

# Reduced and zero emission operations

Energy Storage & Fuel Cells



# Local and global emissions

## Pollutants

Harmful for local environment and health

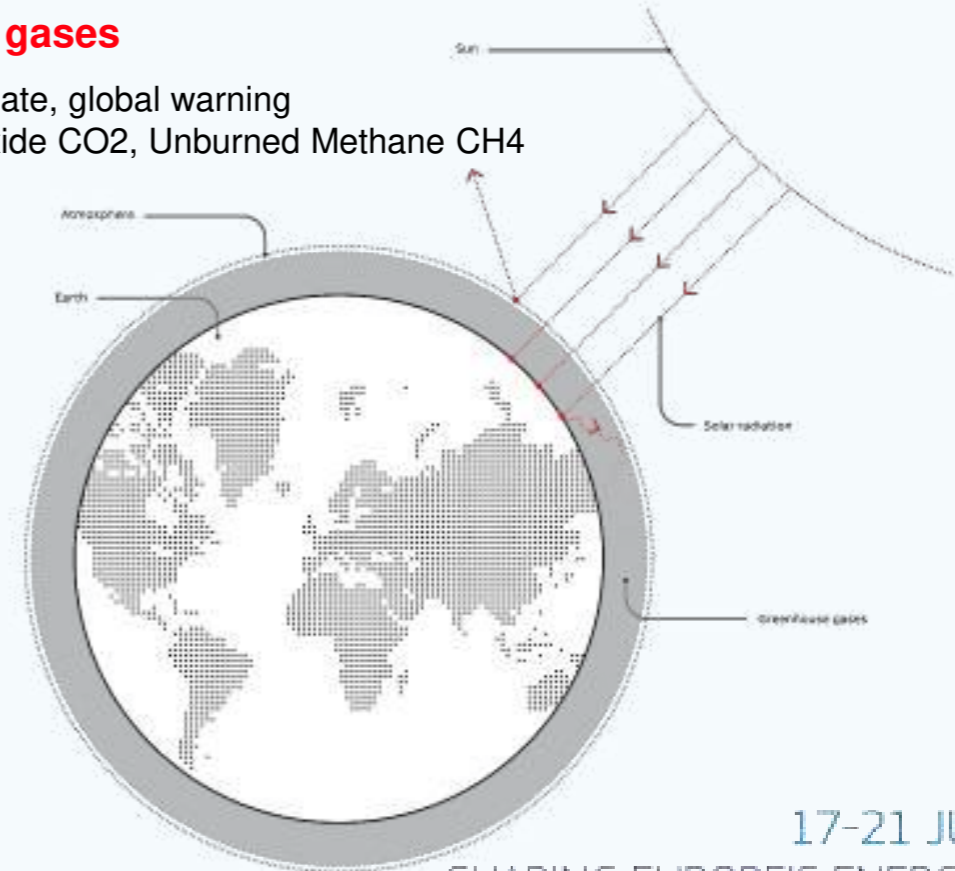
- Nitrogen Oxid NOx, Sulpur Oxides SOx, Soot, particles



## Greenhouse gases

Harmful for climate, global warming

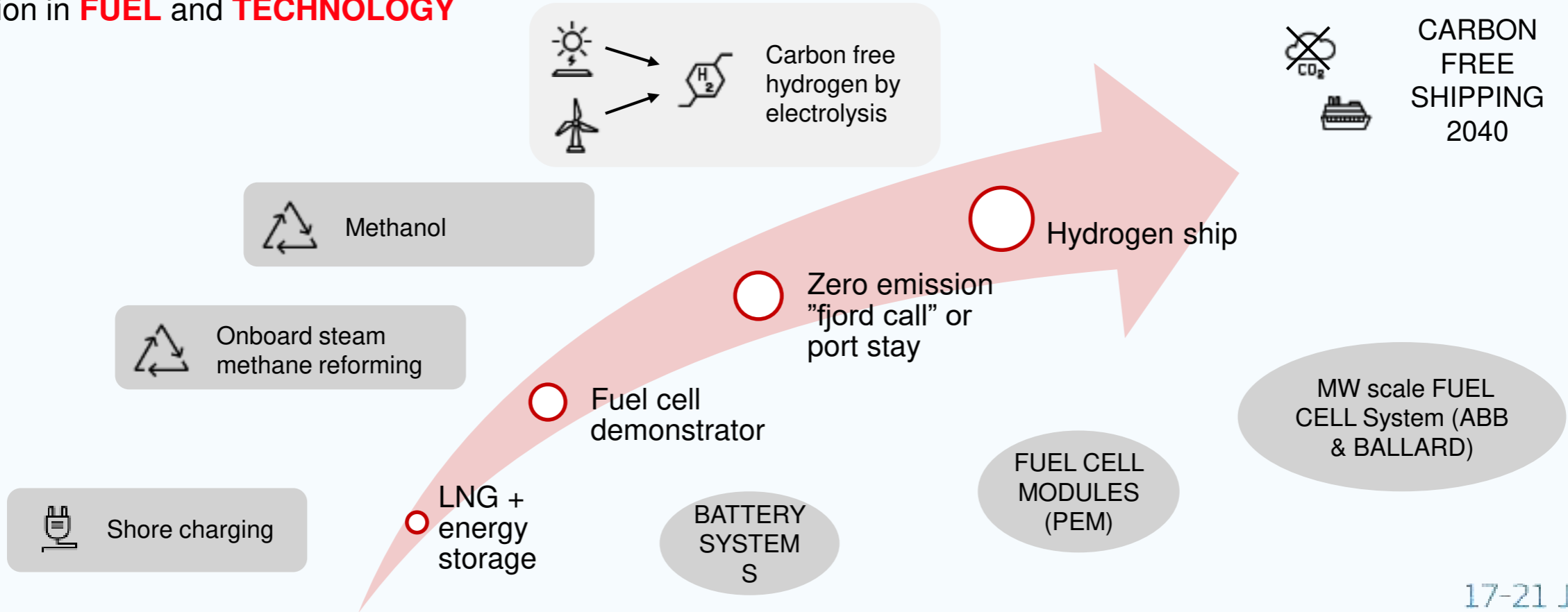
- Carbon dioxide CO<sub>2</sub>, Unburned Methane CH<sub>4</sub>



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# Pathway to carbon free shipping

Transition in **FUEL** and **TECHNOLOGY**



# **Electric & Hybrid Ships**

## **Energy Storage**

# Electric propulsion & Hybrid Power Plants for Ships

## Basic Systems

Diesel or Gas Generator sets to produce electricity to common grid for propulsion and ship use, with variable speed drives to rotate propellers.

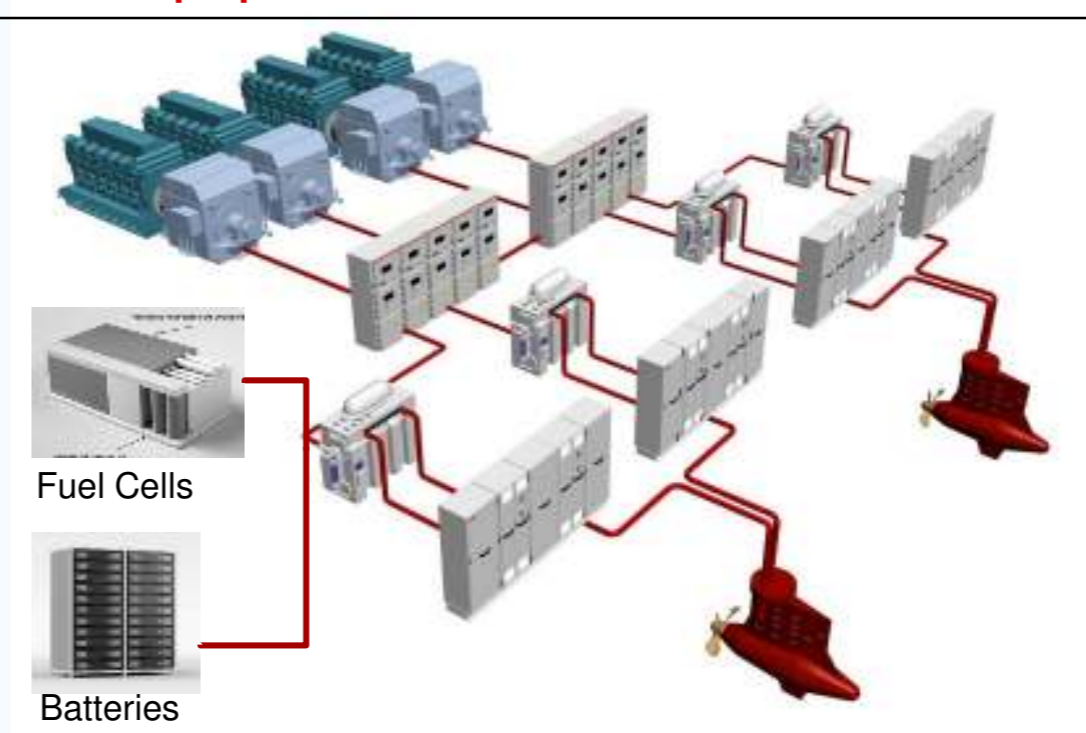
Commonly used in:

- Icebreaking vessels
- Cruise vessels
- Ferries and yachts
- Tankers
- Offshore vessels

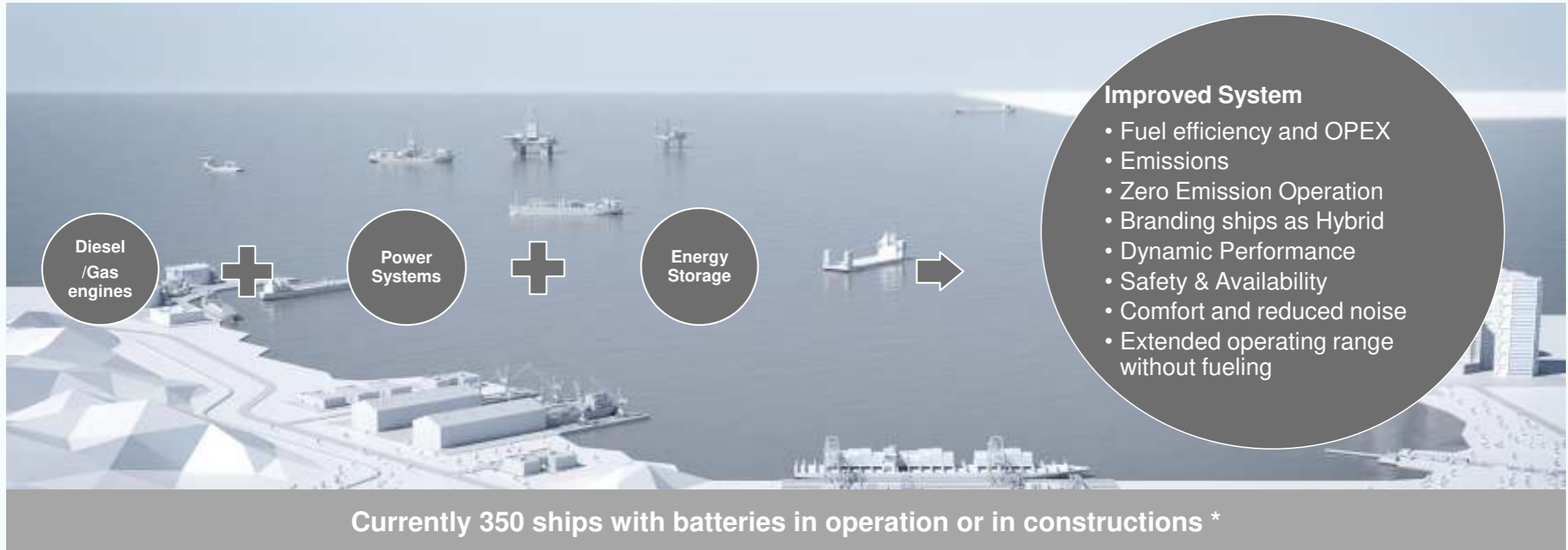
Hybrid Power Plants

- Expand with Batteries
- Expand with Fuel cells

## Electric propulsion



## Why use Battery Hybrid Solutions?



# Energy Storage for expedition cruiser, including Zero emission “Fjord call”

## Example, 6 hour Operation in Zero emission

Hotel & Auxiliary Load:	2MW
Propulsion Power, slow steaming:	1.MW (9 kn)
Energy Demand from battery:	18.000KWh
Needed battery Capacity:	20.000kWh
Charging at sea with Diesel or gas engines without increase in emissions	



## Battery Applications:



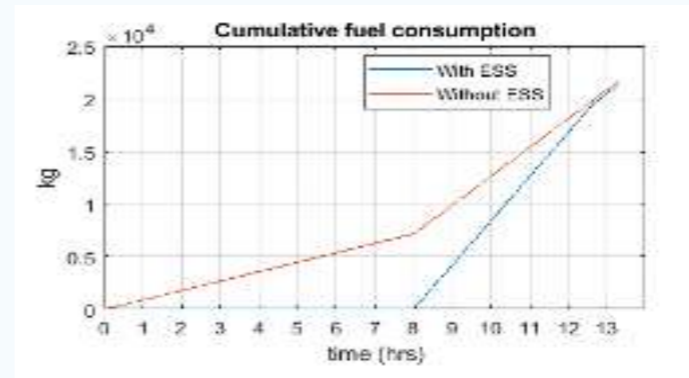
Strategic Loading of Engines to Optimize operating point



Peak Shaving, Level loading seen by engines



Zero Emission, Power system is fully powered by batteries.



Batteries can enable Zero Emission Operations for “Smaller” Cruise Ships

# **Electric & Hybrid Ships**

## **Fuel Cell Systems**



# Industry benchmarks: Fuel Cells are replacing conventional power sources

**Transportation**

>10000 FC cars in operation



**Hydrogen Fuel cell trains are in operation**

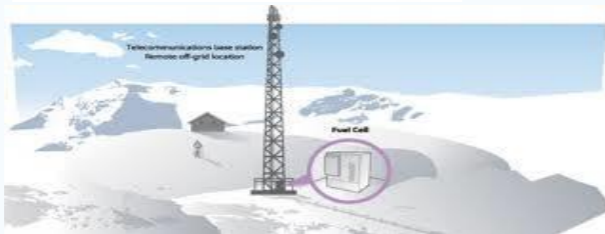
~ 20 000 Fuel Cell forklift in operation



**< 3000 FC bus in operation. Ravidly growing segment**



**Stationary**



**Telecommunication back up power**

**Power Grid back up**



200 000 households powered by FC in Japan



**59 MW FC park in Korea**

# IMO (International Maritime Organization) initial greenhouse gas strategy

April 2018



Reduce **CO<sub>2</sub>** emissions by at least **40% by 2030**

and pursuing efforts towards **70% by 2050**

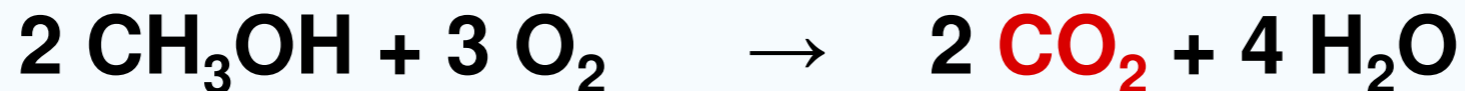
Reduce total annual **GHG** emissions by at least **50% by 2050**  
compared to level of 2008

## Alternative fuels for green shipping

### METHANE



### METHANOL



### HYDROGEN



## Fuel cells and alternative fuels

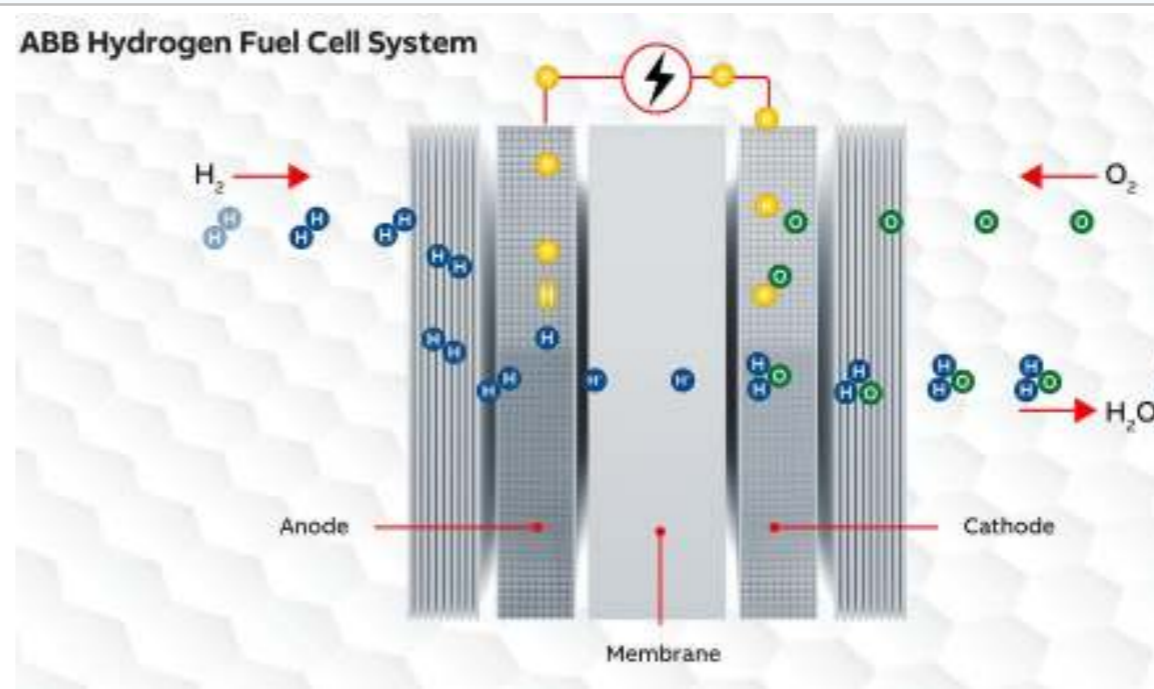
Fuel cell types can be divided by fuel, operating temperature, reaction time or electrolyte material.

### THE 3 MOST PROMISING FC TECHNOLOGIES:

- **PEMFC for pure hydrogen (Proton exchange membrane fuel cells)**
- HT-PEMFC for methanol or diesel
- SOFC for hydrogen or different hydrocarbons (Solid oxide fuel cells)

Emissions depends on used fuel

- Pure hydrogen -> H<sub>2</sub>O
- Hydrocarbons (diesel, natural gas, methanol...)-> H<sub>2</sub>O + CO<sub>2</sub>
- Using hydrocarbons – CO<sub>2</sub> about 60-80% from combustion engine



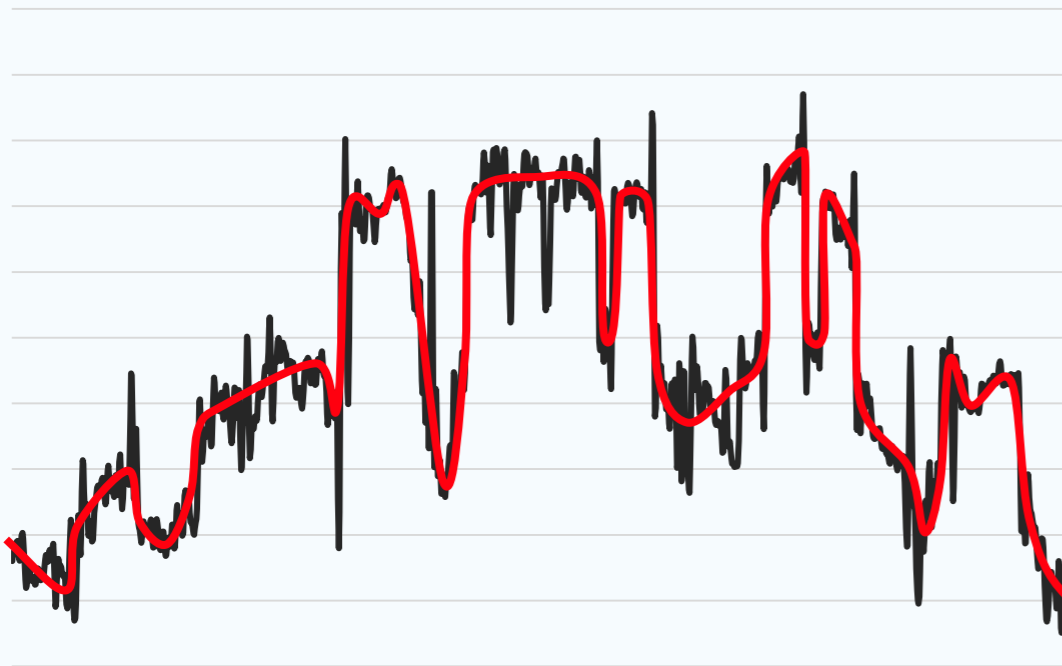
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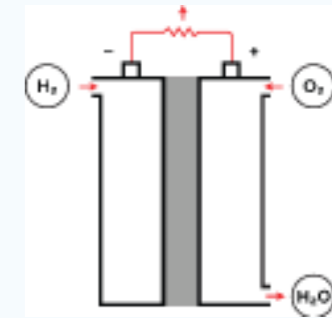
# Integration with batteries

## Operational profile of the vessel



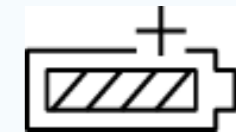
## Fuel cells for base load

- Energy can be stored at high density in hydrogen
- Controlled and stable operation improves life time of fuel cells
- Fuel cells run continuously at high efficiency



## Batteries for dynamics and backup

- Batteries are able to supply variable load at fast response
- System can be designed for high instantaneous power rating
- Backup and cold start can be implemented with batteries



# — Fuel cell systems in marine vessels

*Technology demonstrators and small-scale systems are delivered today*

*and **high-power solutions** are already on the way.*

## Some references on fuel cell installations

### Hydrogenics maritime fuel cell container

- 100 kW fuel cells, power converters and control systems
- Integrated and tested in ports and marine environment
- Used as a demonstration plant towards US Coast Guard.



### RCL fuel cell demonstrator

- 100 kW fuel cells, power converters and control systems
- Presented in RCL Technology Display Days 2017
- To be piloted on Royal Caribbean International vessel



### Research project MARANDA

- 2 x 82,5 kW fuel cells, power converters and control systems
- Integrated and tested in research vessel Aranda
- EU funded research projects 2017...2021



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# Fuel Cell, Zero Emission vessel

River Pusher Tug for CFT, Compagnie Fluviale de Transport



## Project information

One of two FLAGSHIPS projects, supported by the Fuel Cells and Hydrogen Joint Undertaking (FCH JU),

Operation:	Rhône river
Fuel:	Hydrogen from shore-based renewable energy
Design:	LMG Marin
Delivery Year:	2021
Owner:	CFT

## Solution : Fuel Cell with DC Power & Propulsion System

Fuel Cells, 400kW from Ballard Power Systems  
 Converters & Propulsion motors  
 Power & Energy Management & Fuel Cell Control  
 Fuel Cell Power integration  
 System Engineering  
 Energy Storage

## Other information

Consortium members in Flagship project  
 CFT  
 VTT  
 LMG Marin  
 Ballard Power Systems  
 NCE Maritime CleanTech  
 Norled

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# Maritime Fuel Cell Projects

Hydrogen fuel cell vessels, not just a vision anymore



MARANDA , 165 kW FC,  
Operation 2019



RCL, 100kW  
FC demo



Golden Gate Zero 360kW FC,  
Operation 2019



Norled,  
Operation 2021



Fiskerstrand Ferry, Pilot E,



CFT Flagship, 400kW FC,  
Operation 2021



Hyseas III, 700kW FC, Operation  
2021



Havila Kystruten, Pilot E

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## Maritime Fuel Cell Projects continued...



ZEFF, Pilot E



Flying Foil, Pilot E



Sea Shuttle, Pilot E



Kawazaki, LH2 Carrier



Moss, LH2 Carrier



Norled, Flagship

## ABB fuel cell systems

Scalable and compact solutions up to several megawatts

### Small-scale systems – commercial fuel cell modules

Customized solutions built from 100 kW modules

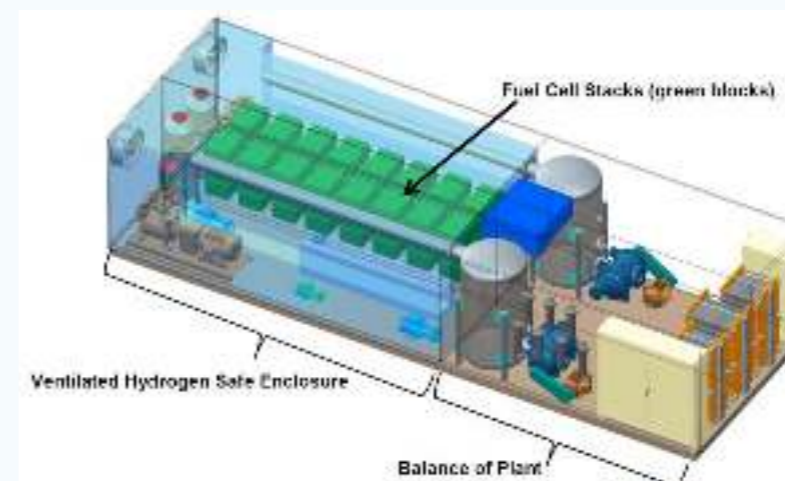
- Multiple suppliers for PEM fuel cell modules
- Small vessels or technology demonstrators
- Power converters, control systems and integration by ABB
- Integration with DC grid or AC network



### Large-scale systems –MW generation units

Joint development of ABB and Ballard

- Fuel cells and balance of plant integrated into single frame
- Modular stand-alone units 12 x 3.6 x 2.4 m (length x width x height), weight with power converters ca. 45 tons



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**Let's write the sustainable future. Together.**

