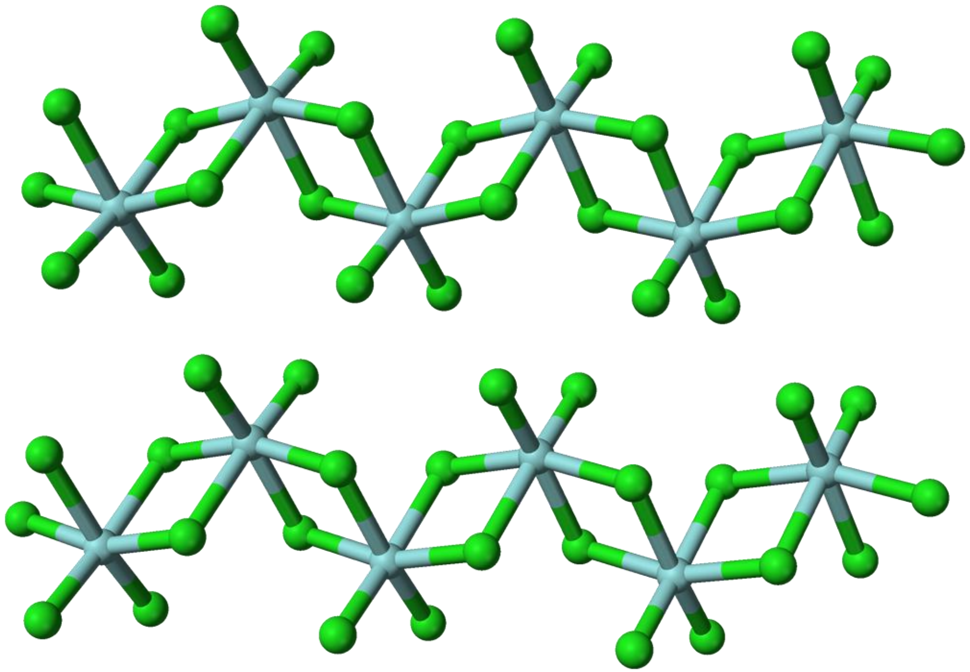
SWIRE PACIFIC OFFSHORE

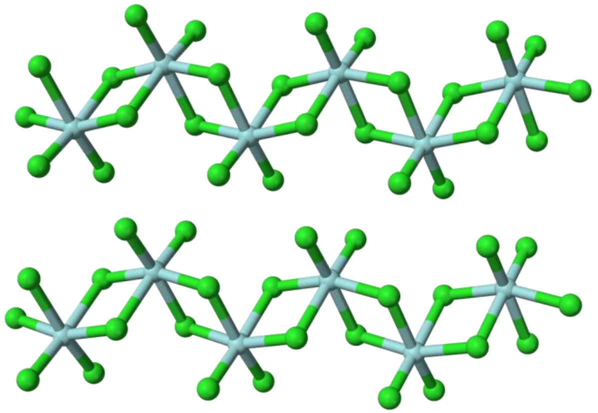


A Hydrogen Pathway to a Lower Carbon Future

www.swire.com.sg

Hydrogen pathway to a lower carbon future

- Introduction – Who are we?
- Why do we need to radically decarbonise?
- Why Hydrogen?
- SPO: Project Hafnium



Hydrogen pathway to a lower carbon future

- Introduction – Who are we?

Our business - SPO

- Established in 1975, headquartered in Singapore since 1998
- Over 2,300 employees globally
- 27 Offices around the world, presence in most major markets
- Over US$2.4 billion in asset value
- 75 ships, average age 7.7yrs comprising:

❖ Traditional AHTS & PSV
plus
❖ Complementary Services:
  - ✓ Seismic Survey Support
  - ✓ Swire Emergency Response
  - ✓ Offshore Wind Farm Installation & Decommissioning
  - ✓ Subsea Support & Engineering Services

Our business - SPO

Towing & Anchor Handling Vessel

Platform Supply Vessel

Accommodation Barge

Subsea / ROV Support Vessel

Windfarm Installation Vessel

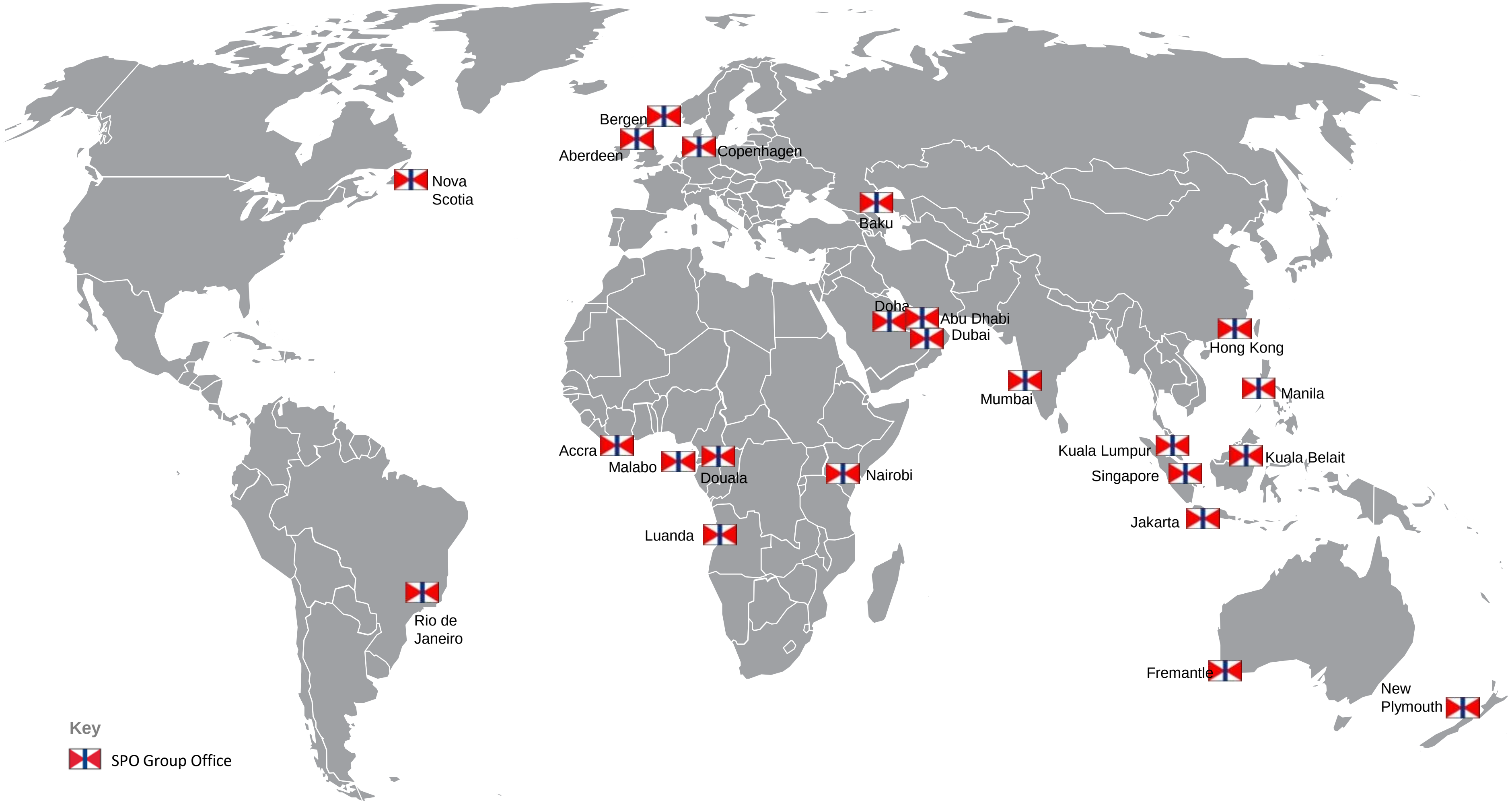
Seismic Vessel

High Speed Catamaran Crew Boat

75 Owned vessels + 1 Managed vessel + 4 New-build vessels.
All manning and technical management in house.

SWIRE PACIFIC OFFSHORE

Our business - SPO

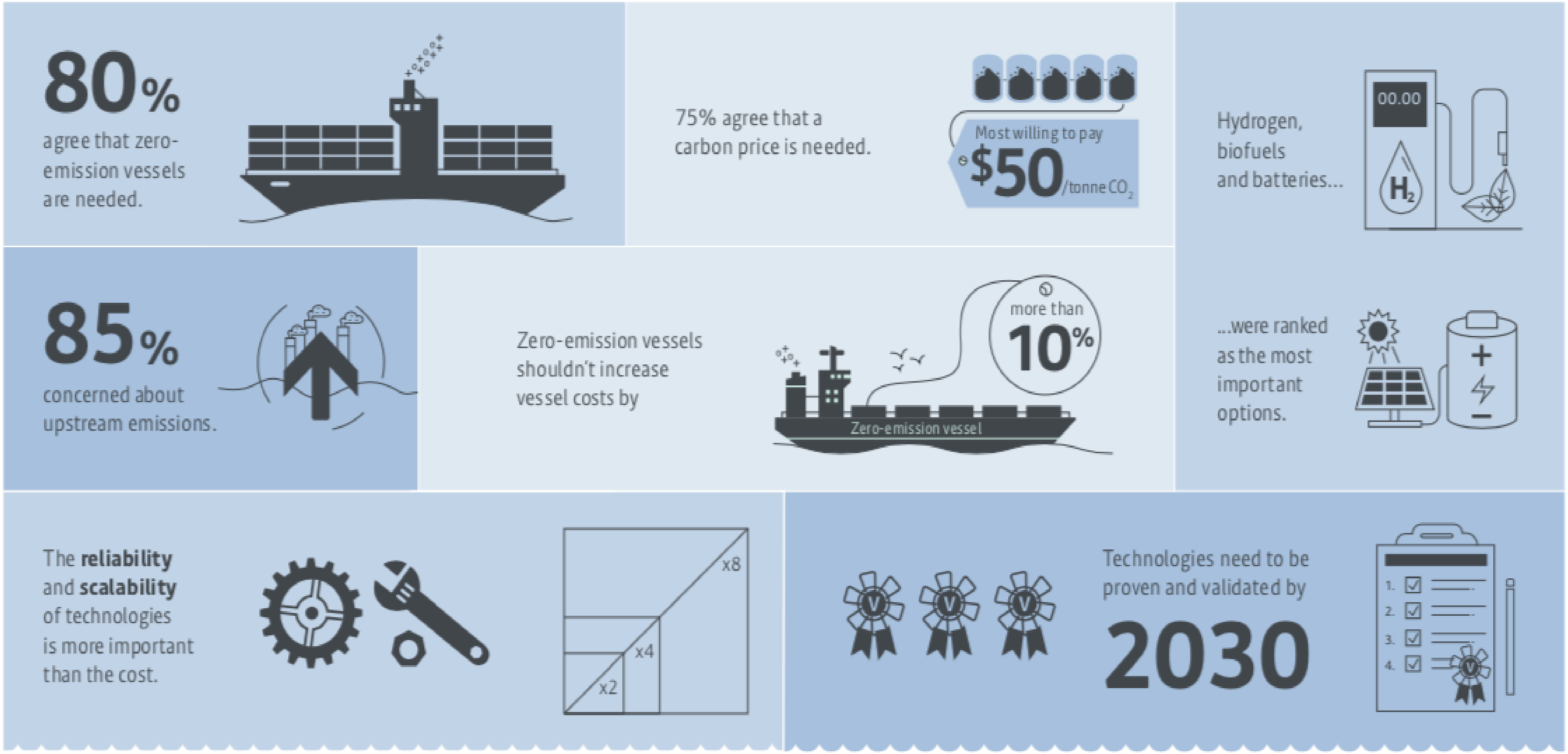


SWIRE PACIFIC OFFSHORE

Hydrogen pathway to a lower carbon future

- Why do we need to radically decarbonise?

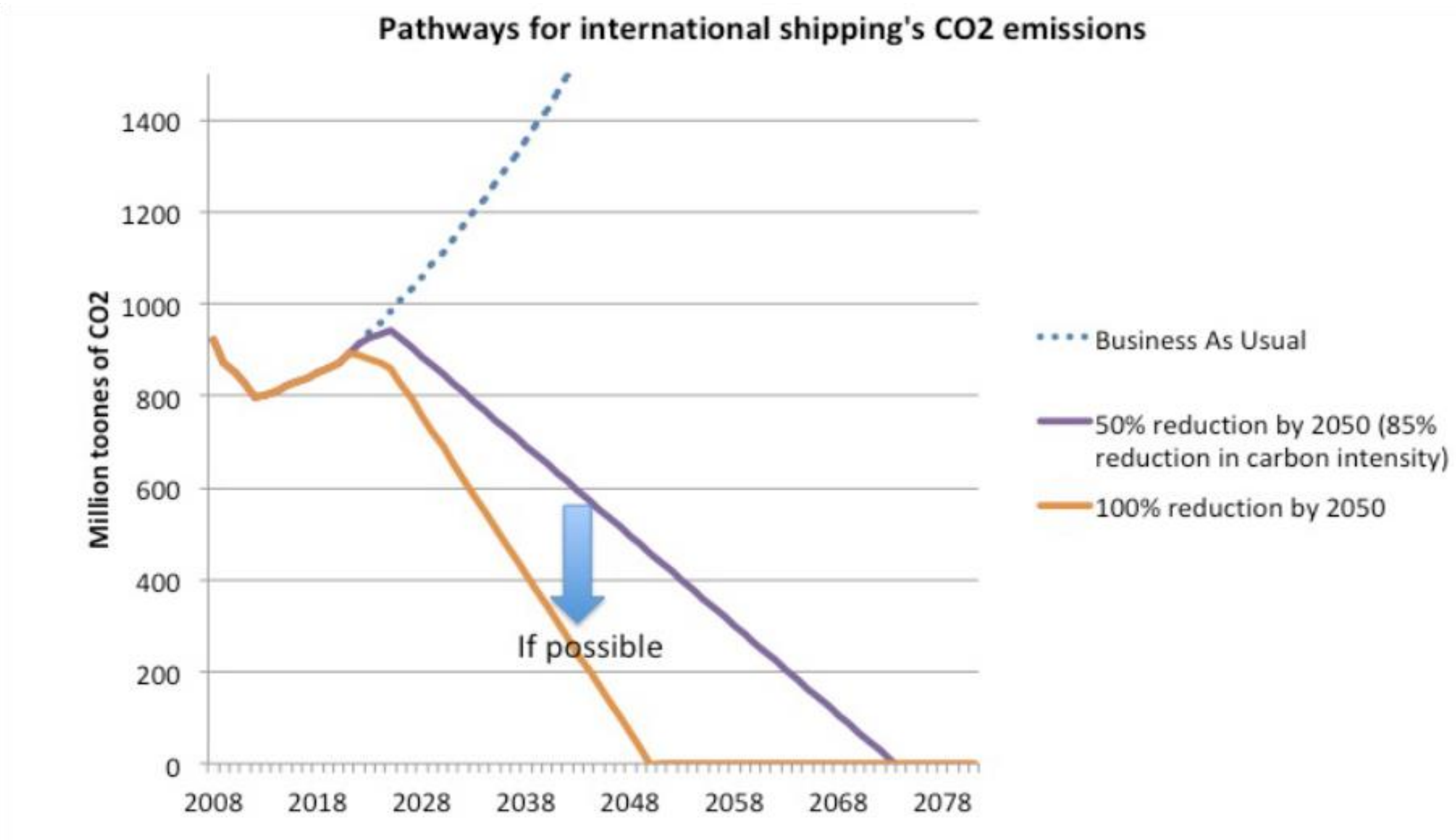
Zero-Emission Vessels



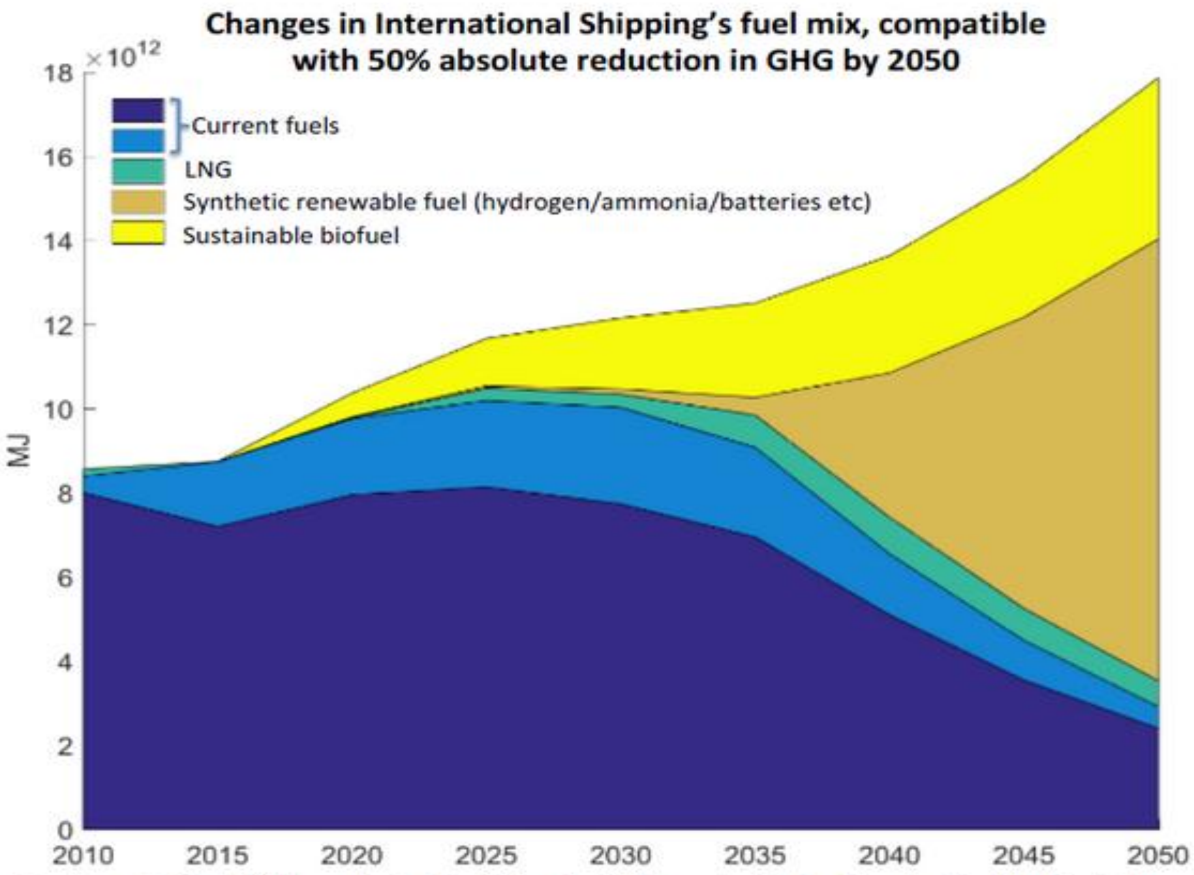
Shipping Stakeholders survey responses

(Source: Lloyd's Register/UMAS, *Zero-Emission Vessels 2030. How do we get there?*, 2017)

Why do we need to radically decarbonise?



Alternative Energy Sources:
Key to a lower carbon future



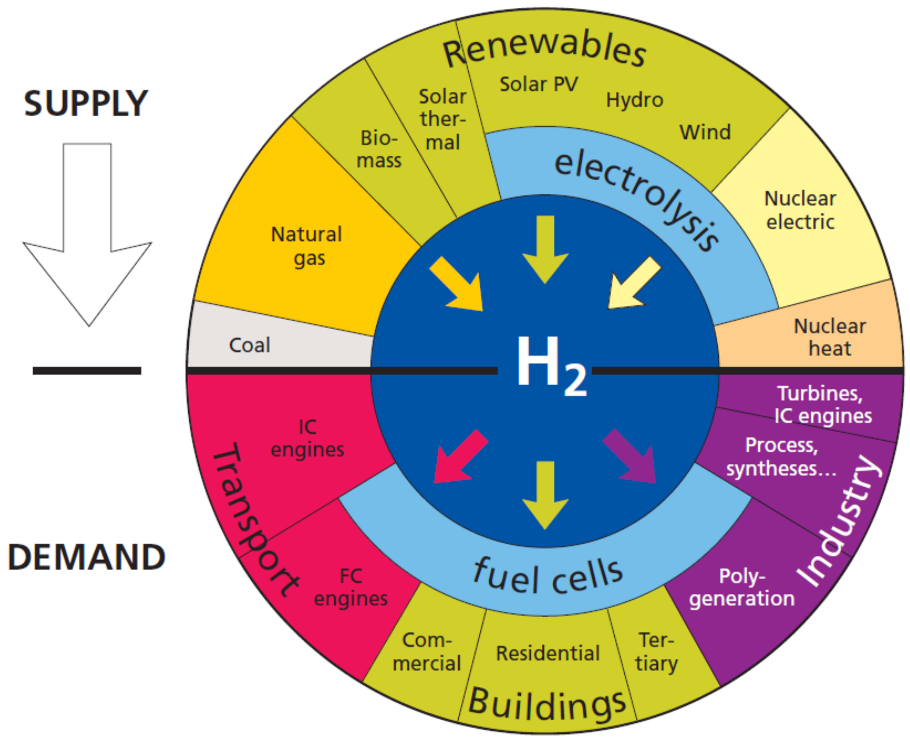
Smith, T., Raucci, C., Haji Hosseinloo S., Rojon I., Calleya J., De La Fuente. S., Wu P., Palmer K. CO2 emissions from international shipping. Possible reduction targets and their associated pathways. Prepared by UMAS, October 2016, London.

Radical reduction in GHG emission can only be achieved through alternative energy sources

Hydrogen pathway to a lower carbon future

- Why Hydrogen?

The Hydrogen Powered Offshore Vessels (OSV) – Key Challenges



Supply and Demand of Hydrogen

Availability

- Where is it produced? Can I get it?

Scalability

- To what size can this approach be applied? Does it cause other issues?

Life Cycle Assessment:

- Are there issues of unaccounted / overlooked upstream emissions?

Applicability to OSV operations

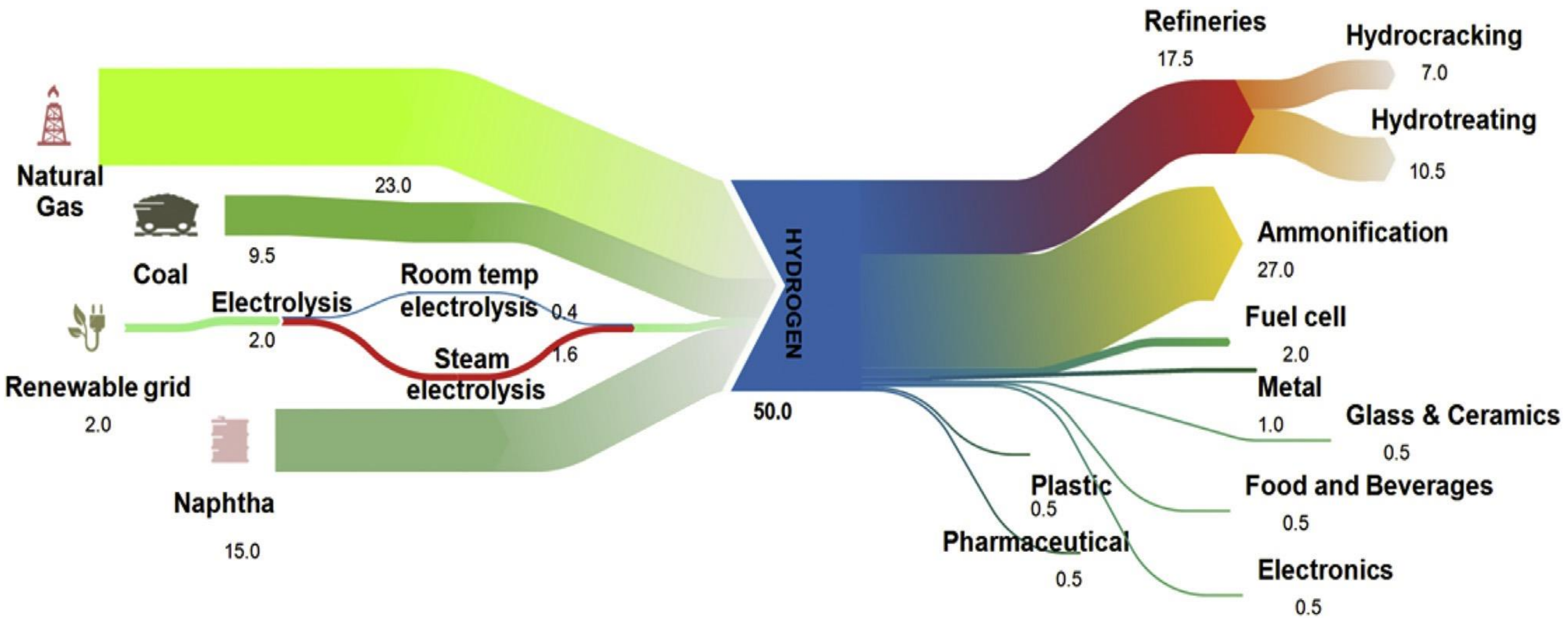
- Storage is a critical limiting factor. Can I produce it on demand?

Reliability

- Is it safe to load and use, and robust?

SWIRE PACIFIC OFFSHORE

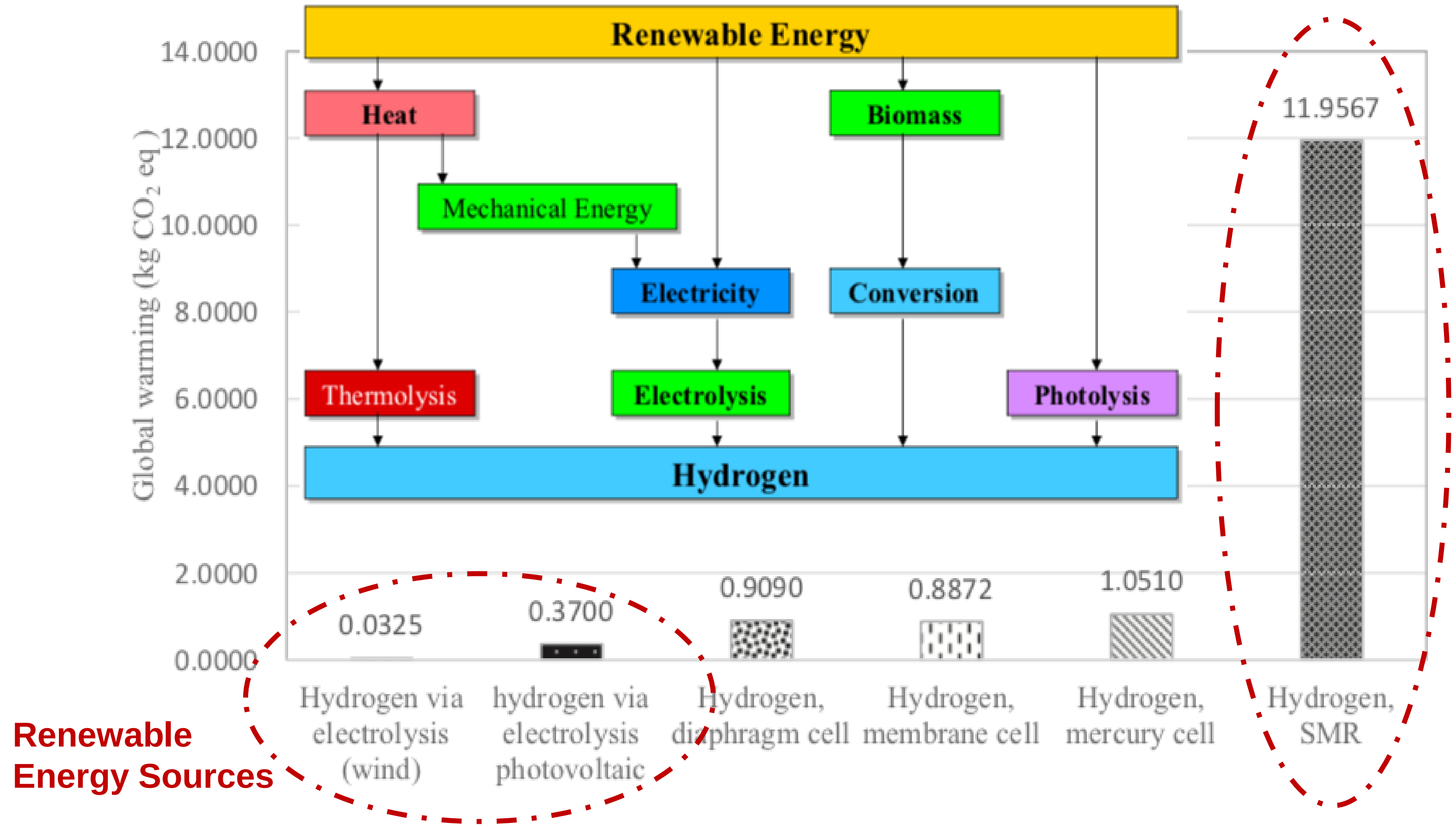
Availability of Hydrogen (Existing supply chain) – Sankey Diagram



The average global hydrogen supply and demand, mil metric tonne

(Source: Fig. 4, *International Journal of Hydrogen*, 41 (2016) 7744-7753)

Generation of Hydrogen: Global warming potential of various methods



Most common approach

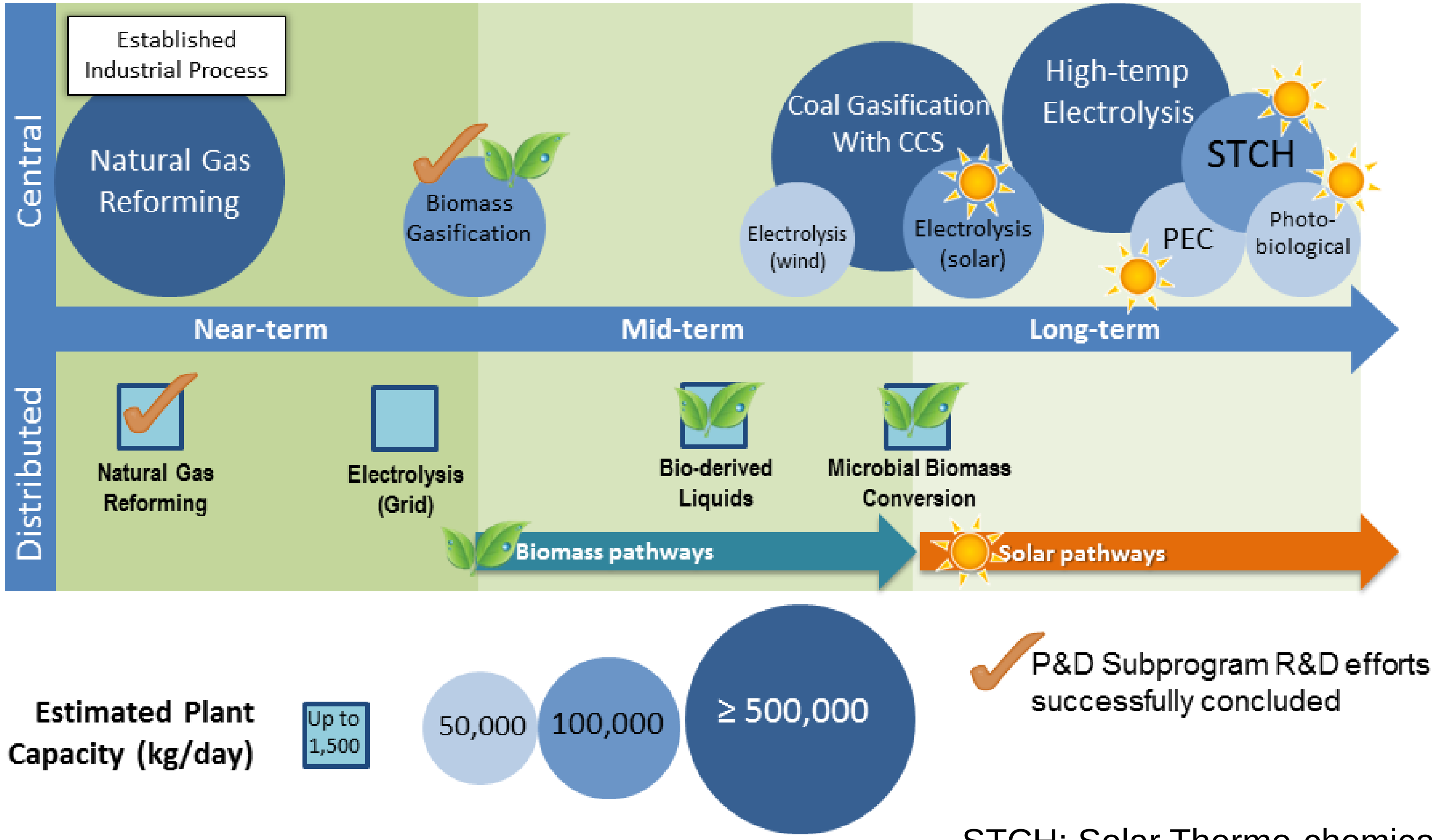
SMR: Steam Methane Reforming

Global warming potential per kg of hydrogen for different hydrogen production methods

(Source: Fig. 7, *International Journal of Hydrogen*, 41 (2016) 8364-8375)

SWIRE PACIFIC OFFSHORE

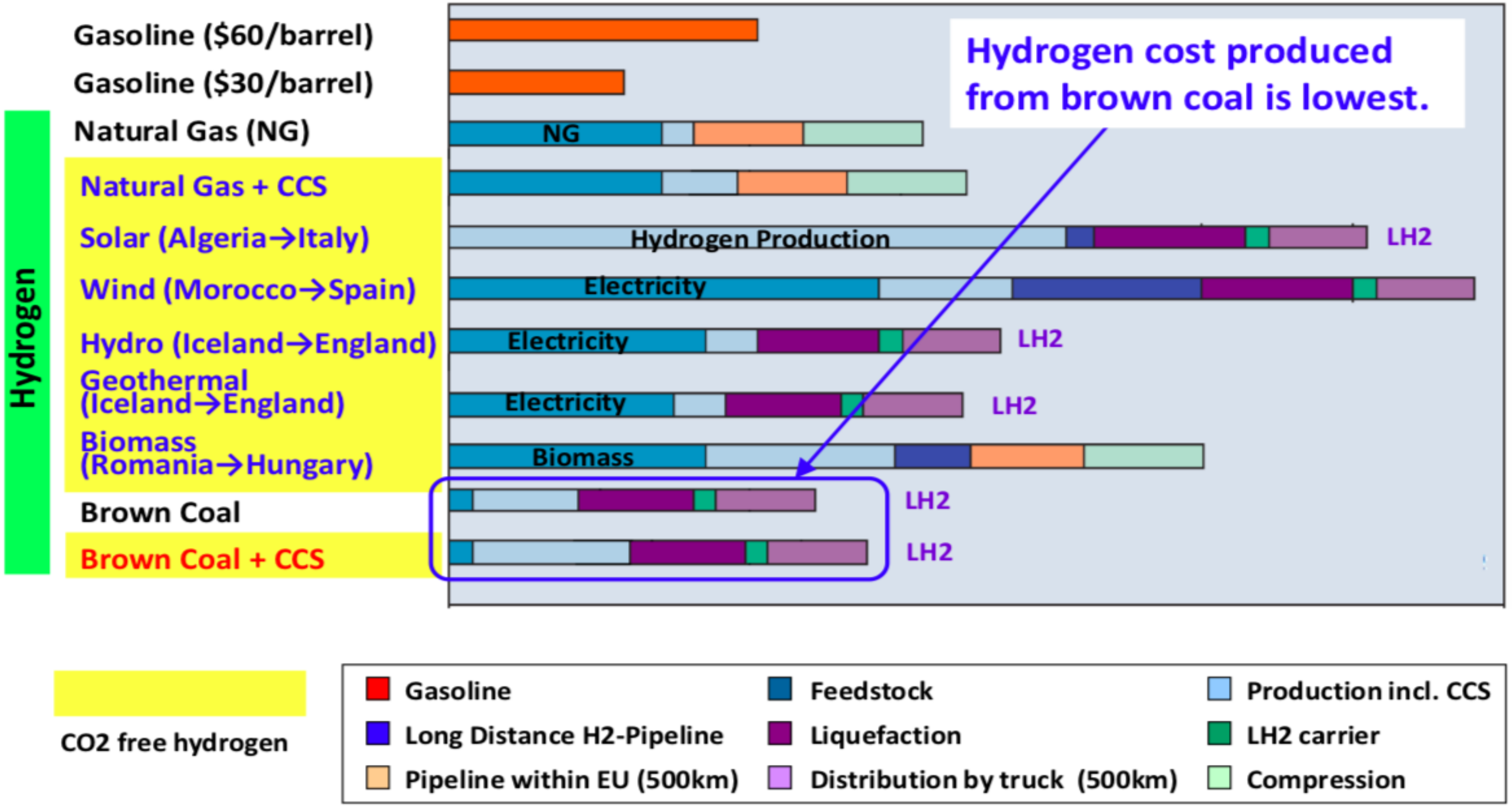
Generation of Hydrogen: Scalability



STCH: Solar Thermo-chemical Hydrogen
PEC: Photo electro-chemical
CCS: Carbon, Capture & Storage

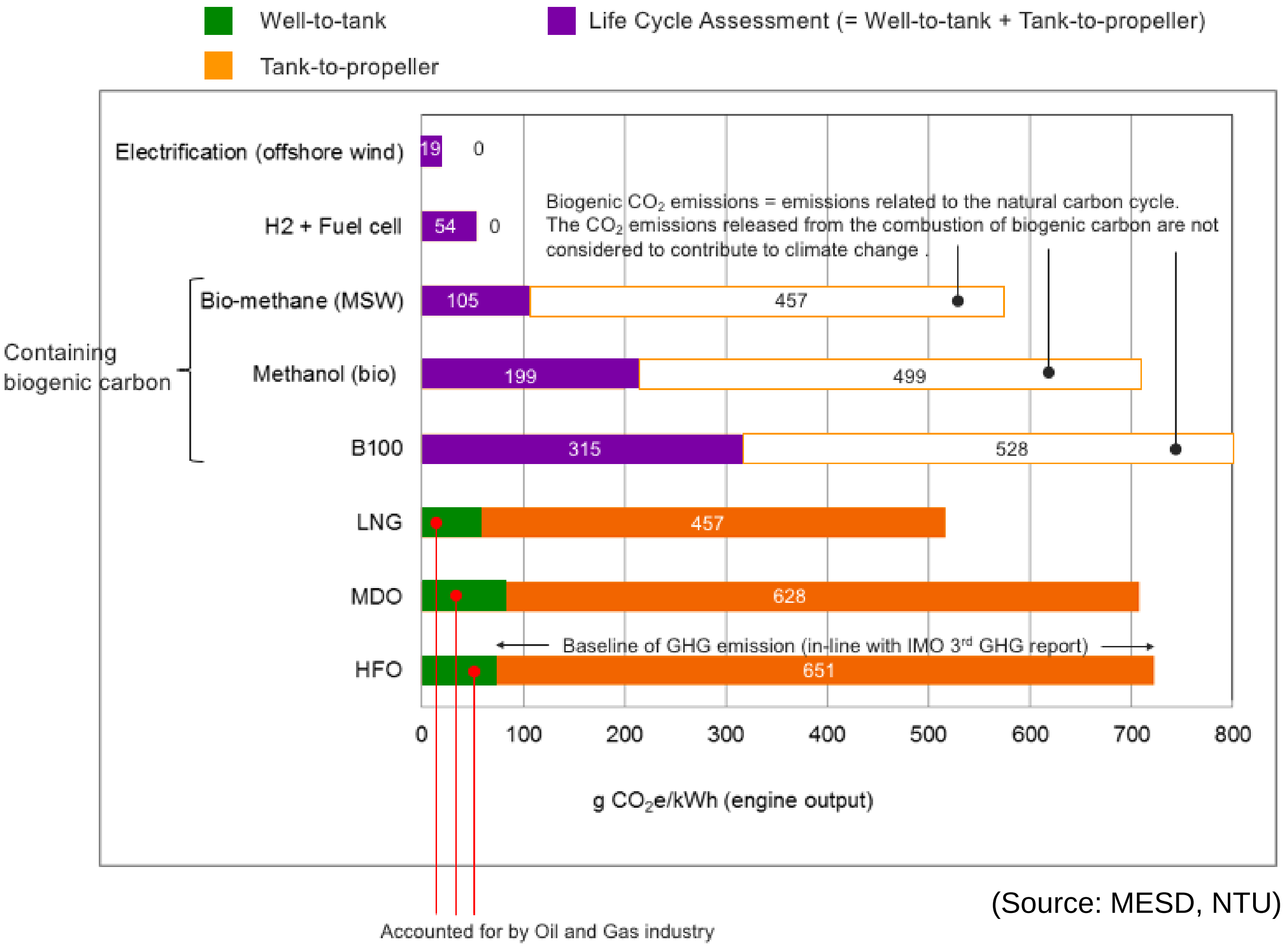
(Source: US DOE)

Hydrogen Energy Supply Chain : Cost



(Source: http://www.nedo.go.jp/content/100580338.pdf)

Alternative Energy Sources:
Life Cycle Assessment (LCA)



(Source: MESD, NTU)

Current marine projects involving Hydrogen (1)

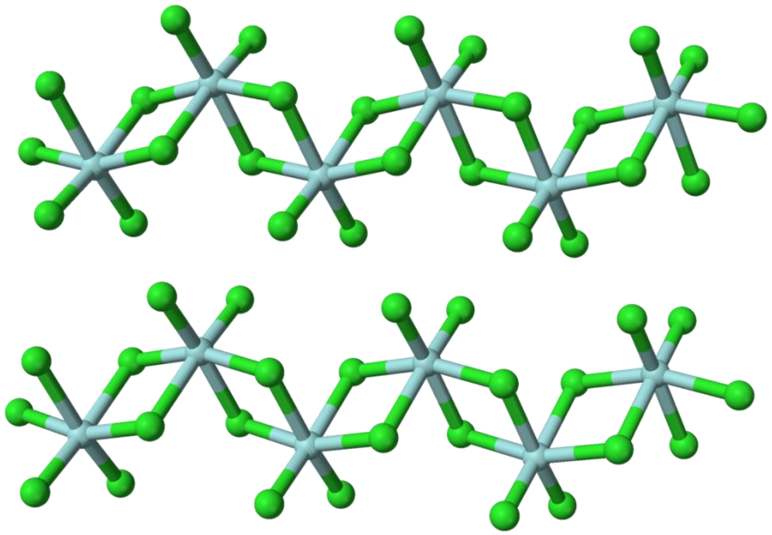
Project	Concept	Main Partners	Yrs	Fuel Cell / ICE	Capacity	Fuel
Cheetah Marine	Hydrogen-fuel powered catamaran (9.95m), 26kW Solar PV. Converted Honda Outboard	ITM Power, IBM & etc.	2016	H2ICE	135hp	H2(15kg)
FellowSHIP	320kW MCFC system for auxiliary power of OSV	Eidesvik Offshore, Wärtsilä, DNV	2003 -11	MCFC	320kW	LNG
E4Ships-Pa-X-ell MS MARIELLA	60kW modularized HT-PEM fuel cell system developed and tested for the auxiliary power onboard passenger vessel MS MARIELLA	Meyer Werft, DNVGL, Lürssen Werft, etc.	P1: 2009-17 P2: 2017-22	HTPEM	60Kw (each staclK30kW)	Methanol
E4Ships-SchIBZ MS Forester	100kW containerized SOFC system developed and test for the auxiliary power of commercial ship. Scalable up to 500kW units.	Thyssen Krupp Marine Systems, DNVGL, Leibniz Uni Hannover,, OWI, Reederei Rörd Braren, Sunfire	P1: 2009-17 P2: 2017-22	SOFC	100kW	Diesel
RiverCell - Elektra	Feasibility study for a fuel cell as part of a hybrid power supply for a towboat	TU Berlin, BEHALA, DNVGL, etc.	2015-16	HTPEM		H2

Current marine projects involving Hydrogen (2)

Project	Concept	Main Partners	Yrs	Fuel Cell / ICE	Capacity	Fuel
Hydroville	2 x Hydrogen Internal Combustion Engines, Shaft power 441kW. Passenger Shuttle	LR, CMB	2017	H2ICE	441kW	H2(205*l*) Diesel (530*l*)
Viking Cruise (H2)	Announced World's first liquid H2 powered cruise. 230m, >900 passengers and crew of 500.	Viking Cruises & partners	Announced. Oct 2017	Fuel Cell	?	H2 (*aq*)
Boreal/Wärtsilä	Commercially operated hydrogen- powered ferries. 50% H2 – electric and full electric	Boreal, Wärtsilä	Announced. Feb 2018	?	?	H2 (*aq*)
HYBRIDShips	Hydrogen-fuel and battery technology powered ferry.	Fiskerstrand Holding AS, NMA & DNVGL, etc.	2020 ready	Fuel Cell	?	H2 (*aq*)

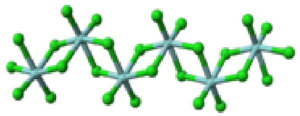
Hydrogen pathway to a lower carbon future

- SPO: Project Hafnium



SWIRE PACIFIC OFFSHORE

SPO: Project Hafnium



SPO has formed a consortium with Nanyang Technological University's (NTU) / Maritime Energy & Sustainable Development Centre of Excellence (MESD CoE) plus other knowledge partners including OEMs and Class, facilitated by The Forum for the Future (FFF) to deliver this project PoC in 2020.

NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

SWIRE PACIFIC OFFSHORE

forum for the future

Phase 1 – Feasibility Study

- By Mid 2018

Identify suitable H2FC technology for SPO vessel

Phase 2 – Pilot proof-of-concept

- Test-bedding Technology
- By 2019

Test-bedding the identified H2FC technology in Phase 1 at METB

Phase 3 – Full scale proof-of-concept

- Sea trial on SPO vessel
- By 1st Jan 2020

Retrofit the tested H2FC technology in Phase 2 onboard SPO vessel and conduct sea trial

Applicability of Hydrogen to OSV (1)

Characteristics of Platform Supply Vessels (PSV)

- The workhorses of offshore oil and gas production supply chain. PSVs designed for maximum cargo delivery.
- Regular working range generally up to 360 nautical miles offshore and are built to work in extreme weather conditions.
- Prime movers maybe diesel (MDO) ICEs or diesel-electric propulsion

G Class

Brake Horsepower	6,434 BHP	Clear Deck Space	810 m2
Deadweight	4,054-4,103 tonnes	Deck Cargo Capacity	1,750 tonnes

The G Class vessels with their 4,000-tonne deadweight, are powered by a four-engine diesel electric propulsion plant, equipped with highly efficient counter rotating azimuth thrusters ensuring excellent fuel efficiency. These FiFi1, DP2 vessels with their high environmental regularity number (ERN), are SPS Compliant, Clean Class and built LFL* notation ready, to allow for future methanol carriage.

Challenge

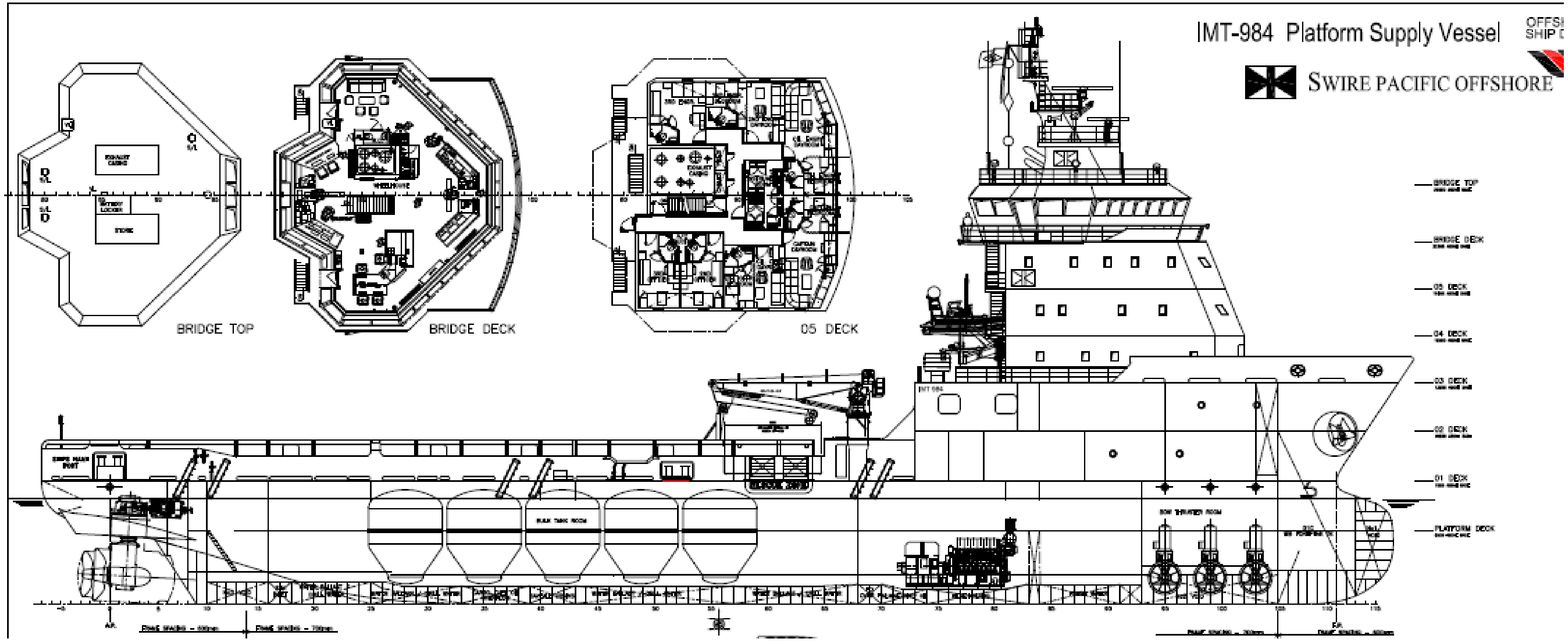
Available Onboard Space - whilst avoiding shutting out revenue earning cargo

M/V Pacific Gannet

SWIRE PACIFIC OFFSHORE

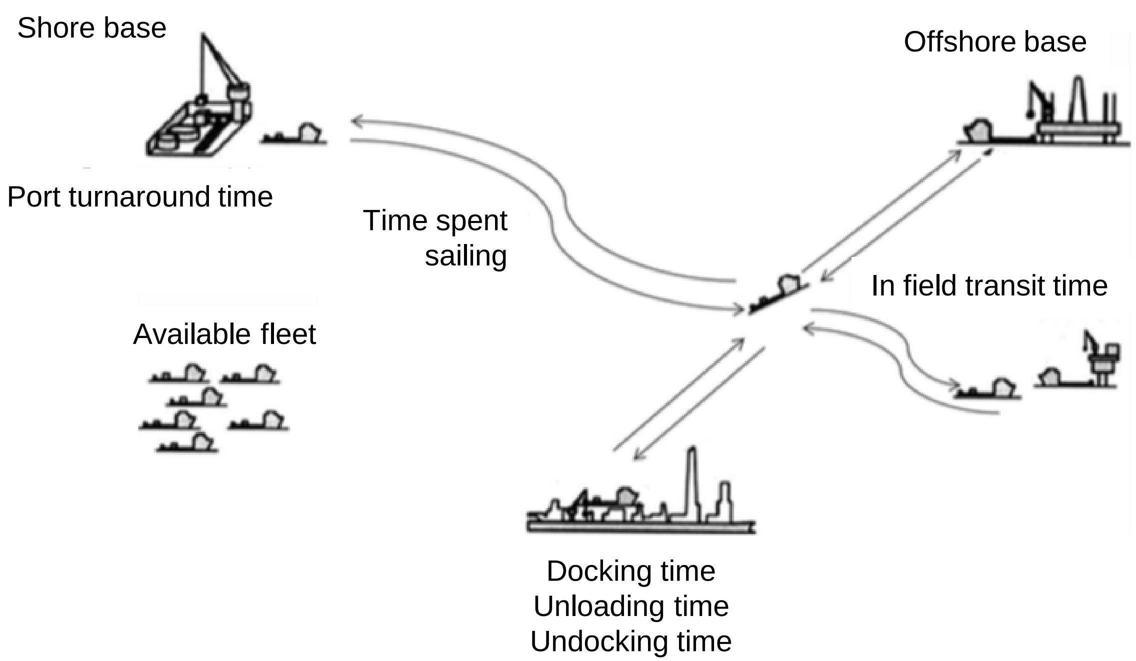
Applicability of Hydrogen to OSV (2)

Applicability of Hydrogen to OSV (3)



Applicability of Hydrogen to OSV (4)

Elements of offshore supply chain



(Source: I.Skoko, M. Jurčević, D. Božić, *Logistics Aspect of Offshore Support Vessels on the West Africa Market*, Promet – Traffic & Transportation, Vol.25, 2013, No.6, 587-593)

- OSVs spend extended time in transit. (Up to 24 hours)

- Average distance from onshore to offshore operating blocks is 1 - 200 nautical miles

Challenges

Refueling options

Availability of H_2 / sources

Fuel storage for extended field time

Thank You!

Any questions?

Simon Bennett
General Manager, Sustainable Development
simon.bennett@swire.com.sg

SWIRE PACIFIC OFFSHORE