Hydrogen and Fuel Cell Solutions for Shipping

Eng. PhD. Thomas Lamberti

Hydrogen and Fuel Cells in Ports and Shipping Workshop
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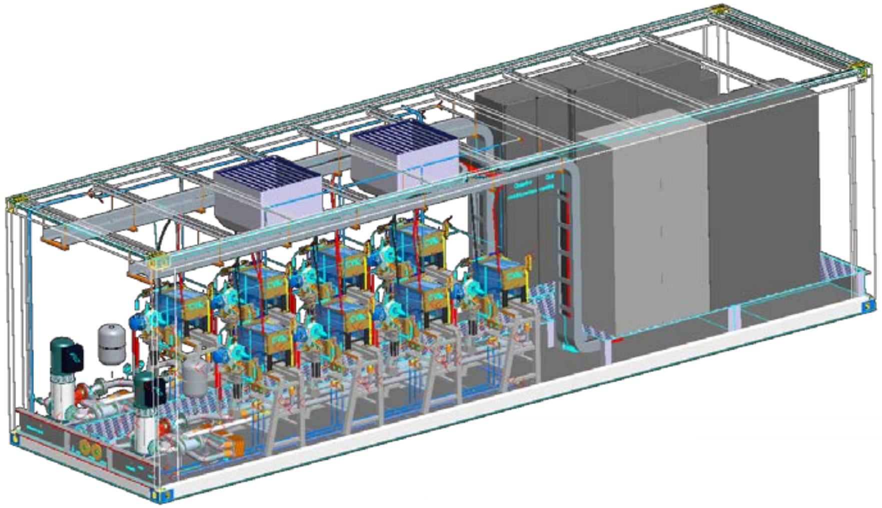
Hydrogen and Fuel Cell Solutions for Shipping

1. **Marine Applications**
2. **Hydrogen as Alternative Fuel**
3. **Fuel Cell Systems for Ships**
4. **Solutions?**



HI-SEA
Joint Laboratory

Eng. PhD. Thomas Lamberti
Naval Architect, PhD, expert in marine applications of Fuel Cell Systems, H2Boat CEO, researcher at TPG
Mail: lamberti.thomas@edu.unige.it

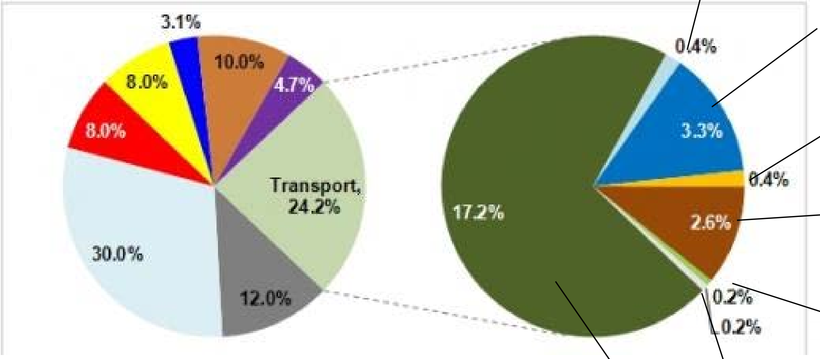
What is the driver for the introduction of hydrogen and fuel cells on-board?

For the first time in history, it's not cost, it's **ENVIRONMENTAL CHALLENGE**

Politics under community and public pressure → Institution

IMO

Source: Change, International Pannel of Climate. *Fifth Assessment Report AR5*: IPCC, 2014



Domestic Navigation

Int. Maritime

Domestic Aviation

International Aviation

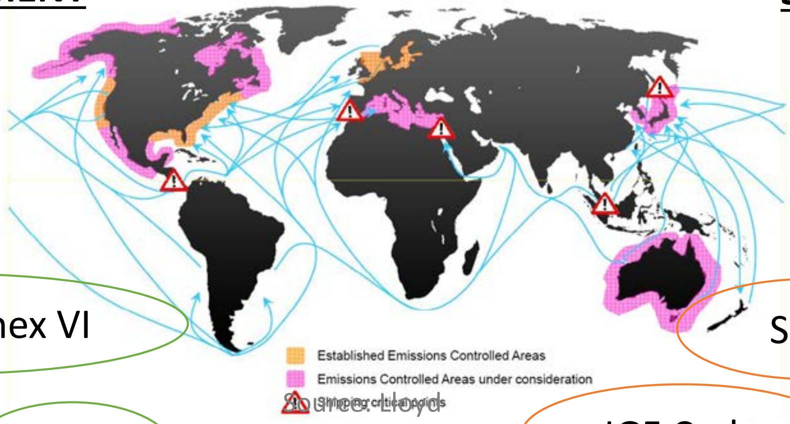
Rail Transport

Other Transport

Road Transport

ENVIRONMENT

SAFETY



Source: Lloyd Register

Marpol Annex VI

SRtP

EEDI

IGF Code

NOx and SOx limitations

FUEL

CO_{2e}

ALTERNATIVE FUELS

3.7% GHG emissions

1. Marine Applications

What are ships performances?

80 g/ton-km — ~14% ton-km

3 g/ton-km — **>70% ton-km** — **~3,7% GHG**

16 g/ton-km — ~12% ton-km

But ship GHGs are growing,
15% by 2050 in a not ruled scenario

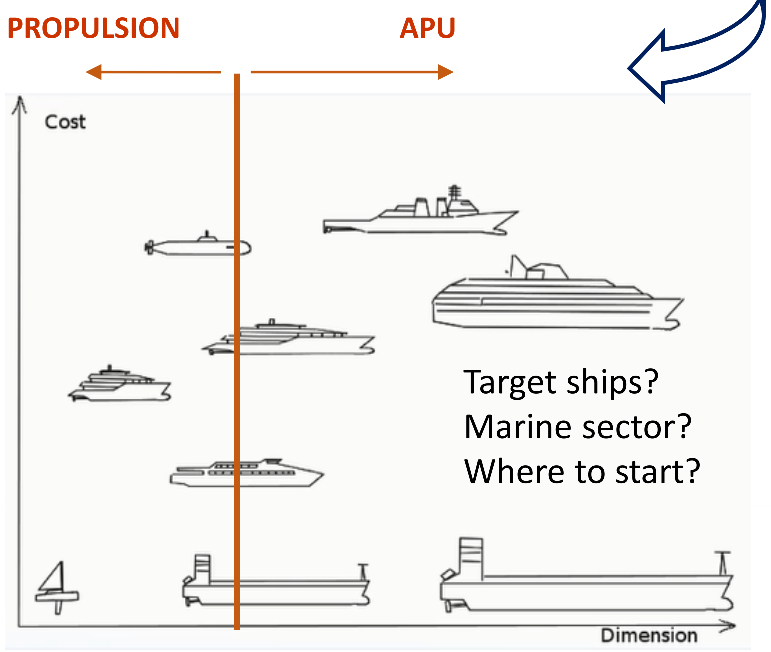
SSS

Short Sea Shipping

Modal shift to SSS element in the EU Transport/Environmental strategy but not only

Focus on Local emission
- Ports
- Costal

Ruling Parameters
- Kind of Ships
- Time of stay in Port
- % in ECA



Some important aspect that have to be considered:

- Redundancy
- Startup Time
- Hybrid Systems
- Operative conditions
- Hydrogen production
- Bunkering
- Traditional vs Diesel-Electric
- **Space**
- **Energy/Power requirements**
- **Costs**

Is Hydrogen an alternative energy vector?

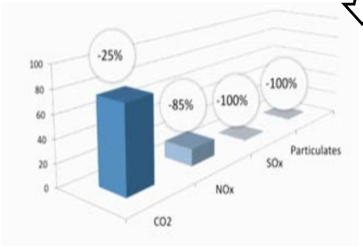
Criteria:

- Local and regional impacts
- Overall environmental impact
- Infrastructure
- Fuel costs

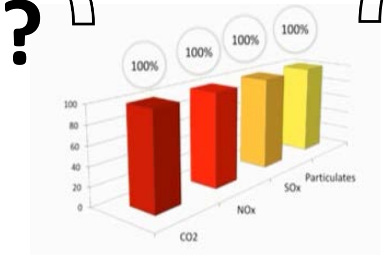
#		S1	S3	S4	S5	S6	S7	S9
MEDIUM		FO	LNG	LPG	METHANOL	CH2	LH2	MH
STORAGE		Bare Tank	Cryogenic	Pressurized	Bare Tank	Compressed	Criogenic	Bare Tank
note			2 bara	18 bara(1bara)		700 bar	- 252 °C	Intermetallic

STORAGE	unit	Bare Tank	Cryogenic	Pressurized	Bare Tank	Compressed	Criogenic	Bare Tank
Energy Density	kWh/l	10.55	3.70	4.01	3.62	0.57	1.33	1.58
Specific Energy	kWh/kg	10.99	6.30	7.03	5.03	0.73	2.11	0.33
CO2 Factor	$kgCO_2/kWh$	0.27	0.18	0.22	0.25	0.00	0.00	0.00
Cost	$/kWh	-	0.94	1.95	2.18	28.5	30.2	332.5
High production	$/kWh					2-4.4	8-15.2	
note			Type C tank	IMO5-container		container sol	liquefaction	30 bar

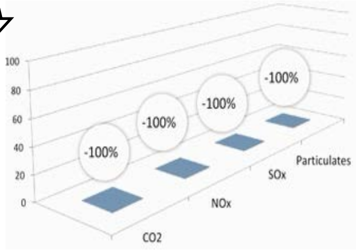
LNG



DIESEL



H2



HYDROGEN

- NO NOx, NO SOx
- NO CO2 (hydrogen production)
- **Storage limitations**

Methane

GWP 20 years	+84
GWP 100 years	+28

Obstacles:
Technical
Political
Investment

Even though LNG is undisputedly a cleaner alternative fuel to diesel oils, it is still a fossil fuel!

NO SILVER BULLET SOLUTION

CARBON NEUTRAL FUEL HAS TO BE CONSIDERED

What is most suitable power generator for hydrogen? Fuel Cells

Which fuel cell typology?

SHORT	MEDIUM	LONG
HTPEM	HTPEM	SOFC
PEM	PEM	

η_{el}

PEMFC
Commercial Technology
Leading Sector: Automotive
Goal: Technology Transfer

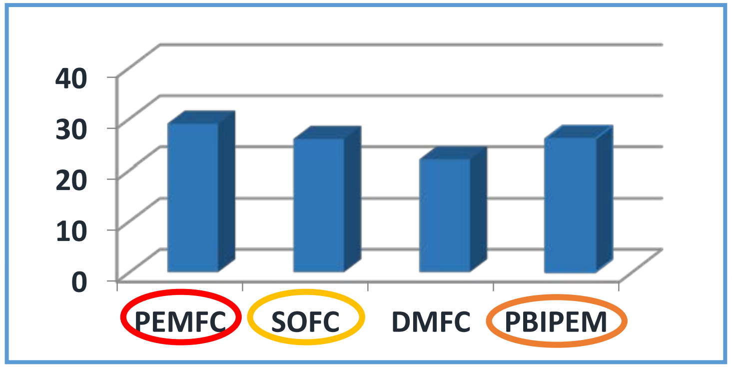
Problems:

- Power range (kW)
- Energy range (kWh)

Tasks:

- Scale-Up
- Marinization

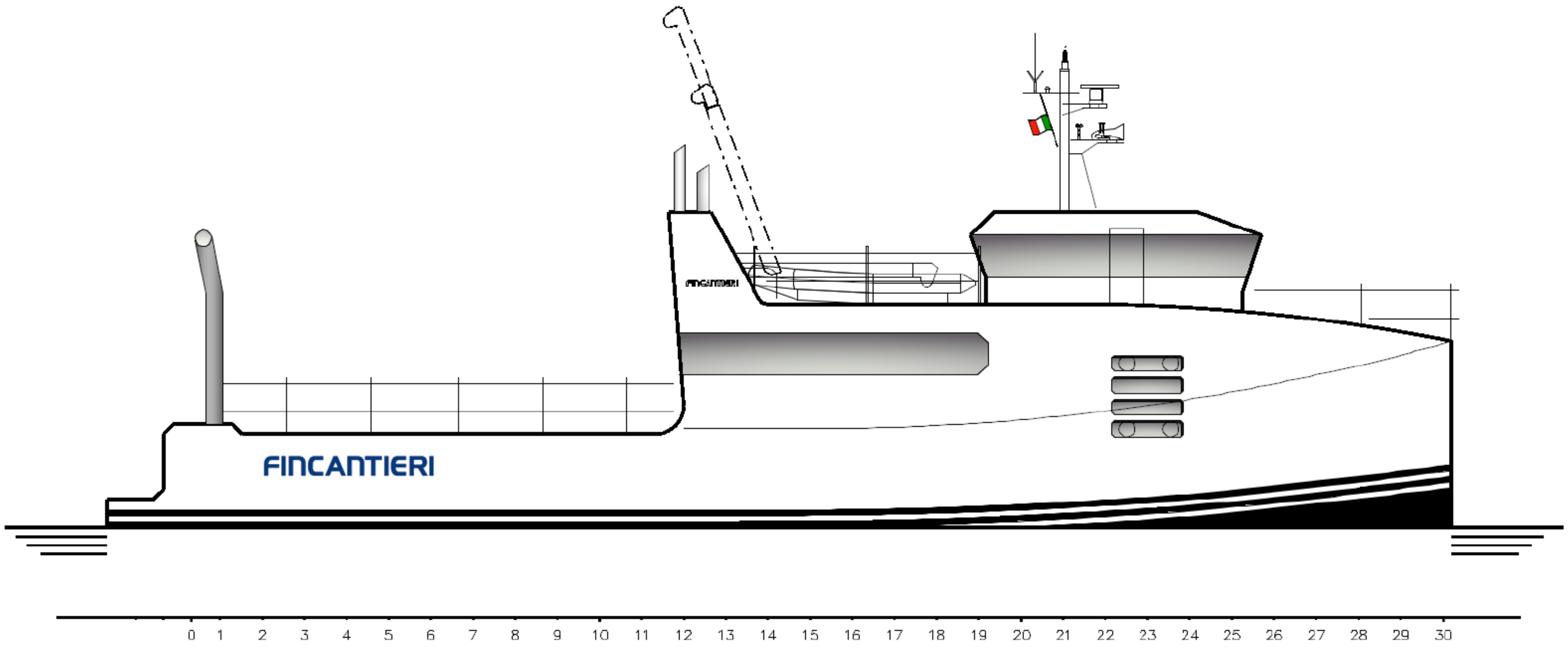
First Fuel Cell Comparative Model



Fuel Cell Comparative Model: EMSA Study

Technology / Attributes	Relative cost	Module kW levels	Lifetime	Tolerance for cycling	Fuel	Maturity	Size	Sensitivity fuel impurities	Emissions	Safety Aspects	Efficiency	Total
Weighting	3	2	3	2	3	3	3	3	2	3	3	
Alkaline fuel cell	3	3	2	3	1	2	2	1	3	3	2	
	9	6	6	6	3	6	6	3	6	9	6	66
Phosphoric acid fuel cell	2	3	3	2	2	2	1	2	3	2	2	
	6	6	9	4	6	6	3	6	6	6	6	64
Molten carbonate fuel cell	1	3	3	1	3	3	1	3	1	2	3	
	3	6	9	2	9	9	3	9	2	6	9	67
Solid oxide fuel cell	1	3	2	1	3	3	2	3	2	2	3	
	3	6	6	2	9	9	6	9	4	6	9	69
Proton Exchange Membrane	3	3	2	3	1	3	3	2	3	3	2	
	9	6	6	6	3	9	9	6	6	9	6	75
High Temperature PEM	2	2	2	3	2	2	3	3	3	2	3	
	6	4	6	6	6	6	9	9	6	6	9	73
Direct methanol fuel cell	2	1	2	3	3	1	2	3	1	3	1	
	6	2	6	6	9	3	6	9	2	9	3	61

Thank you



ZEUS - Fincantieri Research Vessel

2018-2021 TecBIA Research Project

PRIVATE COMPANIES

UNIVERISTY
OF GENOVA

FINCANTIERI
The sea ahead

Genova HI-SEA

Hydrogen Initiative for Sustainable Energy Applications

Fuel Cell Systems
University Technology Centre

EUROPEAN

FUEL CELLS AND HYDROGEN
JOINT UNDERTAKING

Hydrogen Europe

Hydrogen Europe Research

STARTUP

h2boat
hydrogen to boat

INTERNATIONAL

iea Energy Technology Network

TASK39