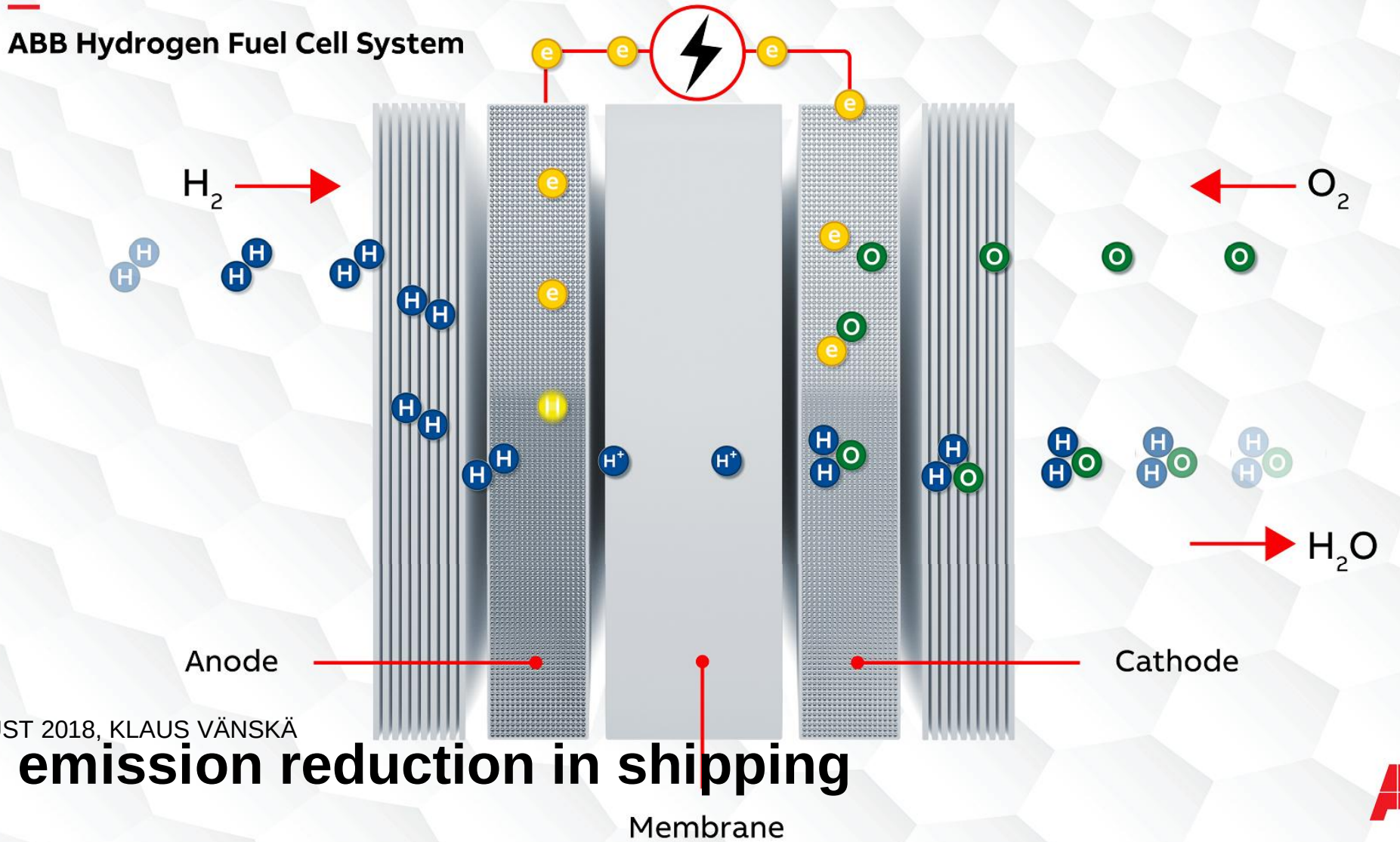


22ND AUGUST 2018, KLAUS VÄNSKÄ

GHG emission reduction in shipping

Content

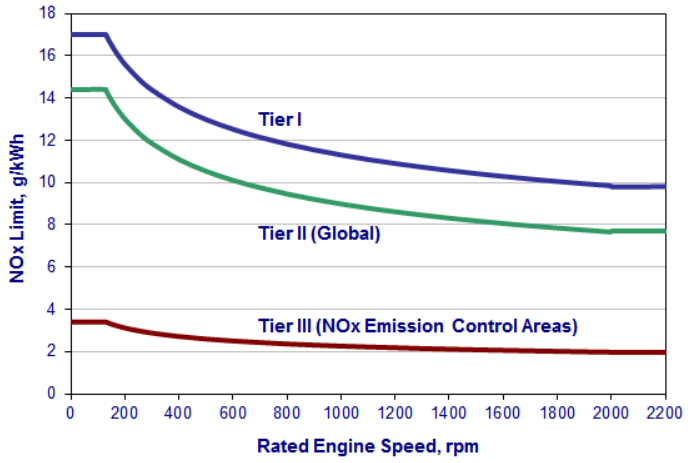
1. Current regulations
2. IMO targets
3. Future fuels and technologies
4. Renewable H2 production
5. Fuel Cells for marine vessels

Current regulations

MARPOL Annex VI Nox limits

Tier	Date	NOx Limit, g/kWh		
		n < 130	130 ≤ n < 2000	n ≥ 2000
Tier I	2000	17.0	$45 \cdot n^{-0.2}$	9.8
Tier II	2011	14.4	$44 \cdot n^{-0.23}$	7.7
Tier III	2016†	3.4	$9 \cdot n^{-0.2}$	1.96

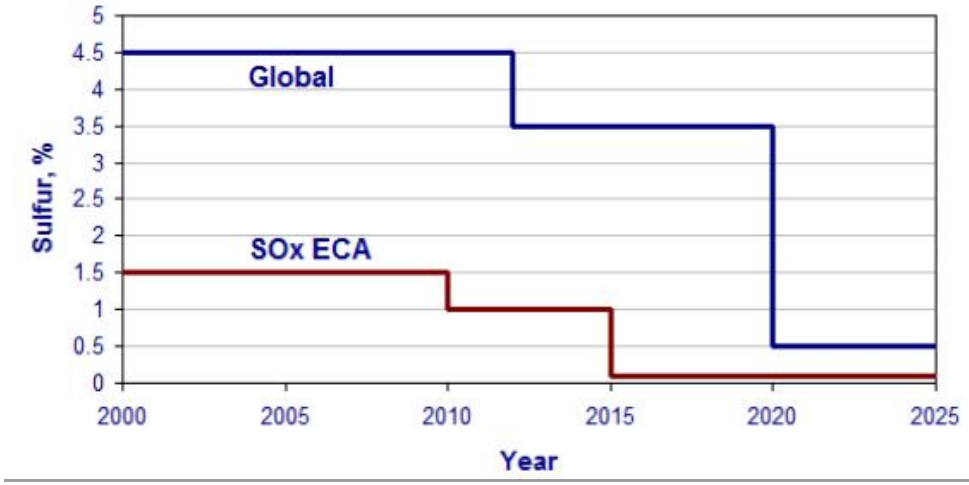
† In NOx Emission Control Areas (Tier II standards apply outside ECAs).



Current regulations

MARPOL Annex VI Sox limits

Date	Sulfur Limit in Fuel (% m/m)	
	SOx ECA	Global
2000	1.5%	4.5%
2010.07	1.0%	
2012		3.5%
2015	0.1%	
2020		0.5%



How to get there?

Used technologies

NOx reduction methods

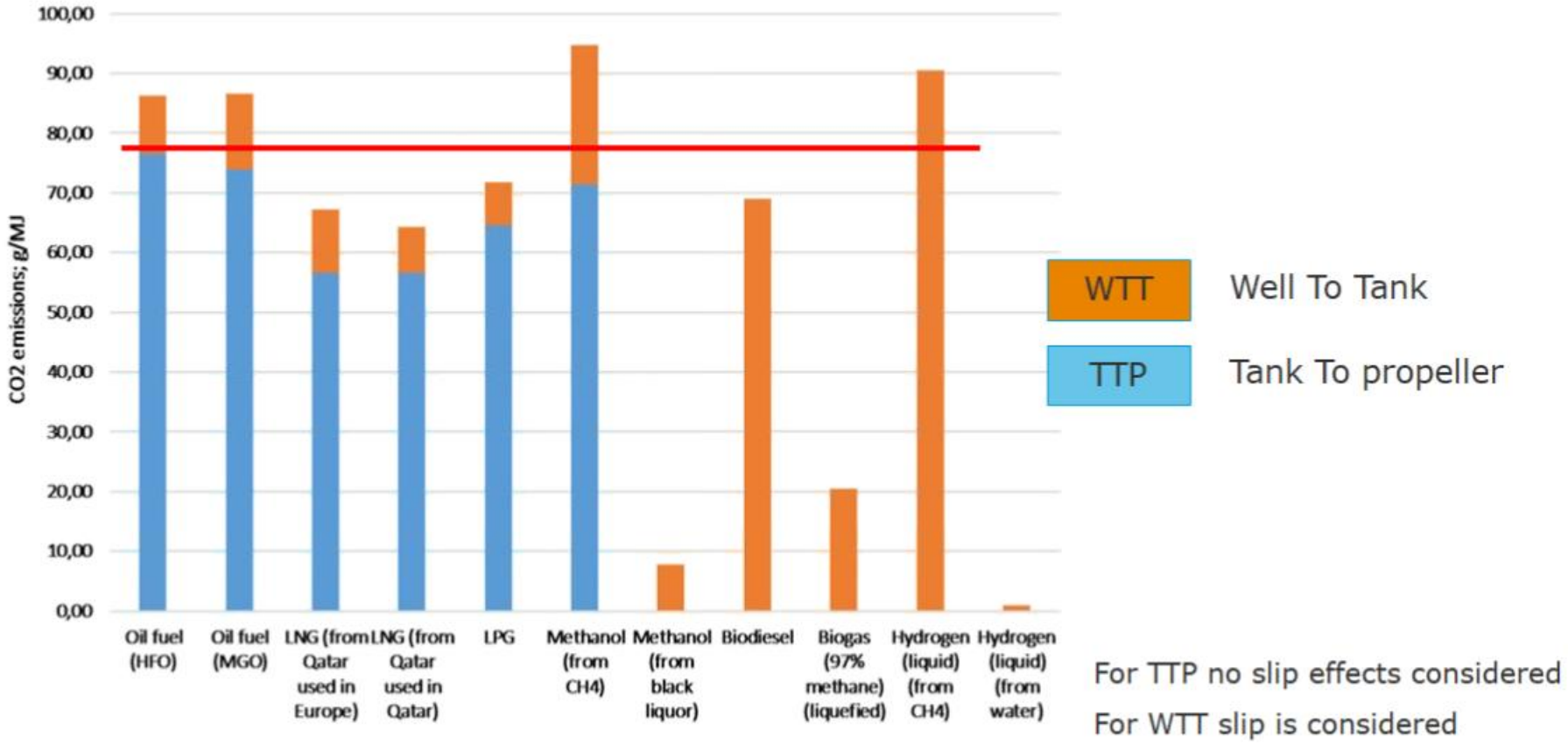
- (SCR) Selective Catalytic Reaction
- (EGR) Exhaust Gas Recirculation
- Water and water vapour injection
- Engine and turbocharger tuning
- LNG engine

SOx reduction methods

- Low sulphur fuels
- Scrubbers
- LNG engine

CO2 equivalent emissions of fuel alternatives in shipping

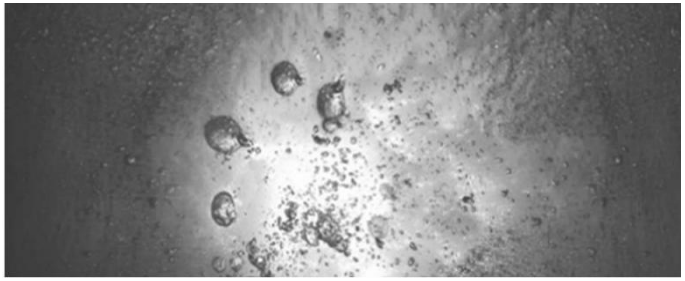
Methane slip of LNG engines not considered



Source: DNV-GL

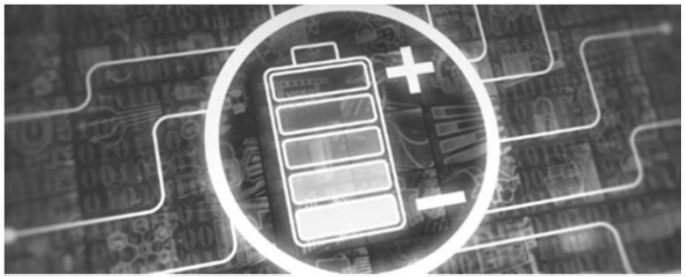
We need to save our environment but also stop global warming

Environment



There are increasing demand to protect of our natural environment and to improve health and well-being of our citizens. There has been high focus to reduce NOx, SOx and particulate matters in past years and this will continue by more tighten requirements.

Carbon Free Resources



Being able to stop Climate Change, it is necessary to limit global surface temperature increase below 1,5 degree compared to pre industrialisation phase. IMO has set a target to reduce absolute greenhouse gas emissions by 50% until 2050.

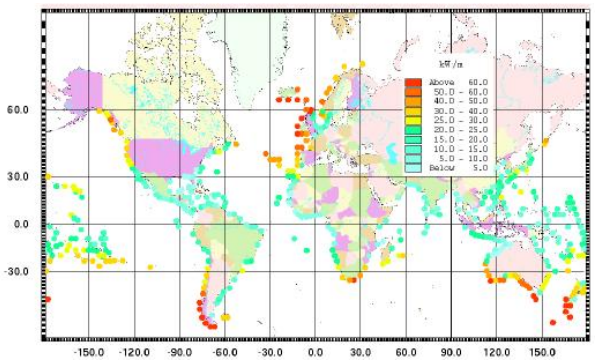
IMO (International Maritime Organization) initial greenhouse gas strategy (April 2018)

Reduce **CO2** emissions by at least	**40% by 2030**
and pursuing efforts towards	**70% by 2050**
Reduce total annual **GHG** emissions by at least compared to level of 2008	**50% by 2050**

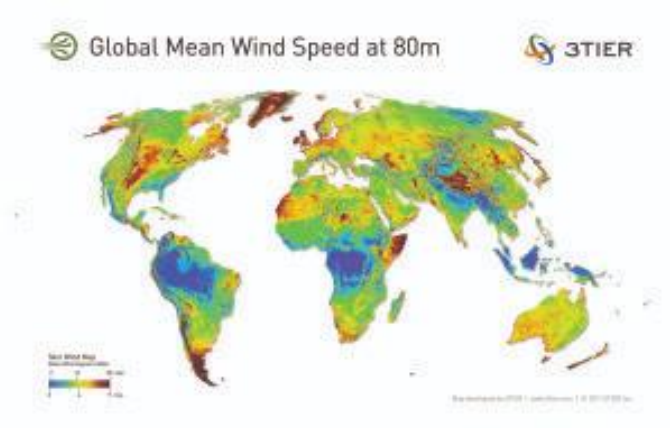
Renewable energy sources

Spots of renewable energy

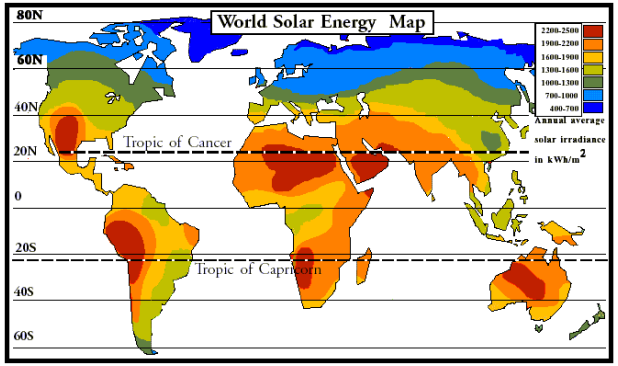
Wave energy spots in coastline



Wind energy spots



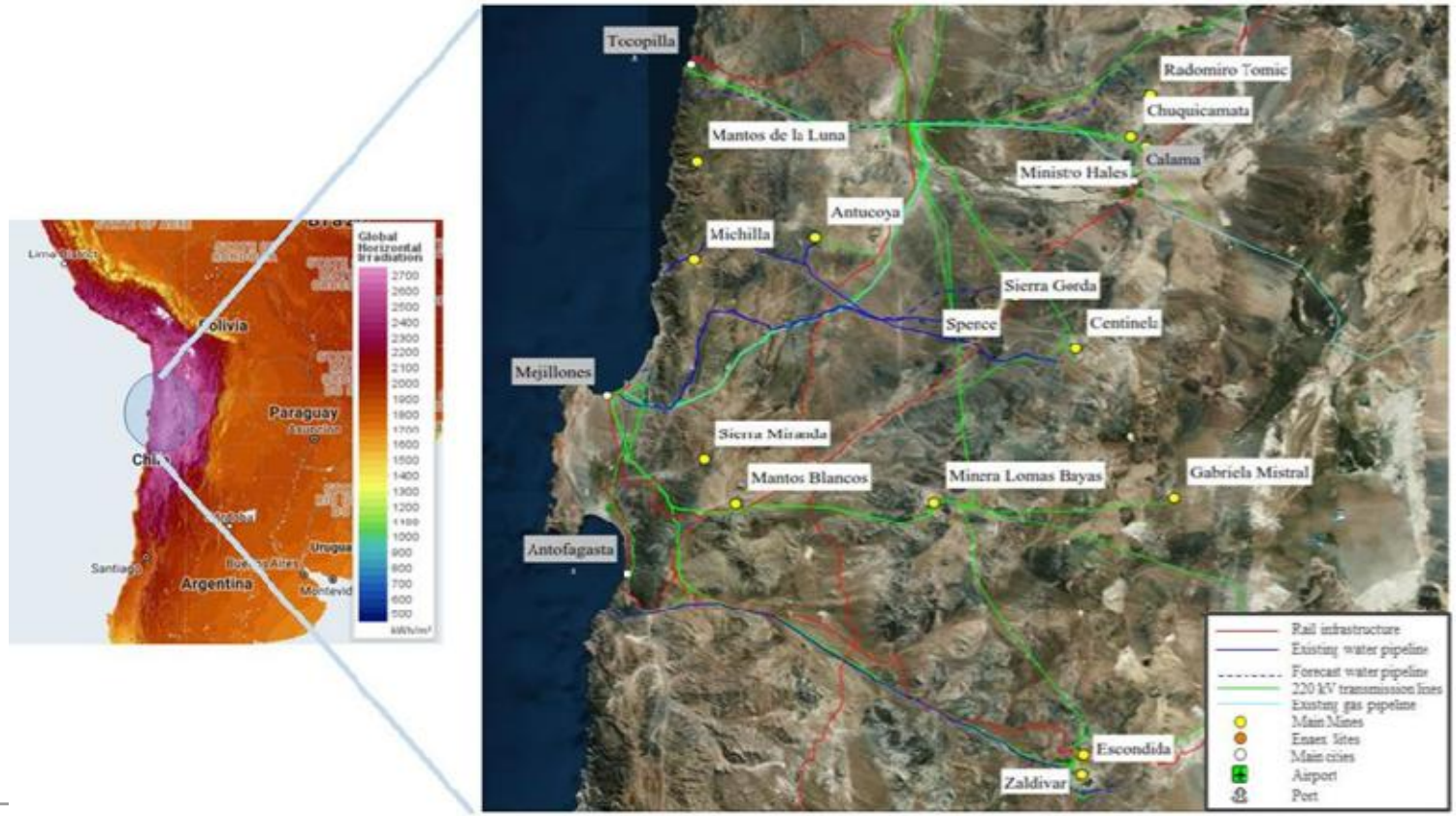
Solar radiation spots



Energy cost is not an issue!

Huge renewable potential to produce H2

Chile has total 1800GW renewable potential – 25GW currently utilized



Demonstration projects

Readiness to go for MW level installations

Hydrogenics maritime fuel cell container

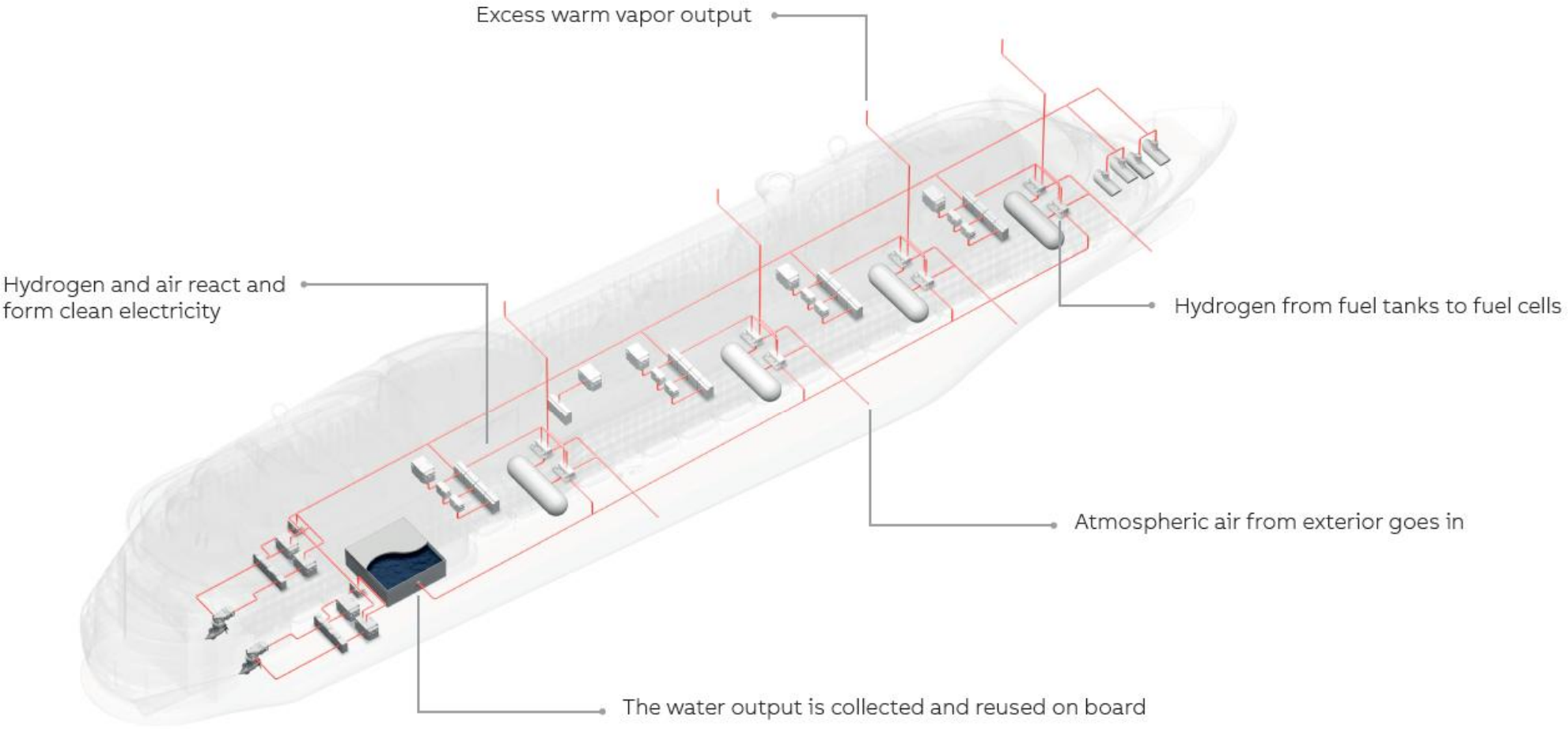
- 100 kW fuel cells, power converters and control systems
- Integrated and tested in ports and marine environment
- Used as a demonstration plant towards US Coast Guard.

RCCL fuel cell demonstrator

- 100 kW fuel cells, power converters and control systems
- Presented in RCCL 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


Excess warm vapor output
Hydrogen and air react and form clean electricity
Hydrogen from fuel tanks to fuel cells
Atmospheric air from exterior goes in
The water output is collected and reused on board

3 MV Fuel Cell Power Generating Unit