NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

Energy Research Institute @ NTU

Potential application of fuel cell in harbor craft

Energy Smart, Research & Innovation.

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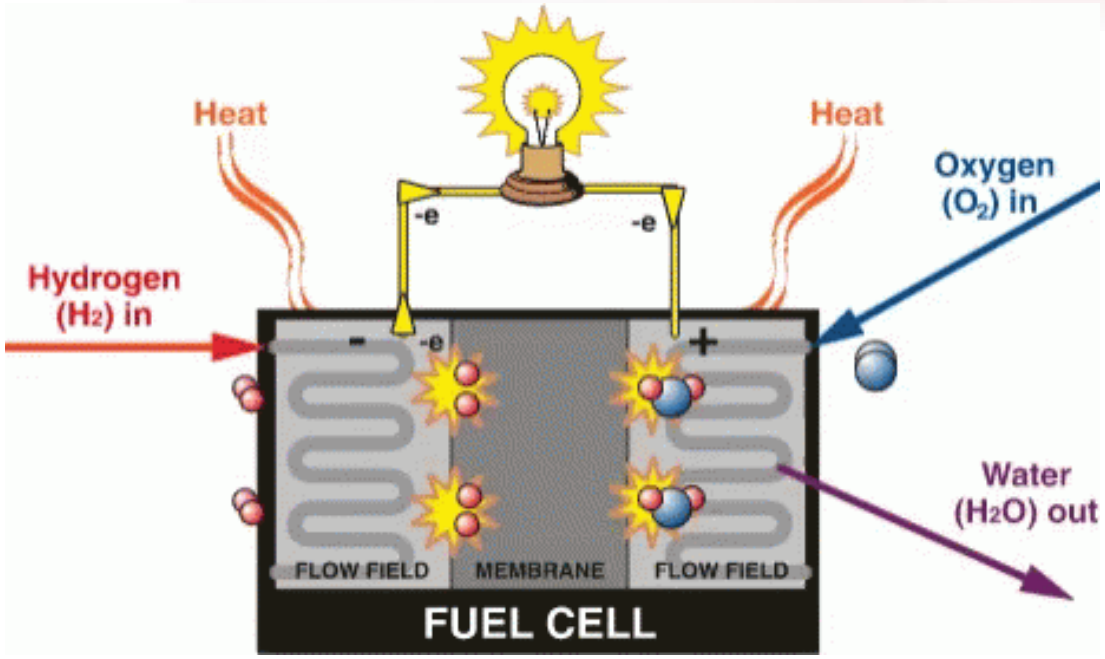
Introduction

Fuel cell - Basics



An electro-chemical device that converts hydrogen and oxygen into heat and power

Water is the **only by-product** of a closed-loop cycle

Low/No environmental impact

No oil or heavy metal

Introduction

Types of fuel cell and their characteristics

Temperature range

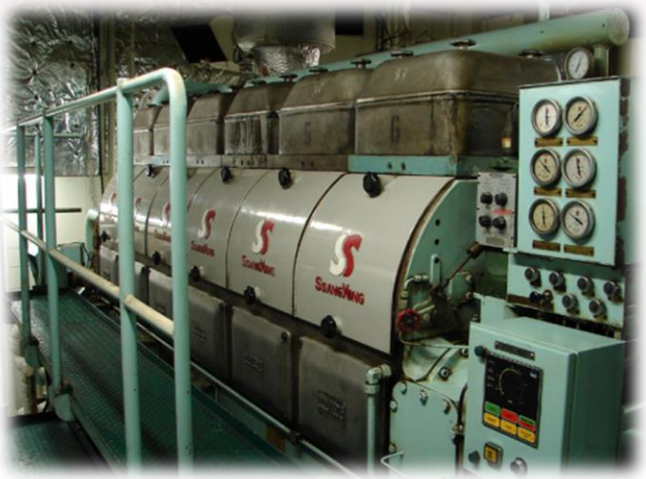
Type of fuel cell	Operating temperature	Fuel	Electrical efficiency
Solid oxide FC	800 to 1000 °C	H2 to NG	45 to 65%
Pros: Fuel flexibility, high efficiency, can be combined with gas turbine, high grade heat Cons: Limited power modulation, long start-up time			
Molten carbonate FC	About 650 °C	H2 to NG	45 to 50%
Pros: Fuel flexibility, high efficiency, high grade heat Cons: Low power density, long start-up time, corrosive electrolyte			
Phosphoric acid FC	About 200 °C	H2	35 to 42%
Pros: Mature, higher tolerance of impurities, medium grade heat Cons: Low power density, relatively long start-up time			
Alkaline FC	90 to 100 °C	H2	35 to 40%
Pros: Quick start-up, mature Cons: Sensitive to CO_2 and other impurities, low grade heat			
Polymer electrolyte FC	60 to 90 °C	H2	35 to 40%
Pros: Quick start-up Cons: Sensitive to impurities, low grade heat, expensive catalyst required			

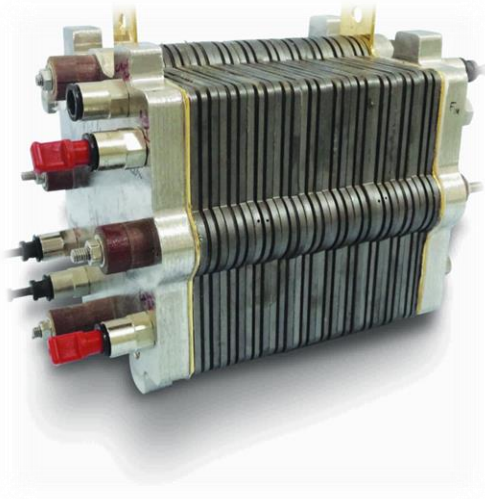
Comparison against other technologies

Vs. diesel generator

Advantages:

- **High part load** electrical efficiency
- **Near zero** NO_x, SO_x and PM emissions
- **Low or zero** CO_2 emission (depending on fuel), possible to reduce by 20-30%
- Low noise (~75 dB@1m)
- Few moving parts
- Low maintenance
- No vibration



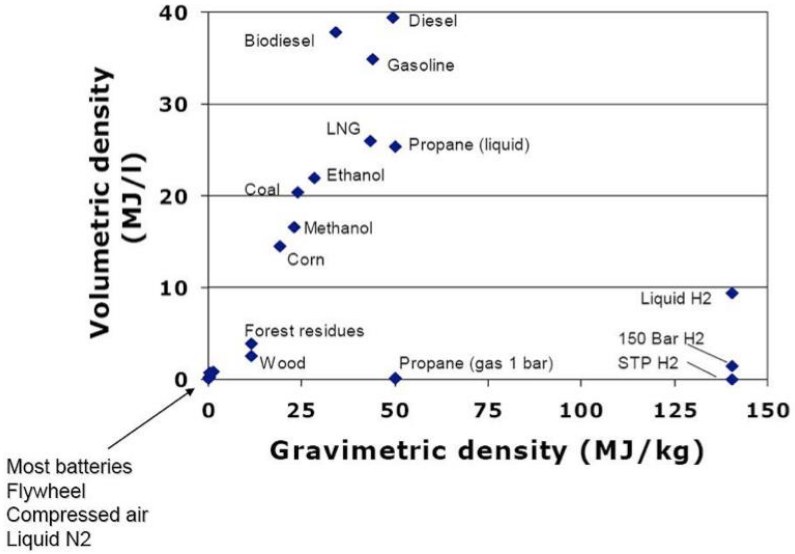


Comparison against other technologies

Vs. battery

Advantages:

- **No self-discharge** over time
- Low maintenance
- Low OPEX (Replacement and air-conditioning)
- No thief of batteries
- **Less environmental impact** upon disposal
- Higher storage capacity
- Heat recovery option

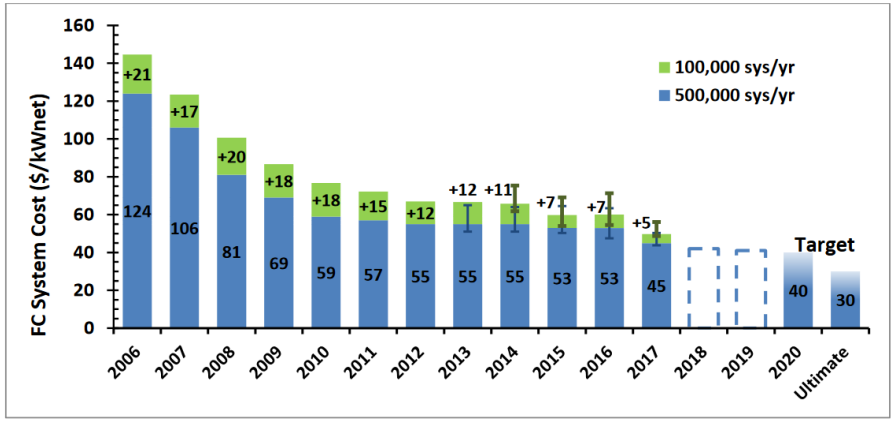


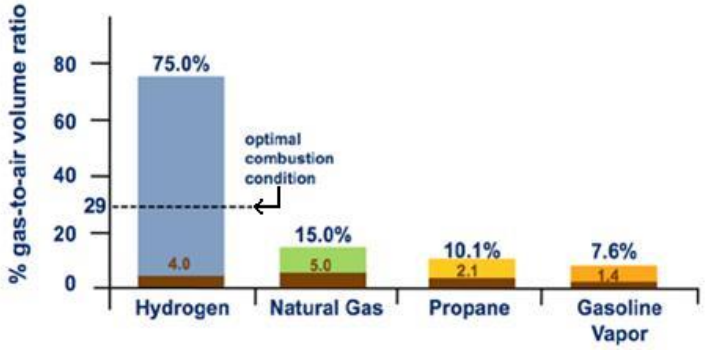
Comparison against other technologies

Challenges Vs. others

Challenges:

- System cost
- Sources and availability of hydrogen
- Unified regulations of fuel production, storage & distribution infrastructure
- Space availability on-board
- Safety concerns
- Public acceptance





Past fuel cell ship projects

Outcomes

	Description	Year	Fuel	
	(30x2) kW modularised HT-PEMFC tem developed and tested for decentralised auxiliary power supply on-board passenger vessel	Phase 1: 2009-2017 Phase 2: 2017-2022	Methanol	Succes Results CHP on-board
E4Ships – SchIBZ	100 kW containerised SOFC system developed and tested for auxiliary power supply of com	Phase 1: 2009-2017 Phase 2: 2017-2022	Diesel	System tested successfully on-shore.
Fellowship	320 kW MCF OSV			Successfully demonstrated
Hornblower Hybrid	Hybrid ferry w PV, wind and fuel cell			32 kW PEMFC, For rent in New York
MC-WAP	Application of MCFC on-board large vessels	2005-2010	Diesel	150 kW MCFC, emonstrated
METHAPU – Viking Lady				emonstrated for
Zemship	100 kW PEMFC system developed and tested on-board of a small passenger ship	2006-2013	Hydrogen	Successful demonstration

(FellowShip)
44.5% electrical efficiency achieved
No NOx, SOX and particulates detected

(Foss tug boat)
Hybrid tug has shown to reduce 73% of particulate matters (PM), 51% of NO_x and 27% of CO_2

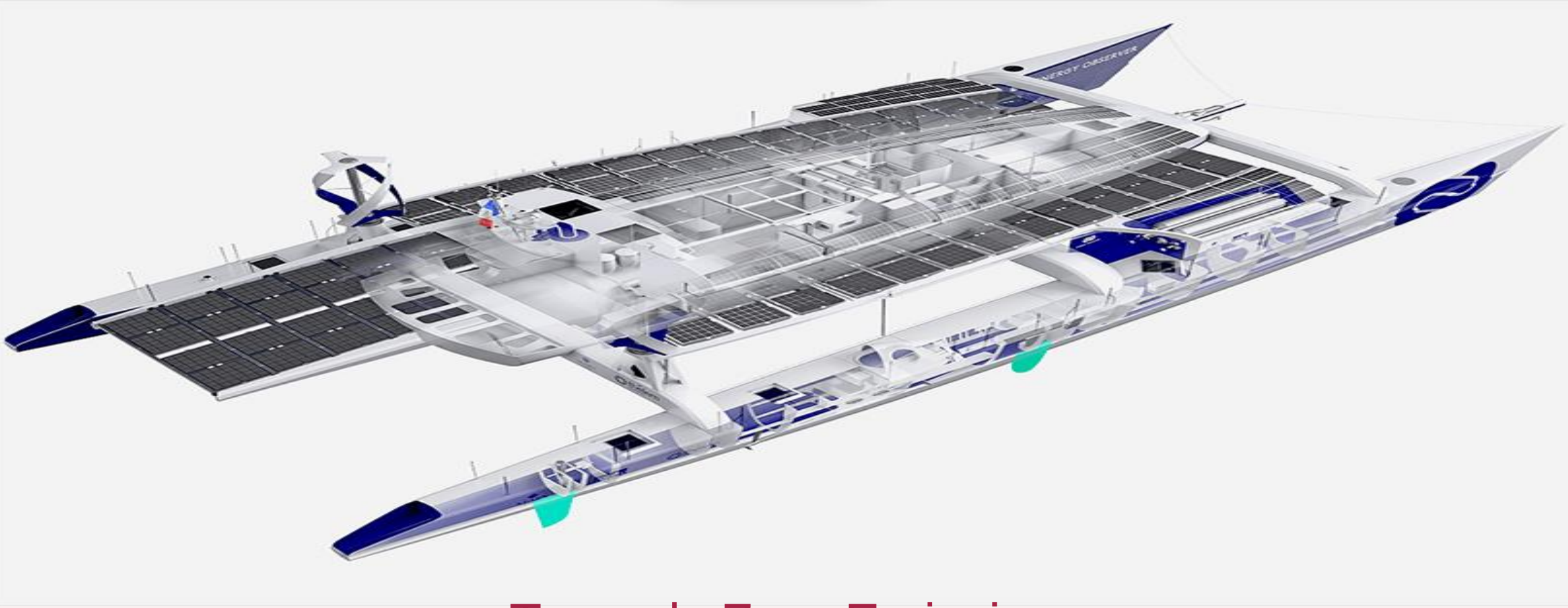
Conclusion

Fuel cell has been proven technically feasible in many of the demonstration and trial projects.

The main barriers to adoption is the supporting infrastructure and the CAPEX required.

There is no one technology that would resolve all the problems.

To obtain the optimal result, we have to explore the synergistic effect between different types of technologies, gathering the strength and eliminate/reduce weakness of each technology.



Towards Zero Emission

❖Transport ❖ Buildings ❖ Power Generation ❖

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