOW !

There is no transition of technology on board

COST

Moderate carbon tax compensates extra cost
Can be deployed in a scalable and progressive manner
Allows increase of cargo intake

CO_2 STORAGE

Although not in place currently,
all evidence points it will develop soon
to a very big scale

FUEL SELECTION

Available, affordable (low cost), acceptable (low risks)

No storage and No Cryo Temp. of H2 on boared

TECHNOLOGY

Simple & Mature
Rapidly developing for FC's
Eliminates Methane Slip, Possible to retrofit

RINA

Thank you !