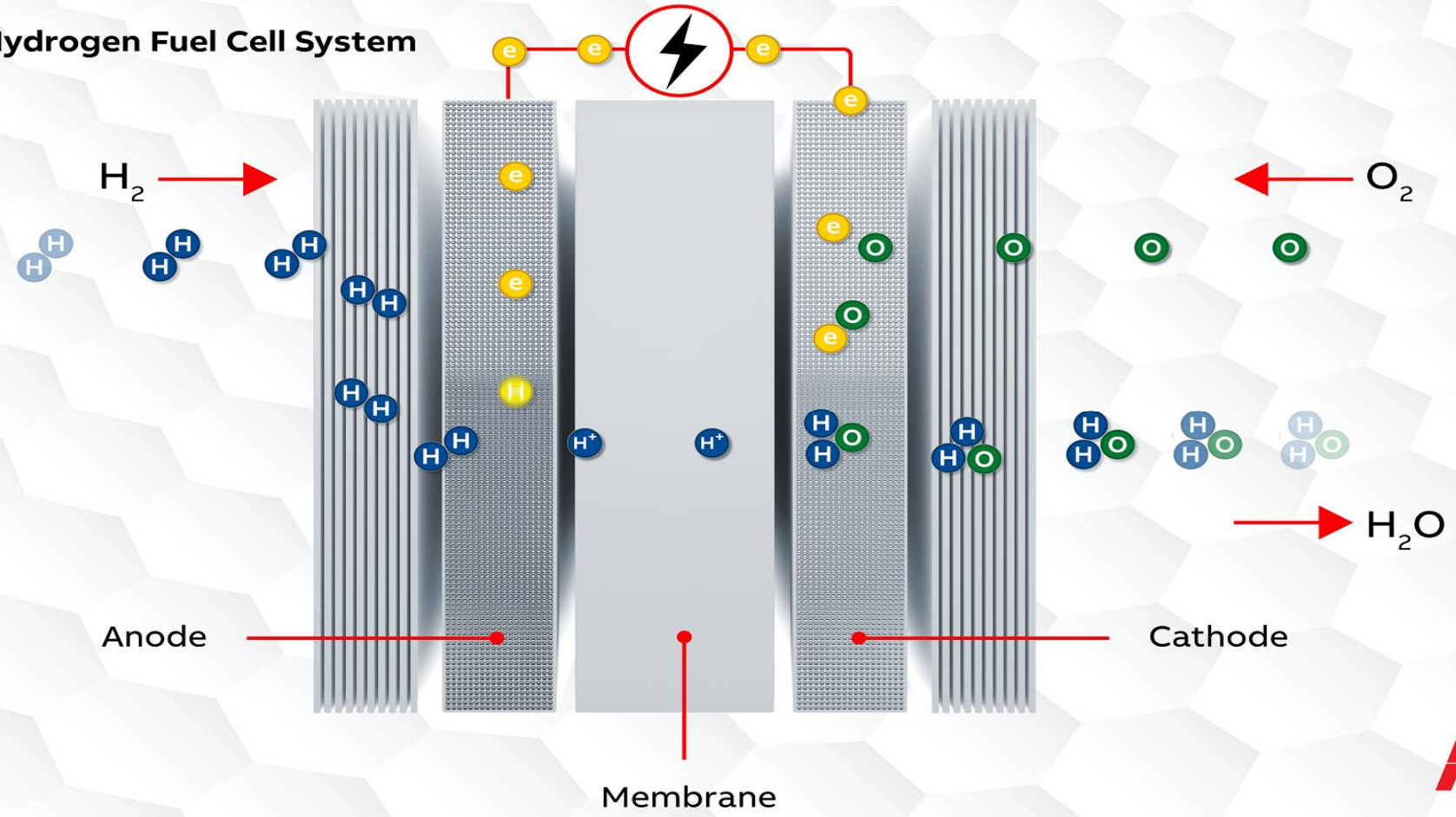


9TH OCTOBER 2018, KLAUS VÄNSKÄ

Opportunities and Constraints for Hydrogen and Fuel Cells in Shipping

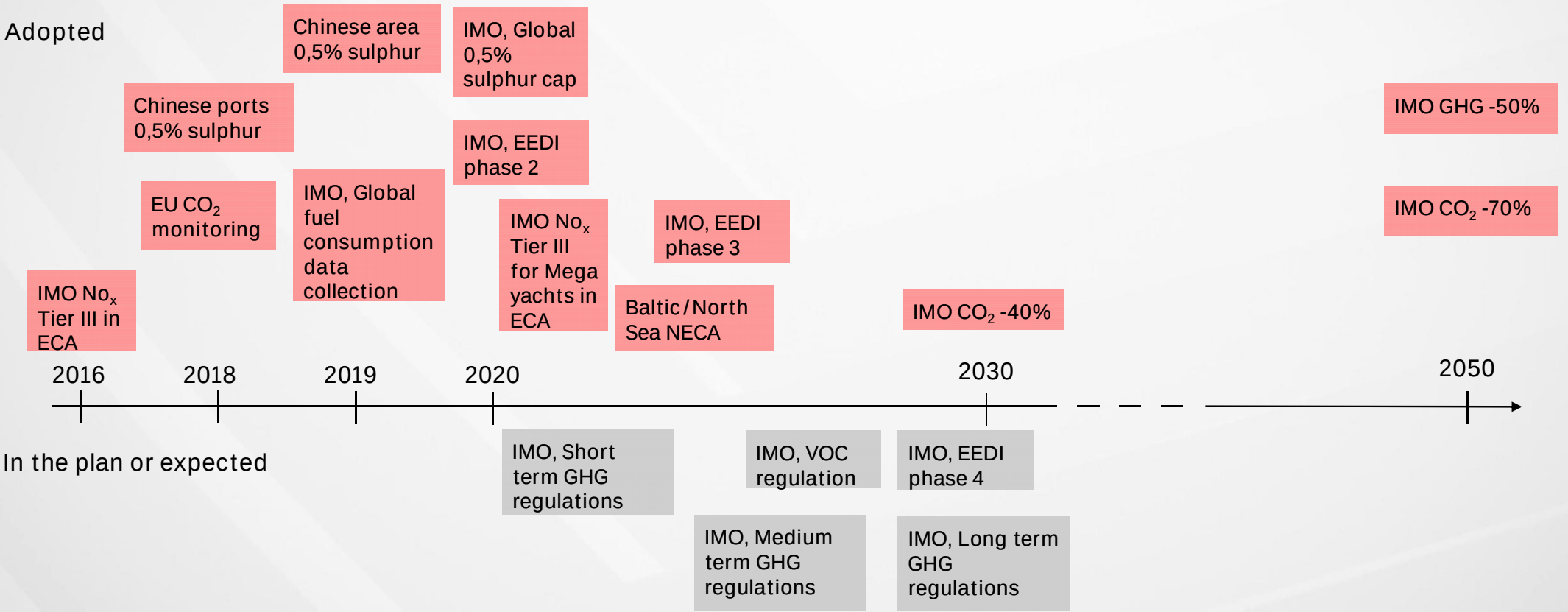
Hydrogen and Fuel Cells in Ports and Shipping Workshop 2018

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

Reduce CO_2 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

Current and expected emission regulations

Towards emission free shipping



Fleet renewal takes time

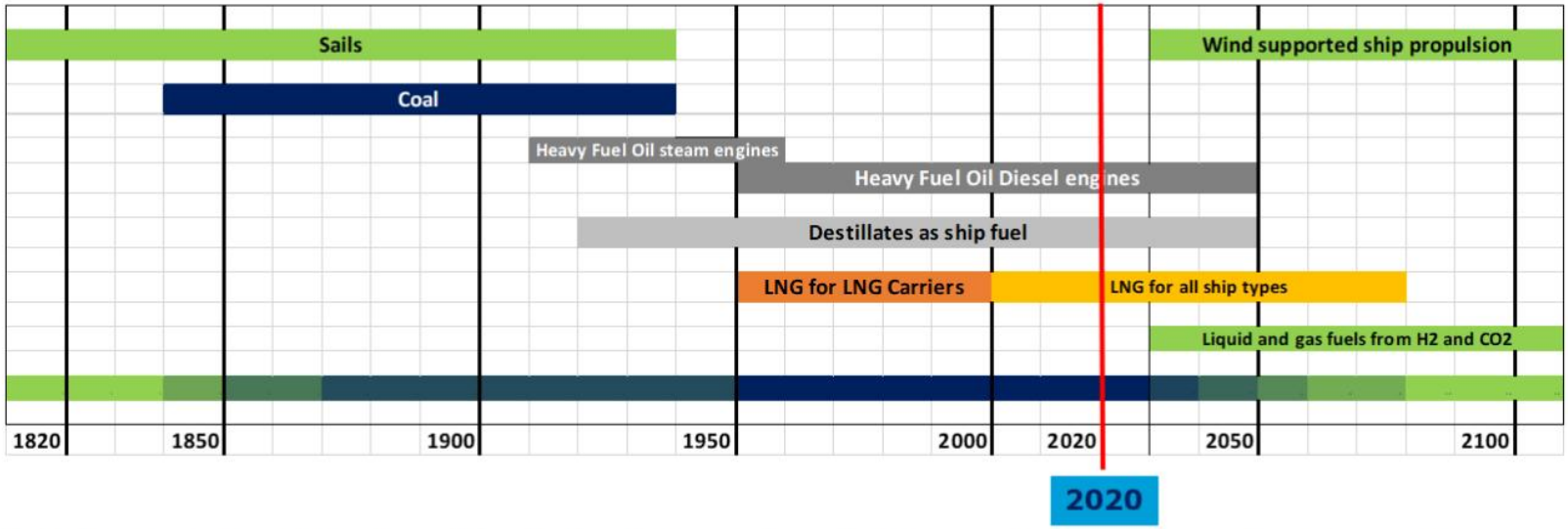
Assumptions on Scrapping Age of Vessels

Vessel Type		Avg. Age of Fleet	Avg. Scrapping Age 96-16		Assumed Scrapping Age		
			Years	No.	Low	Base	High
UL/VLCC	200,000+ Dwt	9.4	23.5	267	25	22	20
Suezmax	125-199,999 Dwt	9.6	23.3	168	25	22	20
Aframax Crude	85-124,999 Dwt	11.2	23.8	303	25	22	20
Coated Aframax	85-124,999 Dwt	7.9	22.5	24	26	23	21
Panamax Tanker	55-84,999 Dwt	10.0	25.0	253	25	21	20
Handy Products Tanker	10-54,999 Dwt	10.9	27.8	892	27	25	23
Small Products Tanker	2-9,999 Dwt	21.3	32.8	417	33	30	27
Crude & Products Tankers	**2,000+ Dwt**	**14.1**		**2,324**			
Handy Chemical Tanker	10,000+ Dwt	10.4	26.7	253	29	26	23
Small Chemical Tanker	2-9,999 Dwt	13.8	29.7	205	31	28	25
Chemical Tankers	**2,000+ Dwt**	**12.0**		**458**			
Handy Misc. Tanker	10-54,999 Dwt	15.1	29.0	27	27	24	21
Small Misc. Tanker	2-9,999 Dwt	24.7	33.8	48	36	33	30
Misc Tankers	**2,000+ Dwt**	**22.5**		**75**			
Total Tankers	**2,000+ Dwt**	**13.8**		**2,857**			
Capesize	100,000+ dwt	7.6	23.1	538	23	21	19
Panamax	65-99,999 dwt	8.6	25.4	800	25	22	21
Handymax	40-64,999 dwt	8.2	26.1	698	26	23	22
Handysize	10-39,999 dwt	10.4	28.9	2,529	29	27	25
Bulk Carrier	**10,000+ dwt**	**8.9**		**4,565**			
LPG Carriers	60,000+ Cbm	8.7	27.9	45	30	28	26
LPG Carriers	30-59,999 Cbm	9.4	29.6	31	30	28	26
LPG Carriers	5-29,999 Cbm	11.3	29.6	113	30	28	26
LPG Carriers	<5,000 Cbm	21.3	30.1	169	30	28	26
LPG Carriers		**16.0**		**358**			

New technology and fuels needed to achieve targets

Renevable H_2 will have a big role in the future

How will ship propulsion power look like in the future?



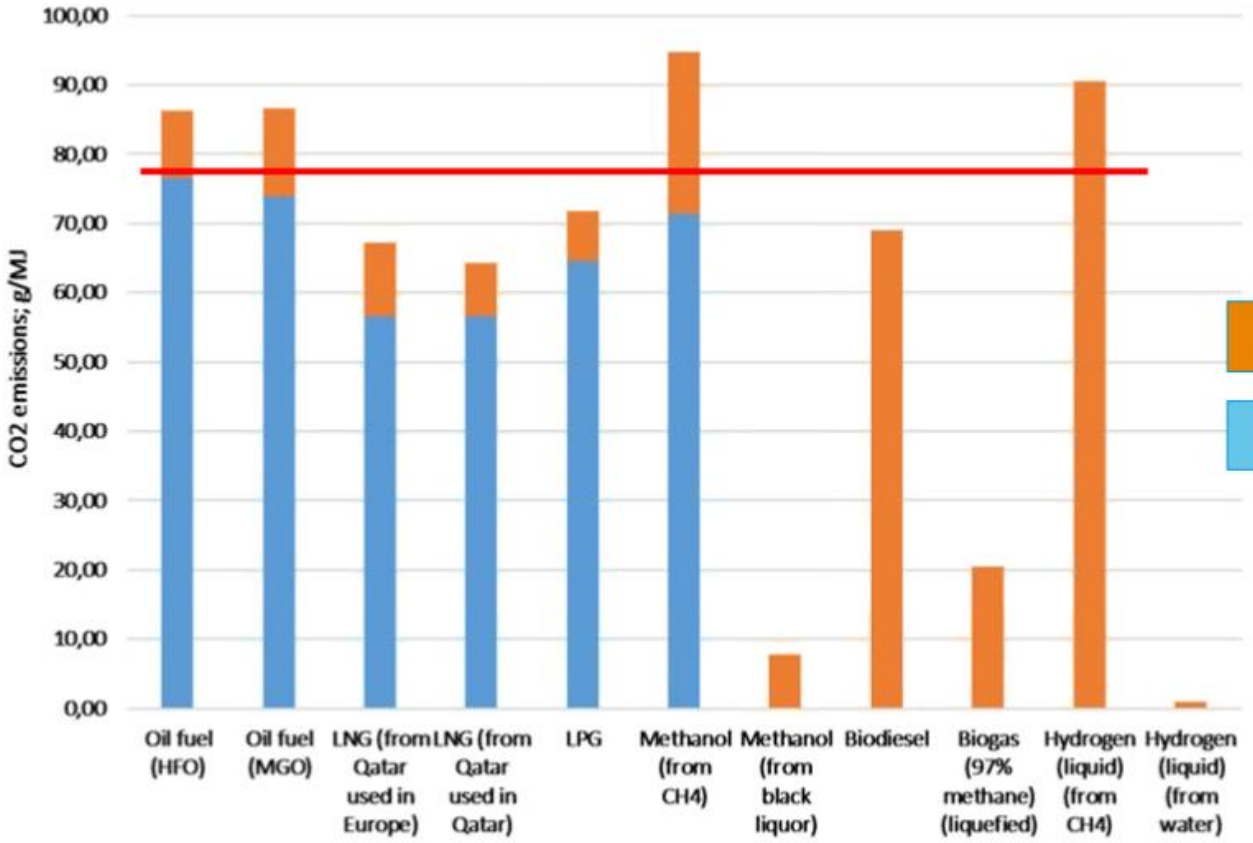
- "Paris Agreement", 2015-12-12 → UN's climate science panel says net zero emissions must happen by 2070 to avoid dangerous warming.; IMO ambition to reduce GHG emission by 50% within 2050 (April 2018)
- Until now there are no taxes on ship fuel.

Source: DNV-GL

7 DNV GL ©

DNV·GL

CO2 equivalent emissions of fuel alternatives in shipping



WTT Well To Tank

TTP Tank To propeller

For TTP no slip effects considered

For WTT slip is considered

Source: DNV-GL

DNV·GL

50 to 80 Million tonnes of renewable H_2 needed only for shipping

Different fuel scenarios

Efficiency improvements defines the split between different fuels

- Is the target to limit global warming to 1,5 or 2.0?
- With fossil fuels CO_2 is released in direct relation to consumed fuel
- Amount of released Co_2 varies between different fossil fuels
- Other GHG emissions to be considered too
- Improvements in energy efficiency and better control of methane slip would extend usage of LNG in transition phase

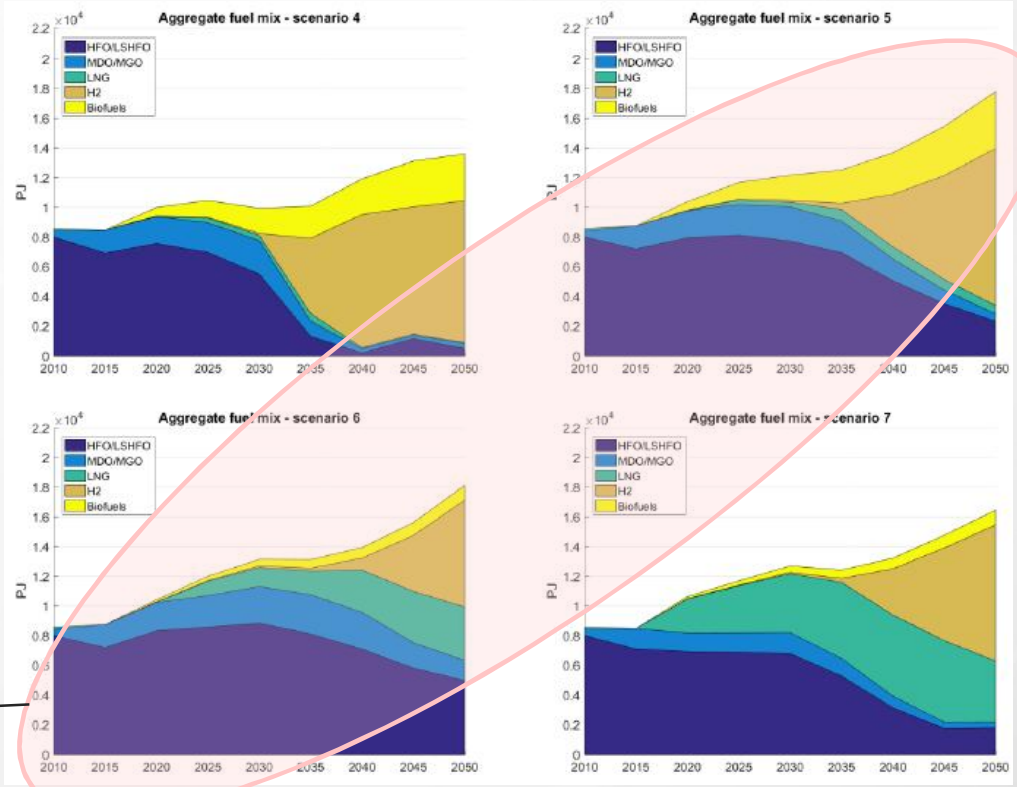


ABB: Most possible scenario somewhere between these two

Source: Co_2 emissions from shipping:
Bibliographical details: Smith, T., Raucci, C., Haji Hosseinloo S., Rojon I., Calleya J., Suárez de la Fuente S., Wu P., Palmer K. CO_2 emissions from international shipping. Possible reduction targets and their associated pathways. Prepared by UMAS, October 2016, London.

Towards sustainable shippng with Fuel Cells

From research to commercial deliveries

MARANDA

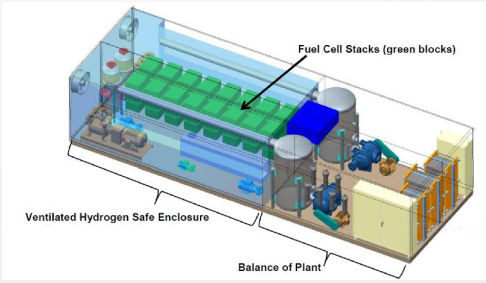
- EU funded research program 2017…2021
- 165 kW fuel cells, power converters and control systems Integrated and tested in research vessel Aranda of SYKE (Finnish Environment Institute)

FLAGSHIP

- EU funded research program 2019…2023 (application - pending)
- 400 kW fuel cells, power converters and control systems Integrated and tested in river pusher

Ballard cooperation

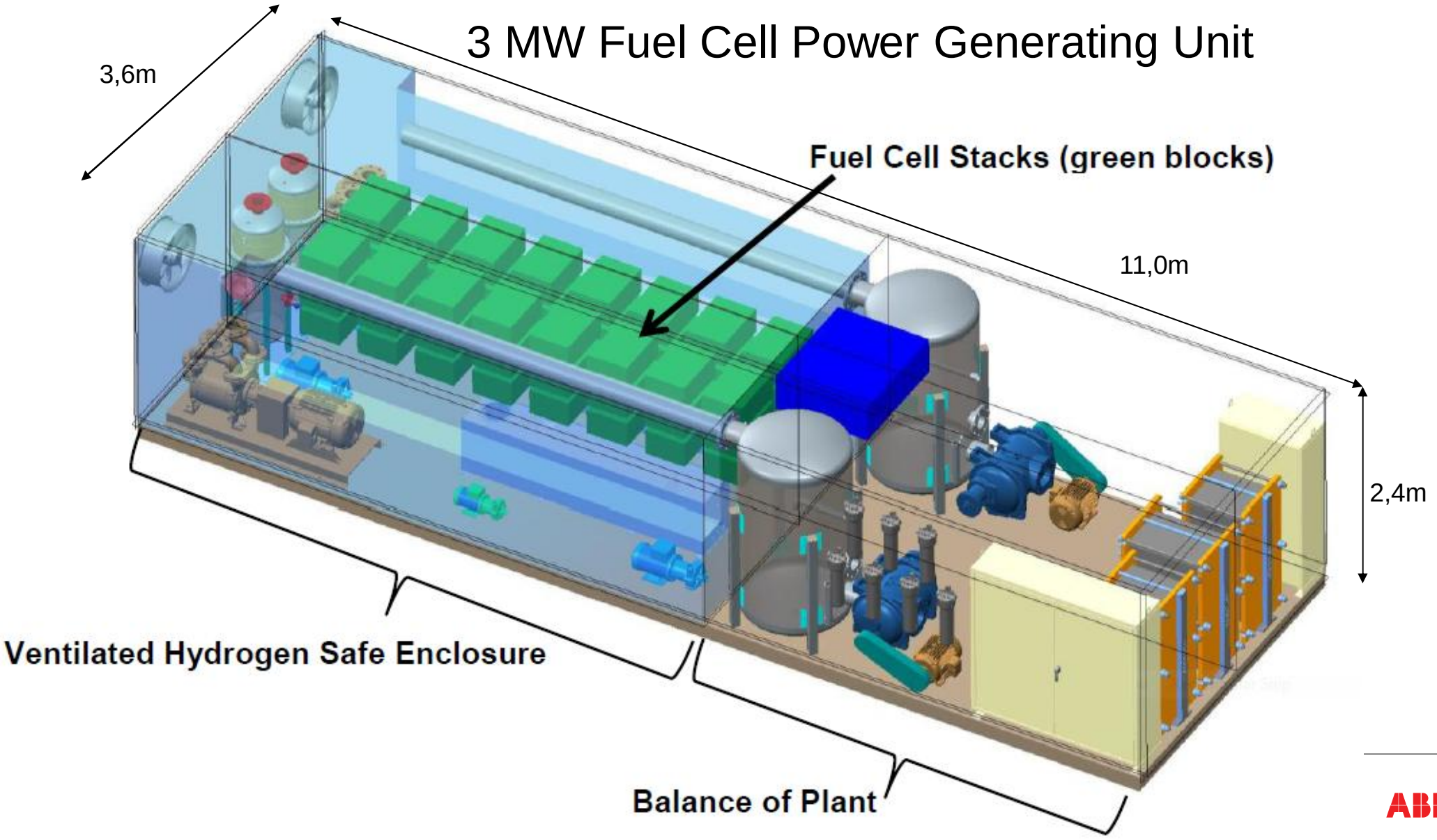
- ABB and Ballard has signed a MOU on developing the next-generation megawatt level fuel cell power system for sustainable marine e-mobility.



Cruise vessel project

- ABB is studying with Cruise vesel owners to install MW level fuel cell units to Cruise vessels to supply hotel load

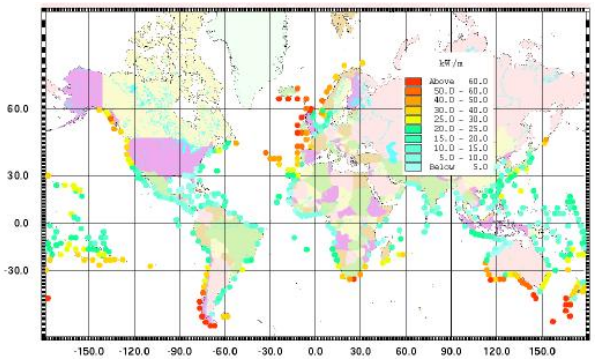
3 MW Fuel Cell Power Generating Unit



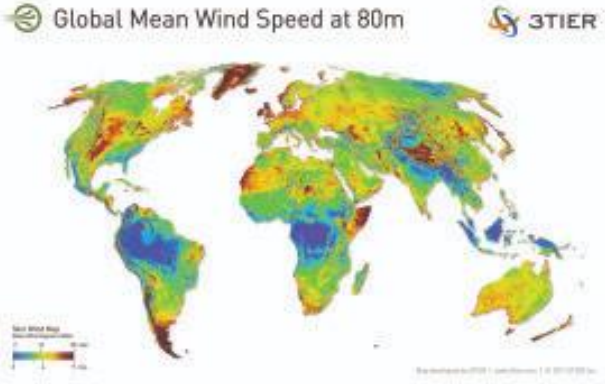
Renewable Hydrogen Production

Spots of renewable energy

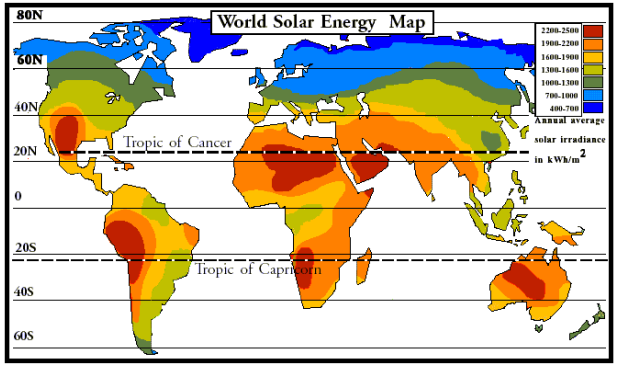
Wave energy spots in coastline



Wind energy spots

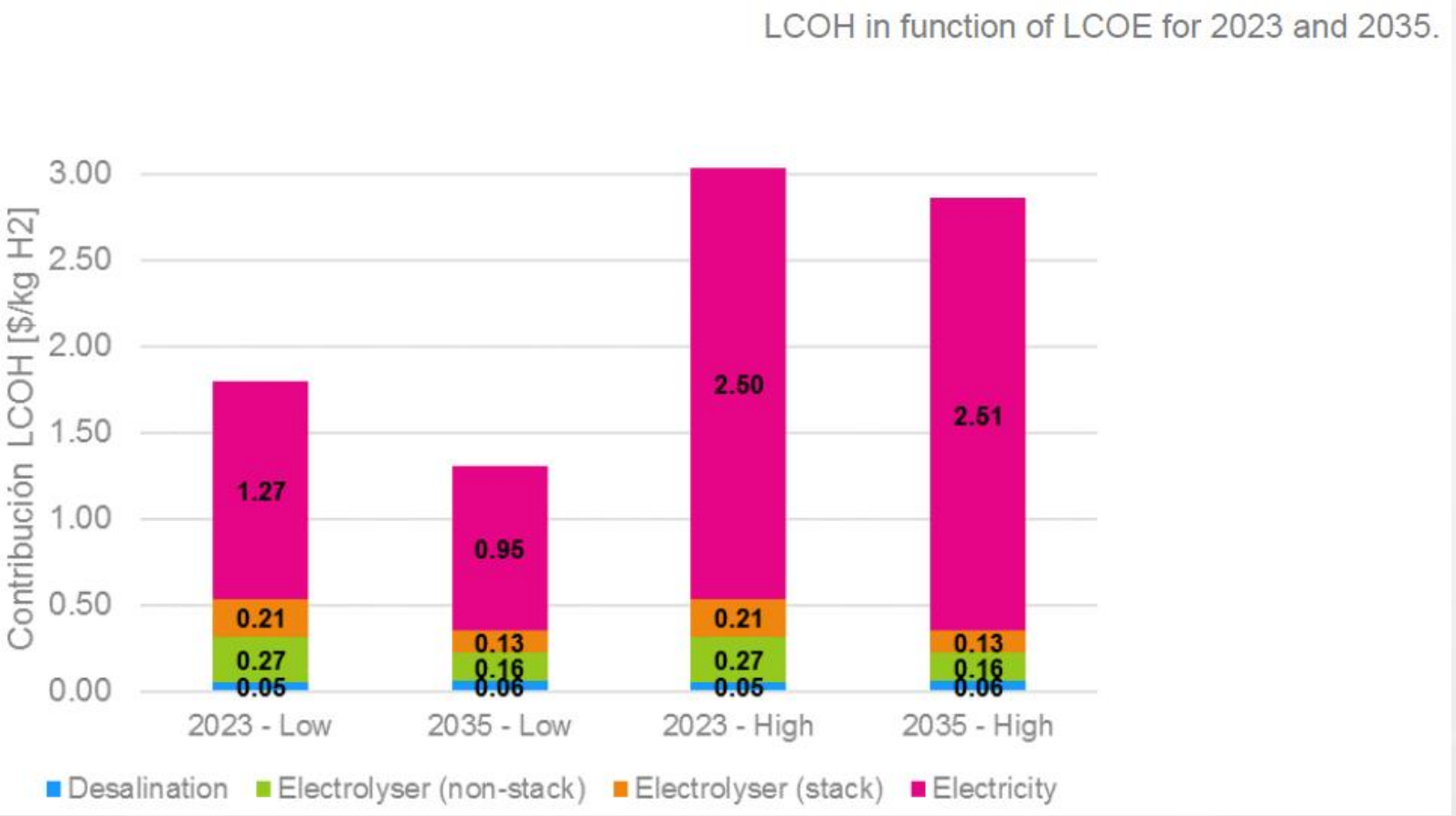


Solar radiation spots



Energy cost is not an issue!

Example of Renewable H_2 production cost

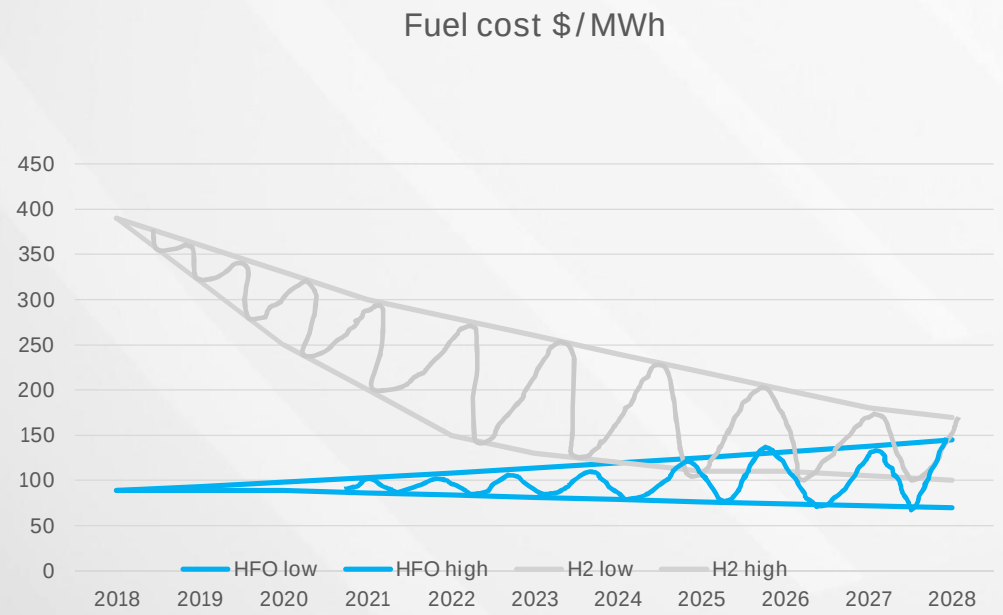


Chile has a great opportunity to produce renewable H_2 with very competitive cost by solar power

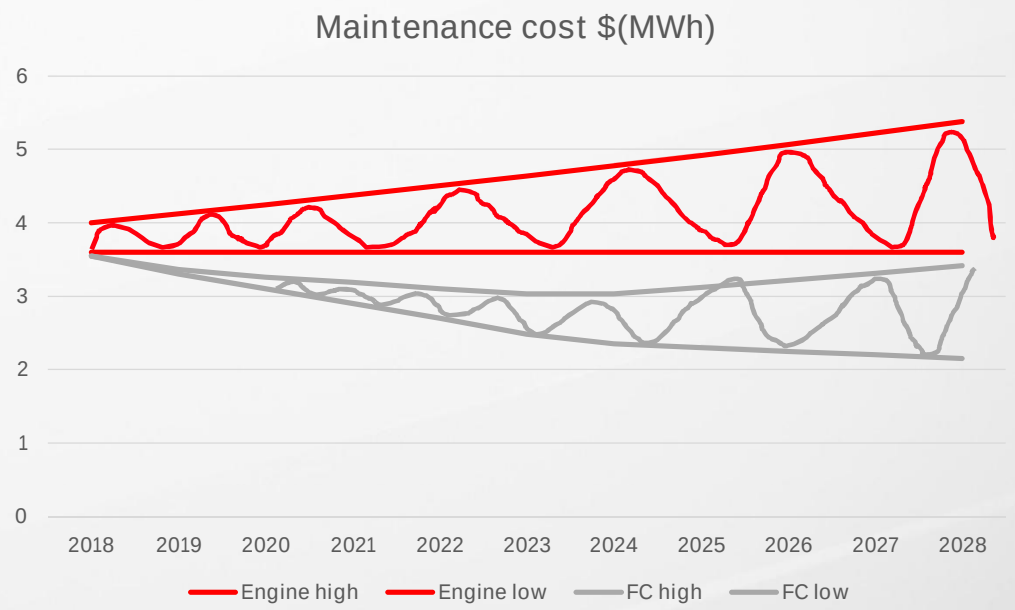
OPEX parameters

Potentially competitive

Fuel cost



Maintenance cost



Other Challenges

- Classification
  - Classification societies are committed to develop rules for fuel cells and hydrogen
  - Projects can be made applying the alternative design method
- Distribution Infrastructure
  - Requires investments from big distributors
- Knowledge to build Fuel Cell vessels
  - Competition will tackle this issue

Hydrogen & Fuel Cells is a solution for future Shipping and Port operations

Thank You!