



**NANYANG
TECHNOLOGICAL
UNIVERSITY**
SINGAPORE

Alternative low-carbon energy for maritime application

Ammonia = Hydrogen 2.0 Conference

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Maritime Energy & Sustainable Development

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- Maritime Singapore
- Who are we?
- Studies by MESD CoE
- Ammonia among other alternative marine fuels

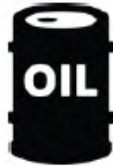
The Singapore Maritime Cluster is a key enabler of Singapore's economic growth

2018 Performance



Container
Throughput
36.6 mil TEUs

2nd Busiest Container Port



Bunker Sales
49.8 mil tonnes

Top Bunkering Port



Ship Registry
Tonnage
90.9 mil GT

5th Largest Ship Registry



Home to more than 140 of the
world's top shipping groups



Connected to 600 ports
worldwide in 123 countries, with
more than 120,000 ship calls
annually



Contributes to more than 7% of
Singapore's GDP, and employs
over 170,000 people in over
5,000 maritime establishments

Maritime activities in Singapore

Core Maritime Activities in Singapore:

- A. Terminals Operations– Cargo Handling
- B. Marine Operations and Services
- C. Marine & Offshore Engineering

- At any one time, there are about 1,000 vessels in the Singapore port.
- Every 2-3 minutes, a ship arrives or leaves Singapore.

Essential Marine Services

Bunkering , Pilotage, Towage,
Mooring, Fresh Water Supply,
Crew Change, Ship Supplies

Maritime Activities within Singapore Port Limits

1. Tuas Mega Port
2. Container Terminals
3. Multi-purpose Terminals
4. Shipbuilding, Repairing, Conversion
5. Petrochemical Terminals
6. LNG Terminal
7. Passenger Terminals
8. Anchorage areas for essential Marine Services like: Bunkering, Pilotage, Towage, Fresh Water Supply, Crew Change, Ship Supplies, Waste Disposal, Minor Repairing, Surveying

* Other Shore-based Maritime Services not labelled in the map

Ship Registry, Ship Management, Shipping Finance, Maritime Legal & Arbitration, Marine Insurance, Shipbroking & etc



Singapore Maritime | Strategic Research Thrusts

Strategic Research Areas:



**Efficient & Intelligent
World Class Next
Generation Port**



**Strategic Sea Space &
Maritime Traffic
Management**



**Smart Fleet Operations
& Autonomous Vessels**



Effective Port Safety & Security



Sustainable Maritime Energy & Environment

Source: MPA

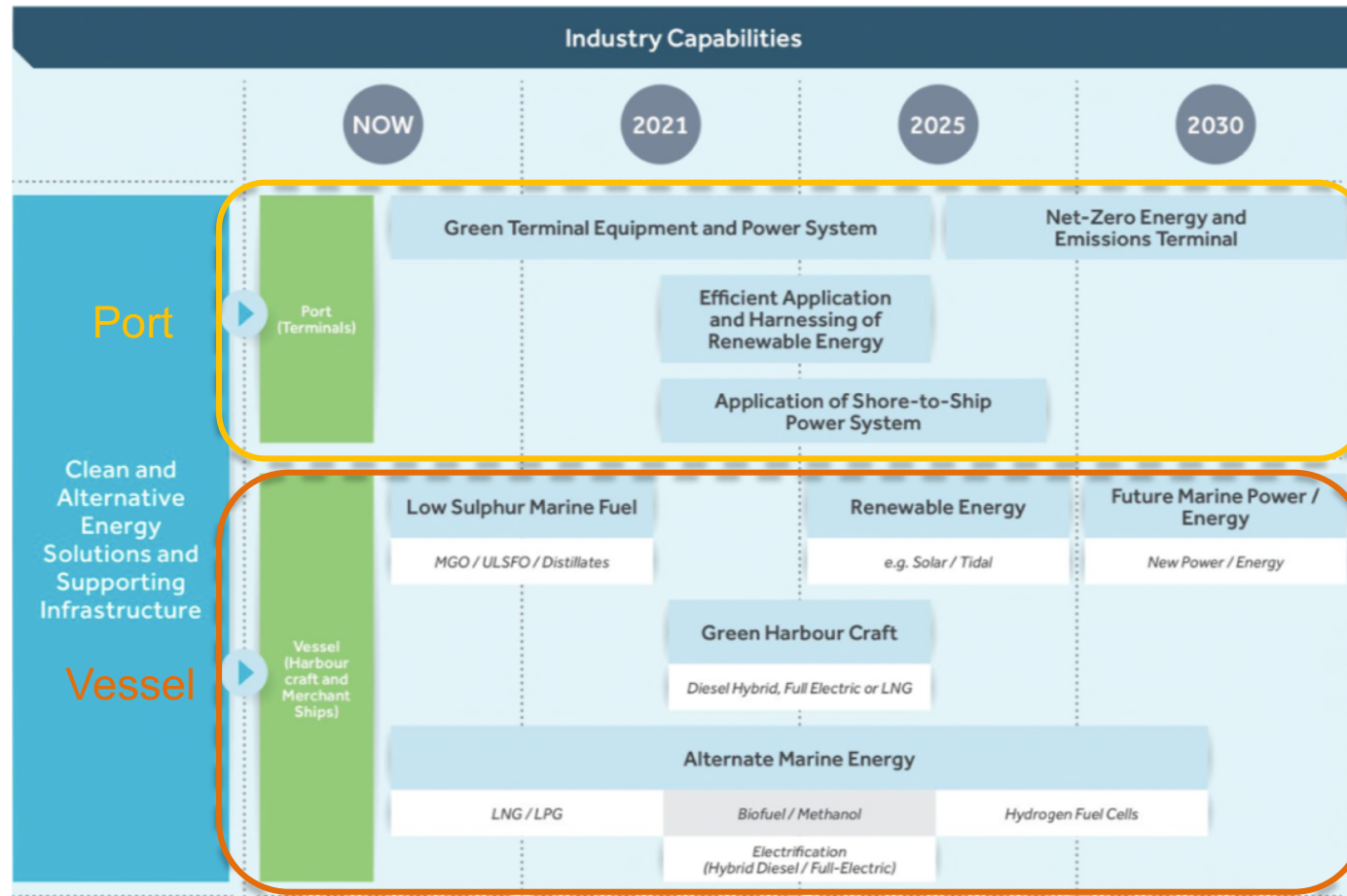
Singapore Maritime R&D Roadmap 2030 | Thrust 5

Maritime Energy

Vision

“We aspire for Singapore to be the centre of excellence for future energy and environmental solutions”

Source: SMI R&D Roadmap 2019



LNG

LPG

Biofuel

Methanol

Hydrogen

Electrification

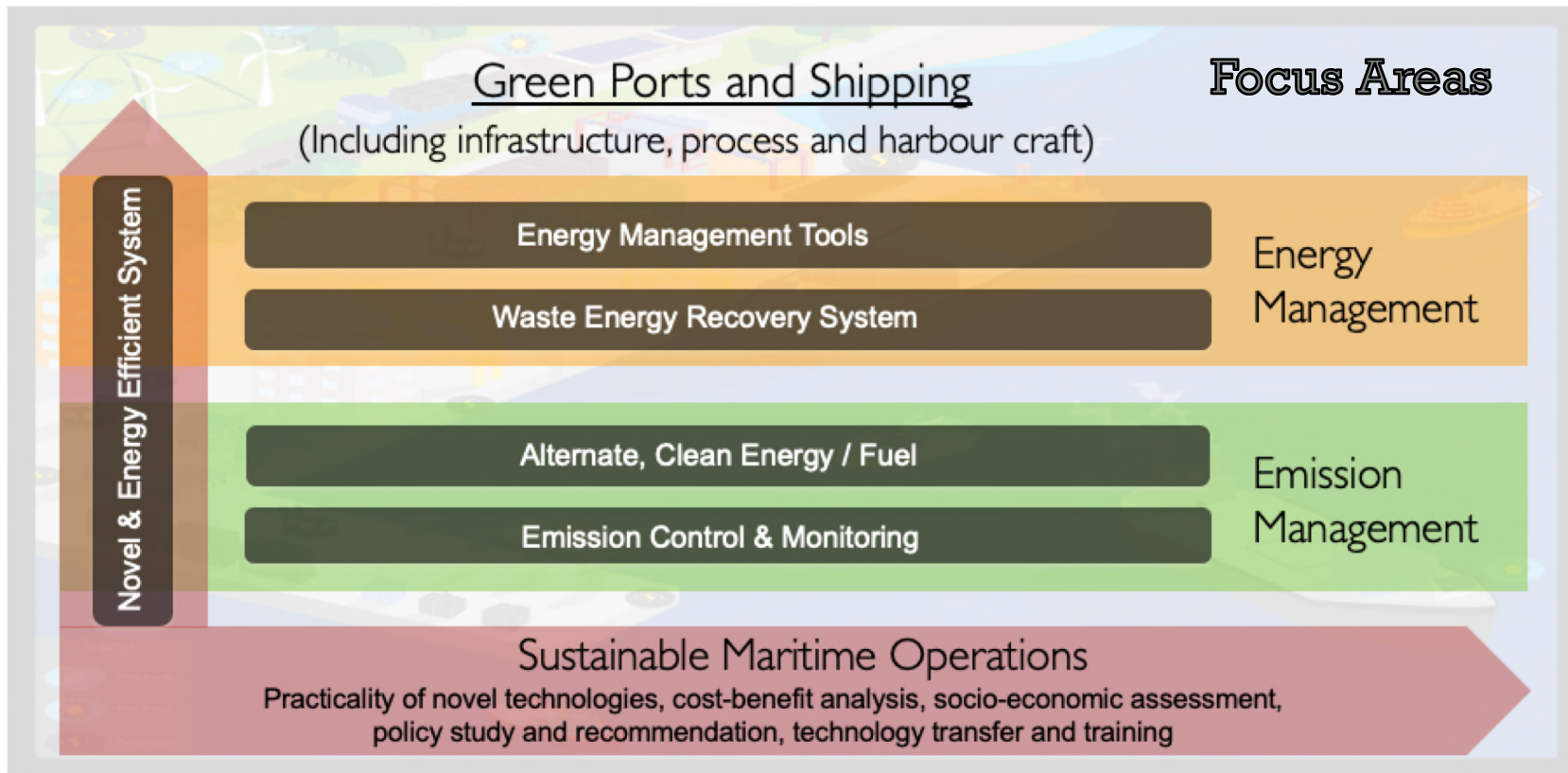
New power /energy



MESD | Maritime Energy & Sustainable Development

Vision |

A leading global translational research centre in maritime energy and sustainable development



Supported by



Translating R&D Investment for maritime Singapore

1. Consultation with End Users to identify / confirm challenges
2. Study/analyze challenges and propose solutions / ideas. Conduct feasibility study if needed.
3. Leverage on testbeds and living laboratories at each stage
4. Identify value capture for Singapore and form project team (including industrial partners)
5. Execute and coordinate projects (program) along with eventual technology adopters and executing entities

Challenges | **Port Sustainability** | **Environment Protection & Air Emissions** | **Maritime Energy**

Feasibility Study

Ideas / Proposed Solutions

Govt Agencies/ Regulators

Startups | **SMEs** | **LLEs** | **MNCs**

Commercialising Party / Parties

Equipment Providers & Others

Classification Societies

End Users

Port Owners & Operators

IHL's Faculty & Researchers

Shipyards

Vessel Owners & Operators

TRL 1-2

TRL 3-7

TRL 8-9

TRL: Technology Readiness Level (1: Basic R&D -> 9: Ready Commercially)



Example of studies by MESD

Alternative Energy

1. Study of potential alternative sources of energy for Shipping Industry
2. Study of potential alternative sources of energy for Next Generation Multi-Purpose Port Operation
3. Study of potential alternative sources of energy for Singapore Harbour Craft Industry
4. Project Hafnium: Hydrogen as a source of energy for OSV
5. GHG Emissions from International Shipping: Strategies and Impacts

Collaborators



Harbour
Craft
Owners

International efforts on climate change

Paris Agreement

In line with the agreement adopted in Paris in December 2015, Singapore has made a commitment to reduce our Emissions Intensity by 36% from 2005 levels by 2030, and stabilise our greenhouse gas emissions with the aim of peaking around 2030.

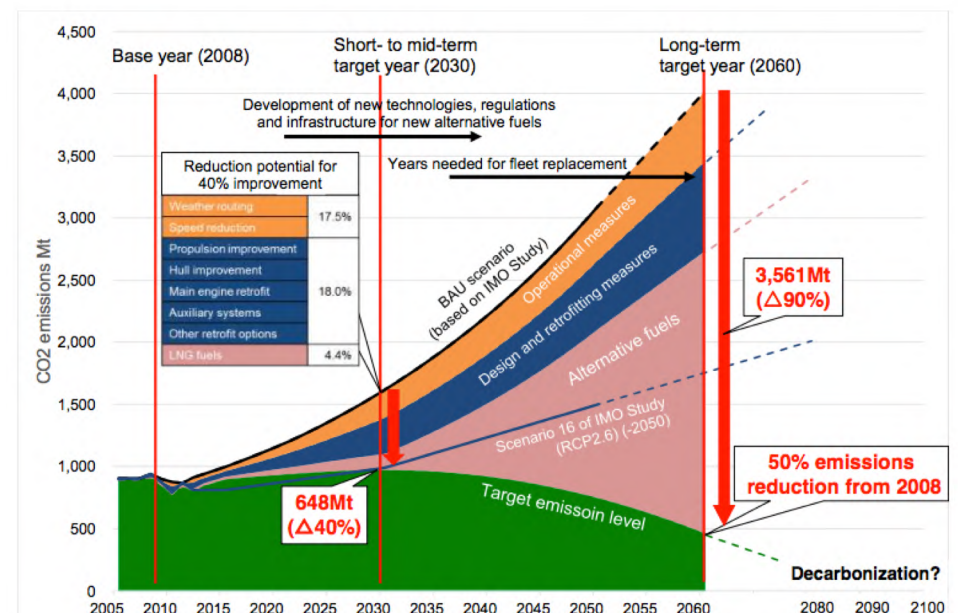


Singapore ratifies Paris Agreement. In the picture is Foreign Affairs Minister Vivian Balakrishnan and the United Nations Secretary-General Mr Ban Ki-moon.

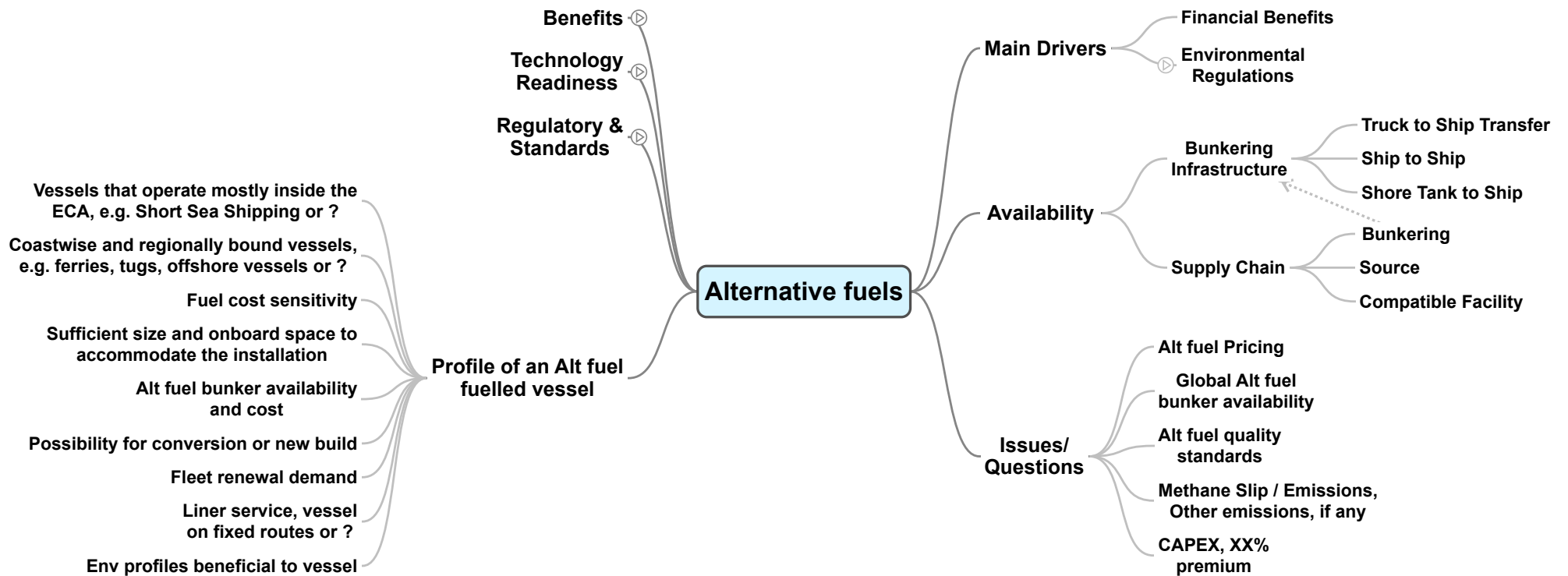
Source: Japan Proposed Pathway – Long Term Co2 emission reduction

Initial GHG Strategy Paper

The initial GHG strategy was adopted by IMO's MEPC during its 72nd session in April 2018. The vision confirms IMO's commitment to reducing GHG emissions from international shipping and, as a matter of urgency, to phasing them out as soon as possible.

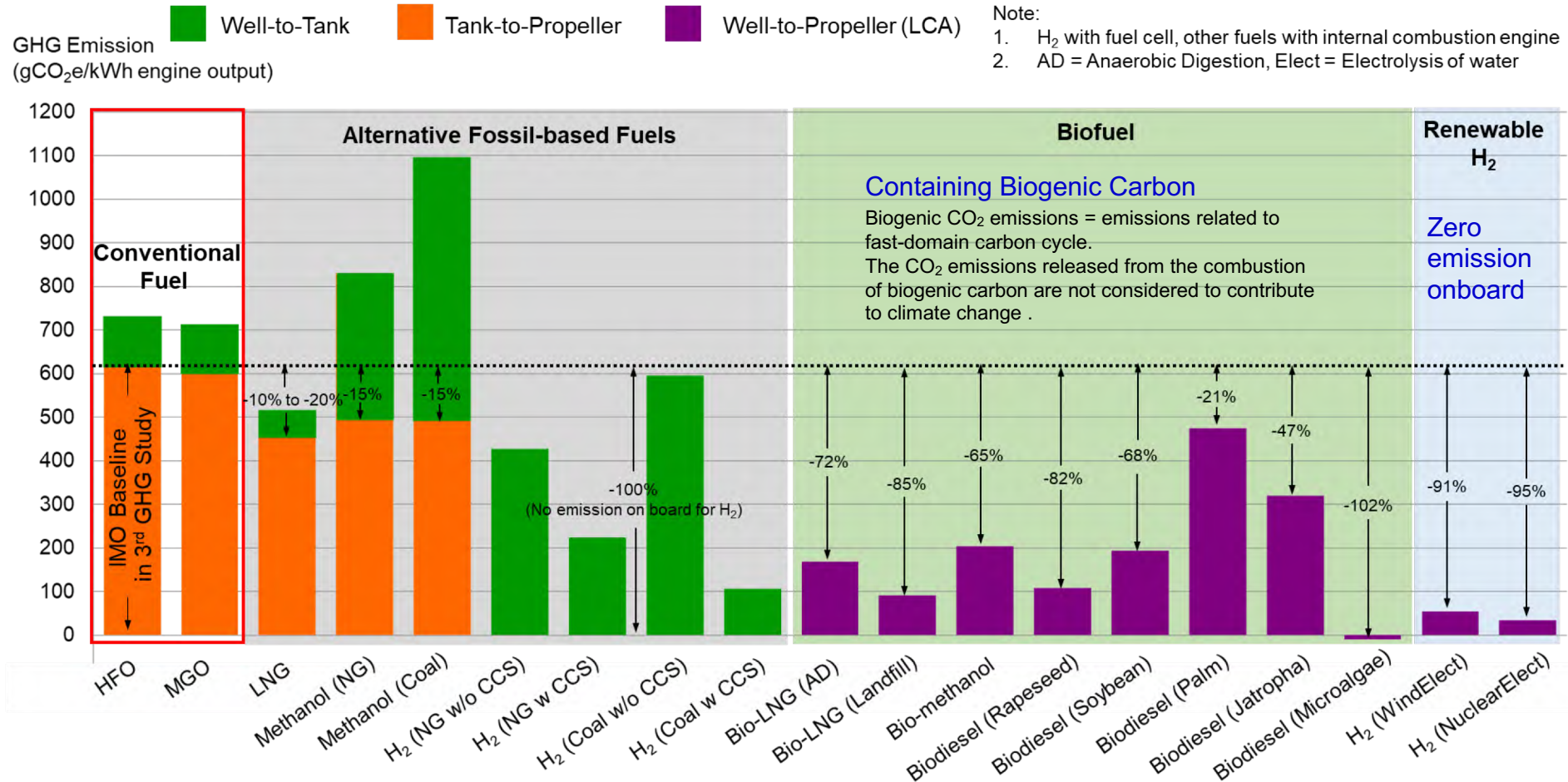


Consideration of alternative fuel for ship



Source: MESD CoE

GHG Emission Reduction Potential

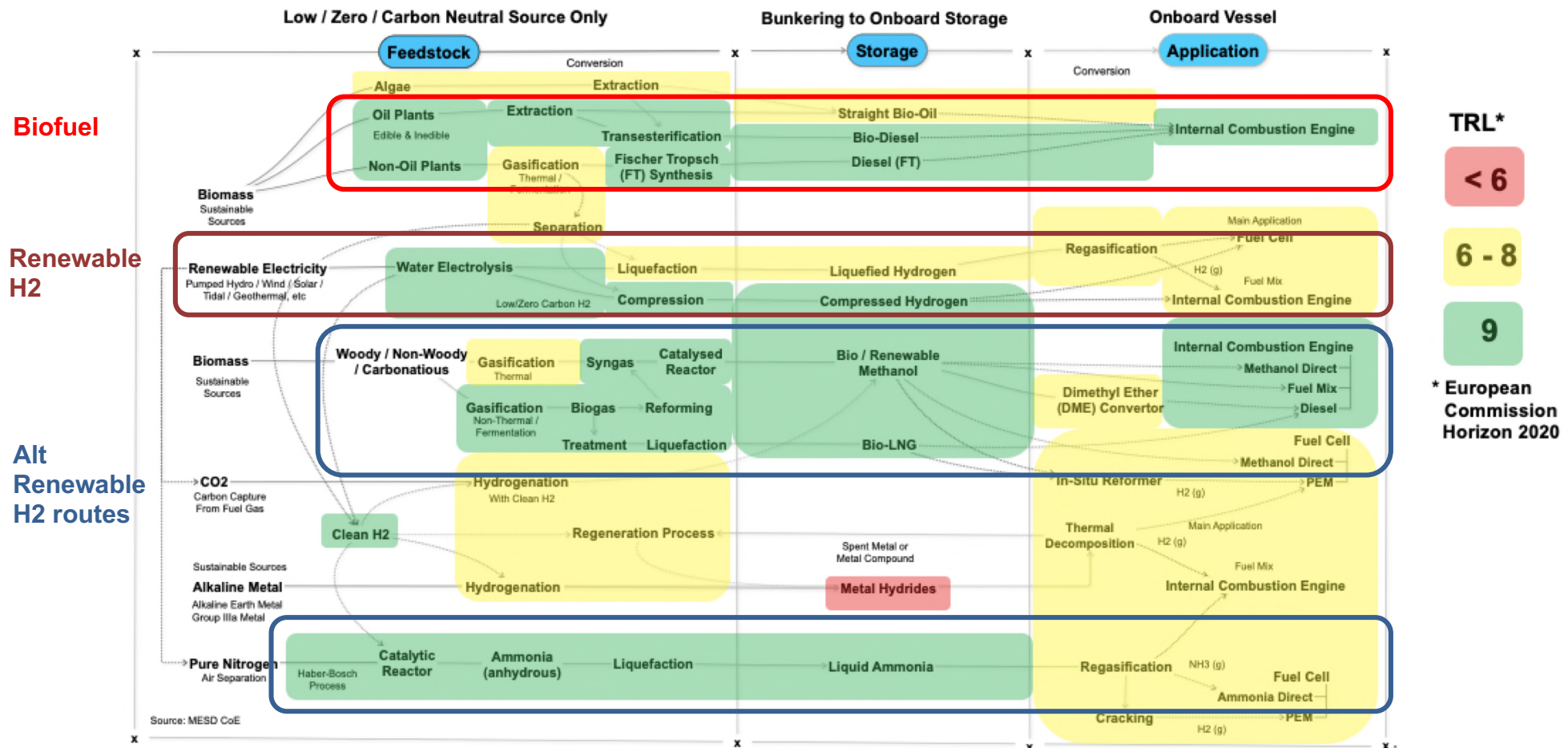


- Yes, if expansion of production capacity
- Yes, but require R&D

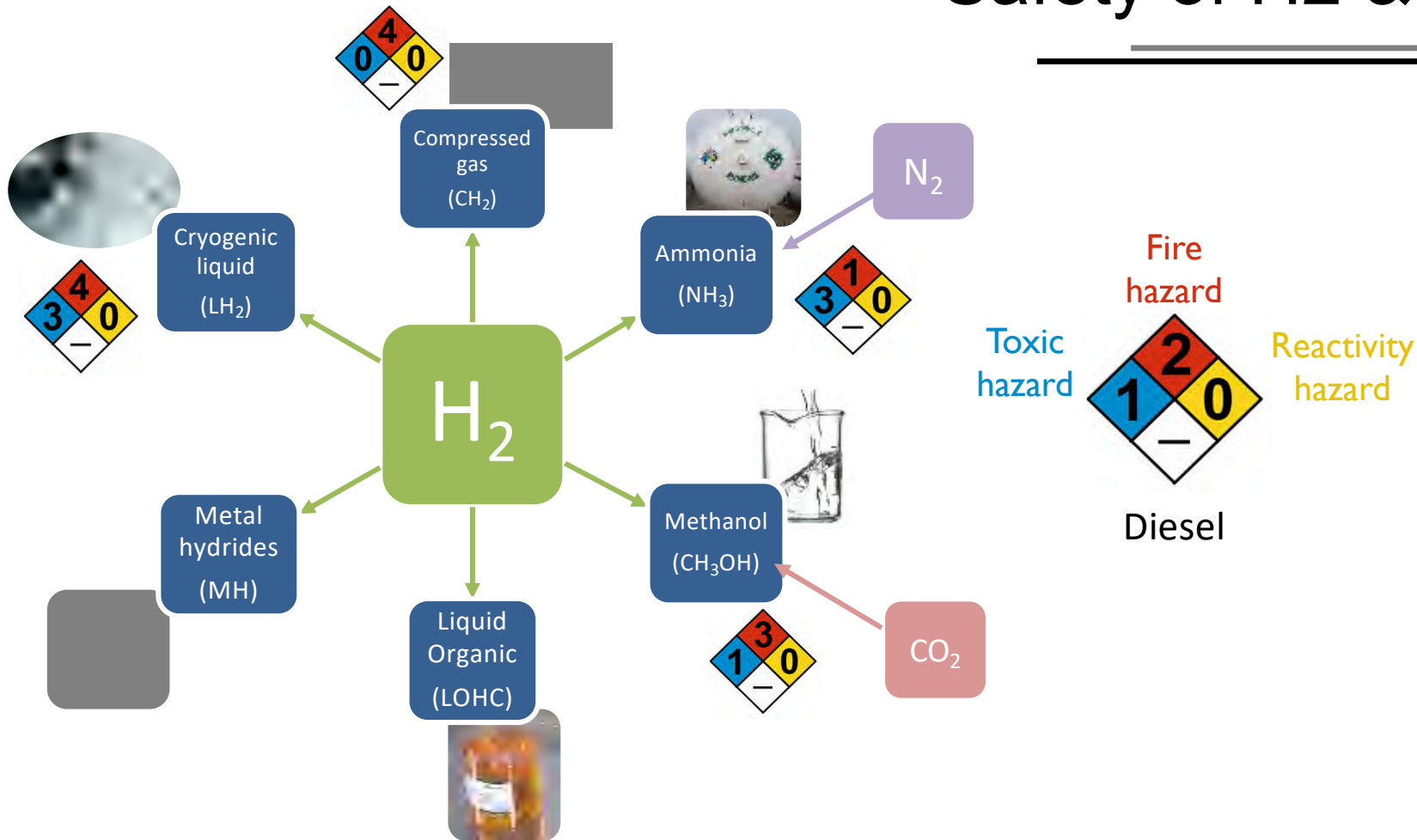
Alt fuels for ships – Supply vs Demand

Type	Conventional	Fossil-based			Biofuels				Renew
	LSFO/MGO	LNG	Methanol	Hydrogen	Bio-LNG	Bio-methanol	Biodiesel 1 st and 2 nd	Biodiesel 3 rd	Renewable Hydrogen
Feedstock	Crude oil reserve	Natural gas reserves	Natural gas and coal	Natural gas, oil and coal	Food & agricultural waste and wastewater	Biomass, non-biogenic	Edible and non-edible oil	Microalgae	Renewable energy and water
Availability of feedstock (MT/year)	Meet global demand for at least 50 years	Meet global demand for at least 50 years	Refer to Crude oil and natural gas	Refer to Crude oil and natural gas	Technical potential = 900 MT of bio-LNG	Technical potential = >900 MT of bio-methanol	180 million tonnes (used by other sectors)	Technical potential = 3,780 MT of biodiesel	Technical potential = 1,260 MT of H ₂
Current production (MT per year)	4,671	3,195	91	50	NA	0.2	31	NA	-
Demand by shipping industry (MT per year)	260-290	200	508	76	200	508	250	250	76
Adequacy for Int'l Shipping	Yes	Yes	Yes, if expansion of production capacity				No	Yes, but require R&D	Yes, if ..

Maturity of alt fuels and their well-to-propeller routes



Safety of H₂ & its carriers

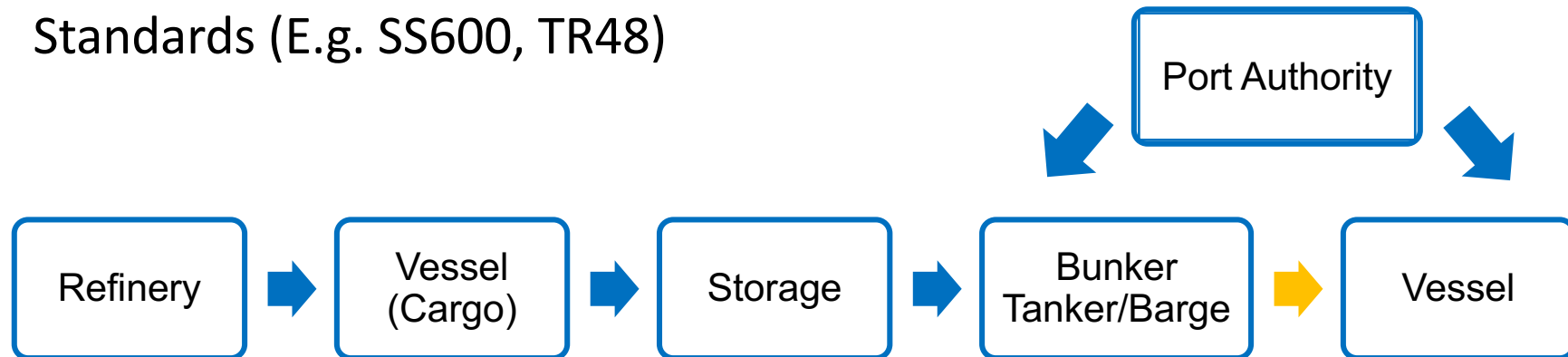


Bunker fuel supply chain

Quality of fuels (e.g. ISO 8217, IMO Regulations)

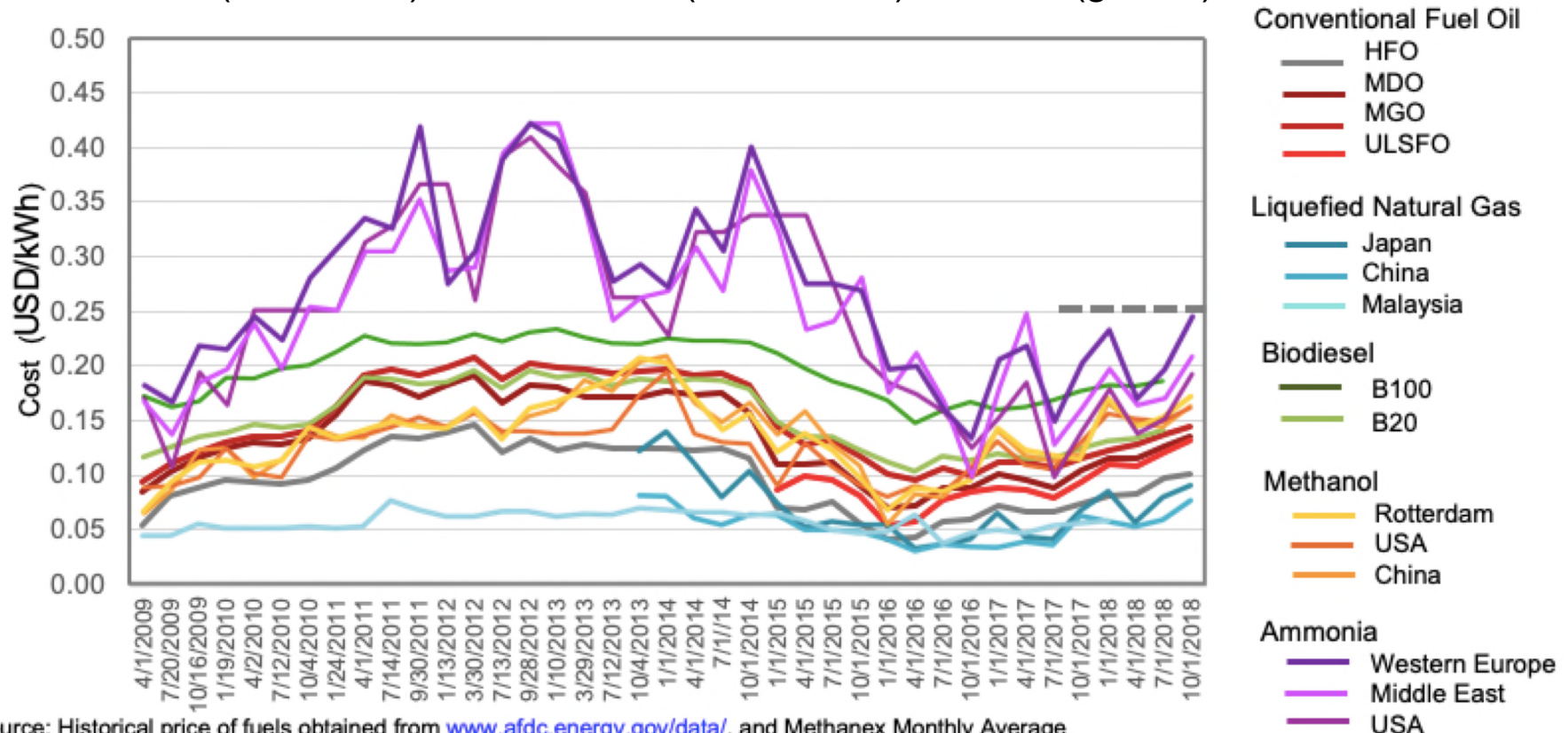
Delivery process (S2S, Shore2S, T2S)

Standards (E.g. SS600, TR48)



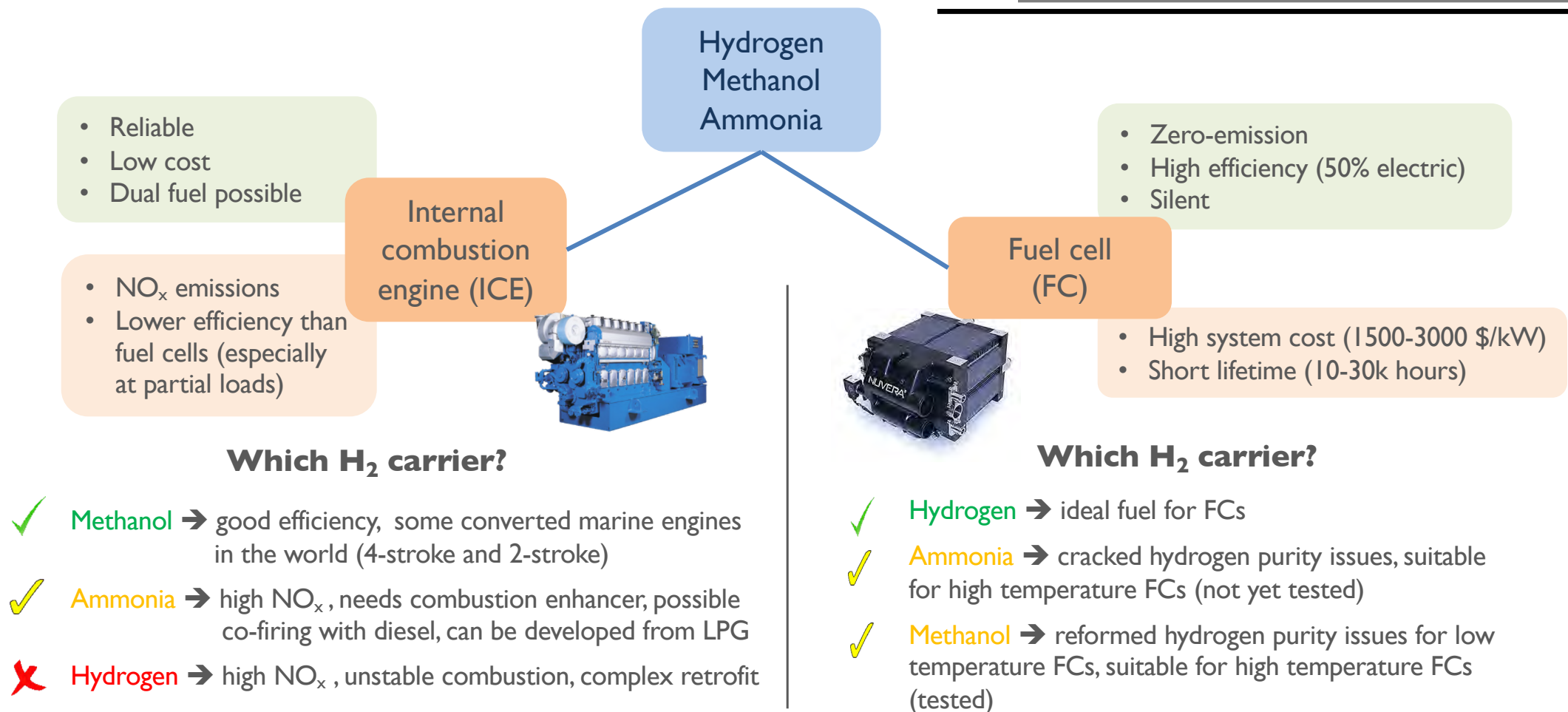
Fuel cost

$$\text{Fuel cost (USD/kWh)} = \text{Cost of fuel (USD/tonne)} \times \text{SFOC (g/kWh)}$$

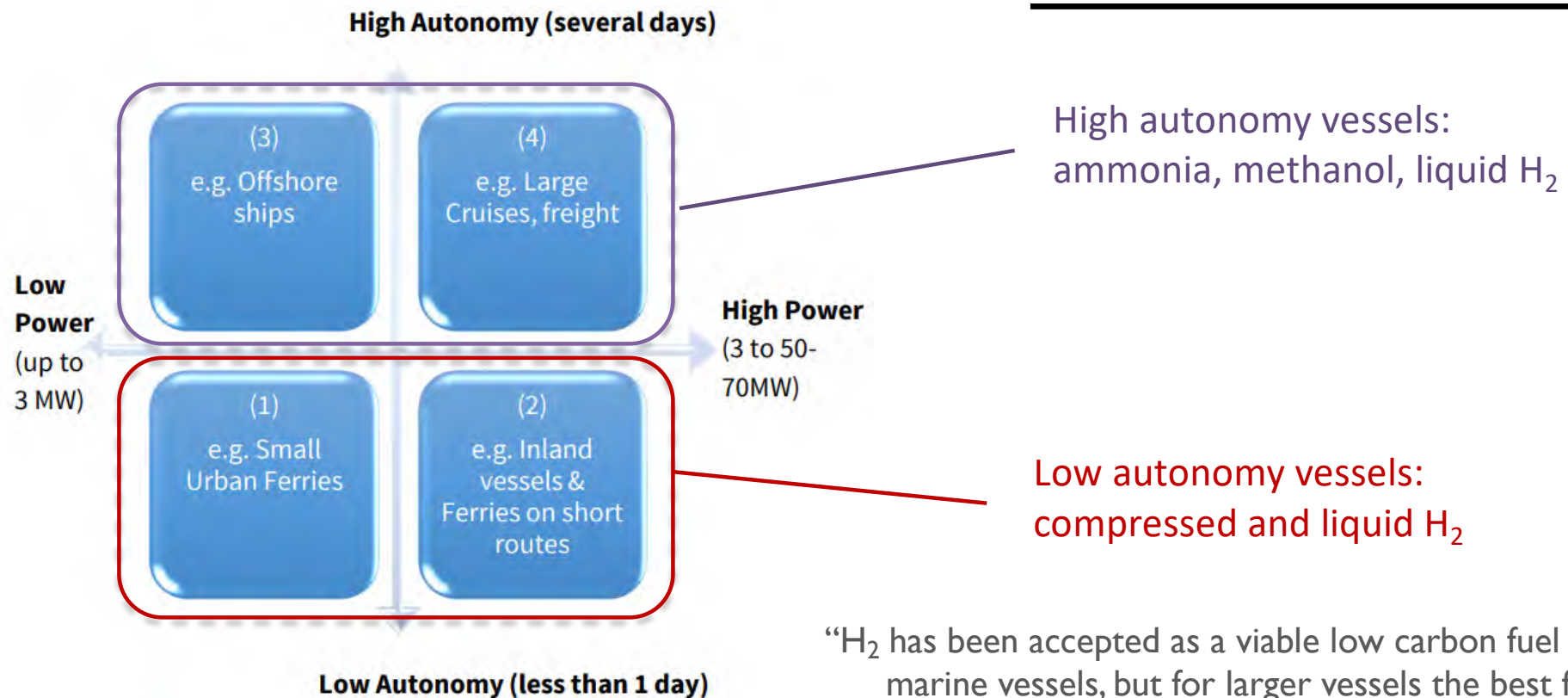


Source: Historical price of fuels obtained from www.afdc.energy.gov/data/, and Methanex Monthly Average Regional Posted Contract Price History

On-board energy conversion



Energy density of H₂ carriers

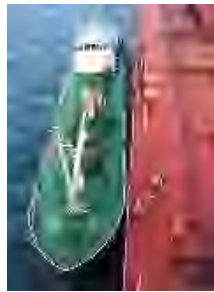


“H₂ has been accepted as a viable low carbon fuel for smaller marine vessels, but for larger vessels the best fuel for decarbonisation is undetermined”
(Hydrogen Europe, 2018)

Source: Hydrogen Europe Technology Roadmap to 2030, 2018

Singapore Harbour Crafts

- There are ~2,300 ships with engine size of 300-3,000 kW.
- All motorized operation use diesel oil (~70% of overall)



Tankers [SB]



Lighter [SC]



Passenger boat [SP]

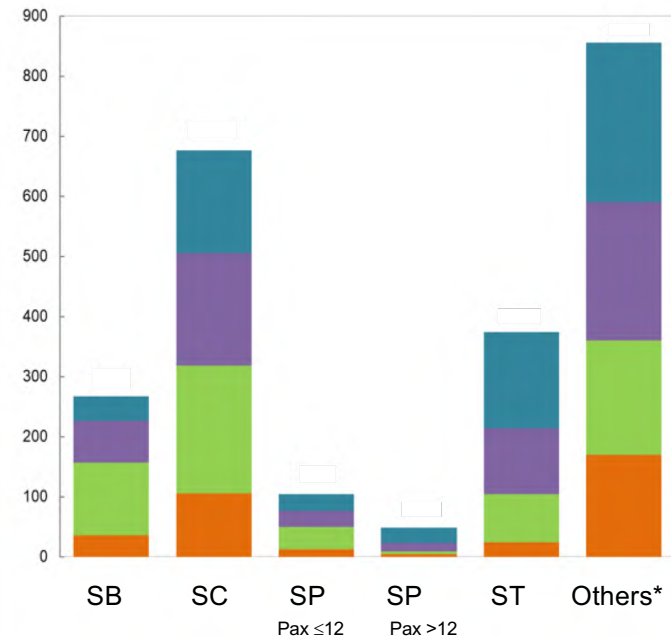


Pilot boat [SP]



Tug boat [ST]

- More than half of SG HC is more than 10 yrs (~30% > 20yrs)
- Excluding 'Others' category, Lighter, Tugboat, Tanker and Passenger form the main profile
- Sg HC's Gross Tonnage (GT) is evenly distributed between "10-49", "50-499" & "500 & above"



Source: MPA, 2017

*Provide services regardless of port limits that is not the usual norm within the HC industry

Knowledge to application

1. In-depth studies to enable actual application of potential alternative energy sources
2. Pilot “identified” proof-of-concept/value solutions at living laboratories with industry partners
3. Improve data collection and measurement of engine performance and emission
4. Formation of thematic industry & related stakeholder’s consortium to address future challenges, pooling resources with same interests

“ It is the long history of humankind (and animal kind, too) that those who learned to collaborate and improvise most effectively have prevailed.”

- Charles Darwin



Thank you

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For more information, please visit MESD website http://coe.ntu.edu.sg/MESD_CoE