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Ammonia as a future marine fuel - bunkering

*The 2nd Ammonia = Hydrogen 2.0
Virtual Conference*

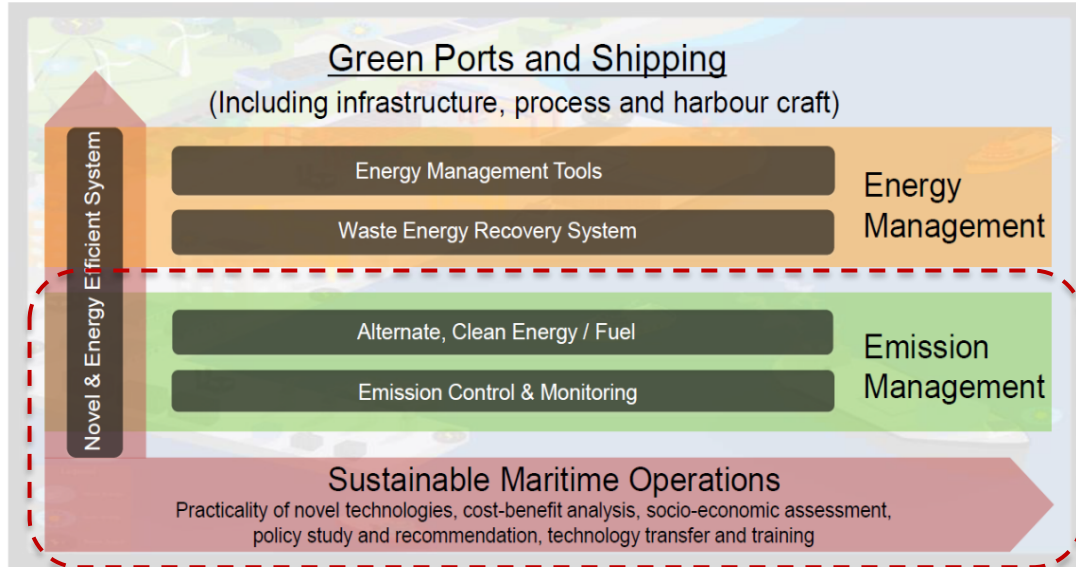
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Maritime Energy & Sustainable Development (MESD)
Centre of Excellence

28 August 2020



R&D Focus



Vision

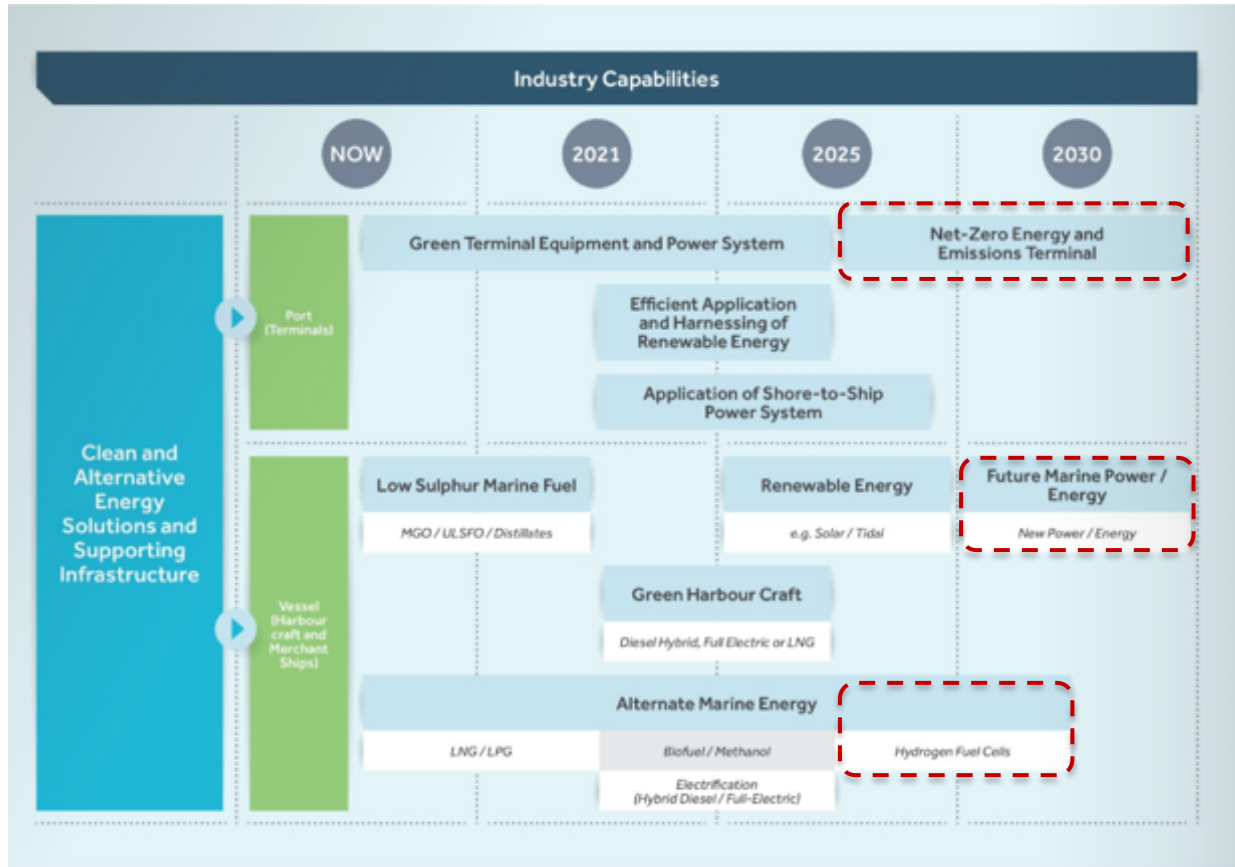
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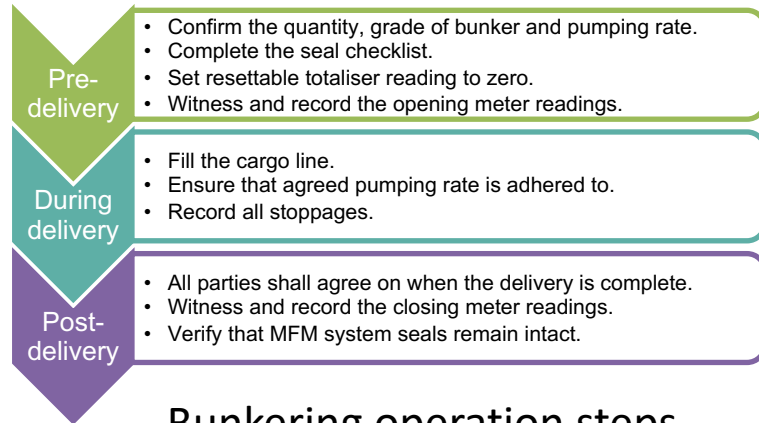
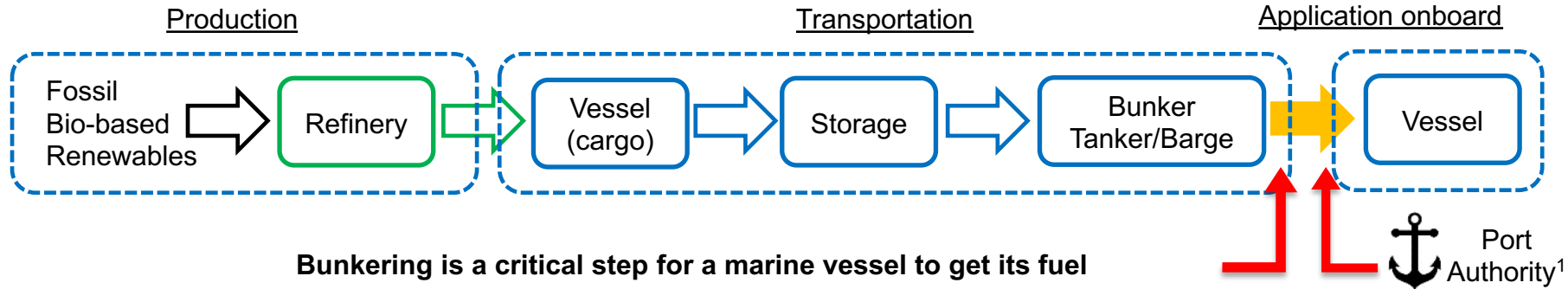
RESEARCH THRUST 5 | MARITIME ENERGY

Launched in SMTC 2019

Source:
<https://www.maritimeinstitute.sg/roadmap2030/>

Marine Fuel Bunkering - Overview

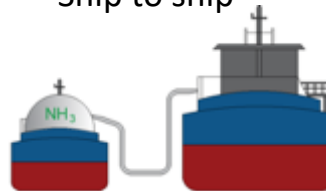
Marine fuel supply



Bunkering operation steps

- ❑ Similarly the ammonia bunkering is expected to follow the steps of marine fuel oil.
- ❑ No ammonia as a marine fuel bunkering procedure, guideline and standard is established.

Ship to ship



Shore to ship



¹ for Singapore context

Ammonia Bunkering – Relevance

Land Based Experience

Chemical Industry



Source: Pneumsys Advance Energy Solutions

Power Plant (SCR)



Source: Rocky Mountain Power, PacifiCorp

Fertilizer Industry



Source: Successful Farming

Refrigeration



Source: SubZero Constructors

Marine Experience

Ammonia Terminal



Source: Indonesia Ammonia Export Terminal - MDR

LNG Bunkering



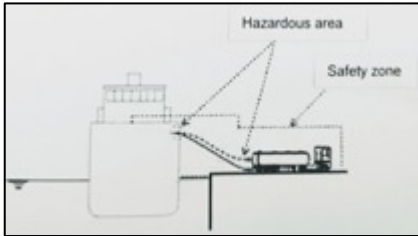
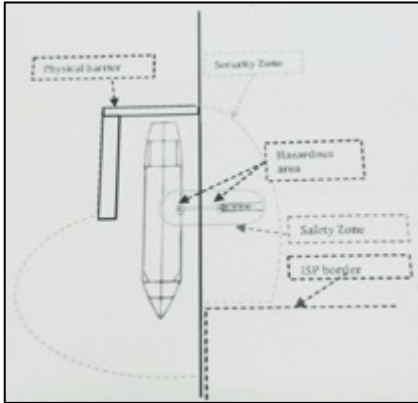
Source: Word Energy News, Amsterdam Port

Experience from chemical, fertilizer and relevant marine sectors serve as good reference to establish ammonia bunkering operation.

Ammonia Bunkering – Safety

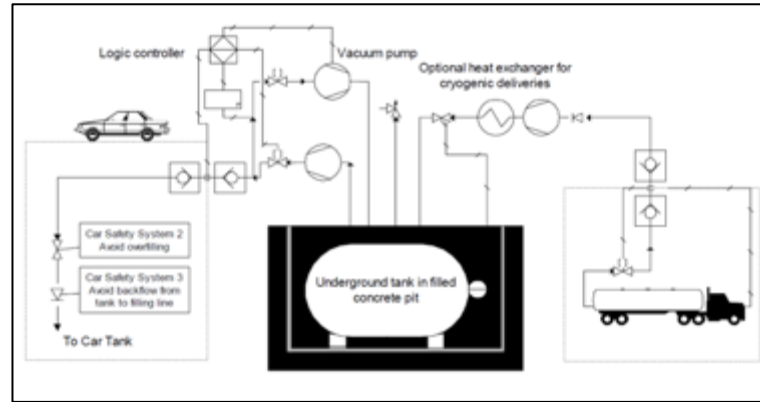
Safety Zone

LNG Bunkering



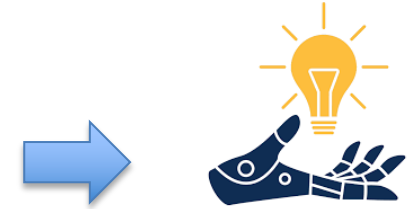
Source: TR 56 LNG Bunkering

Ammonia Refueling



Source: N. J. Duijm, F. Markert, and J. L. Paulsen, "Safety assessment of ammonia as a transport fuel," 2005.

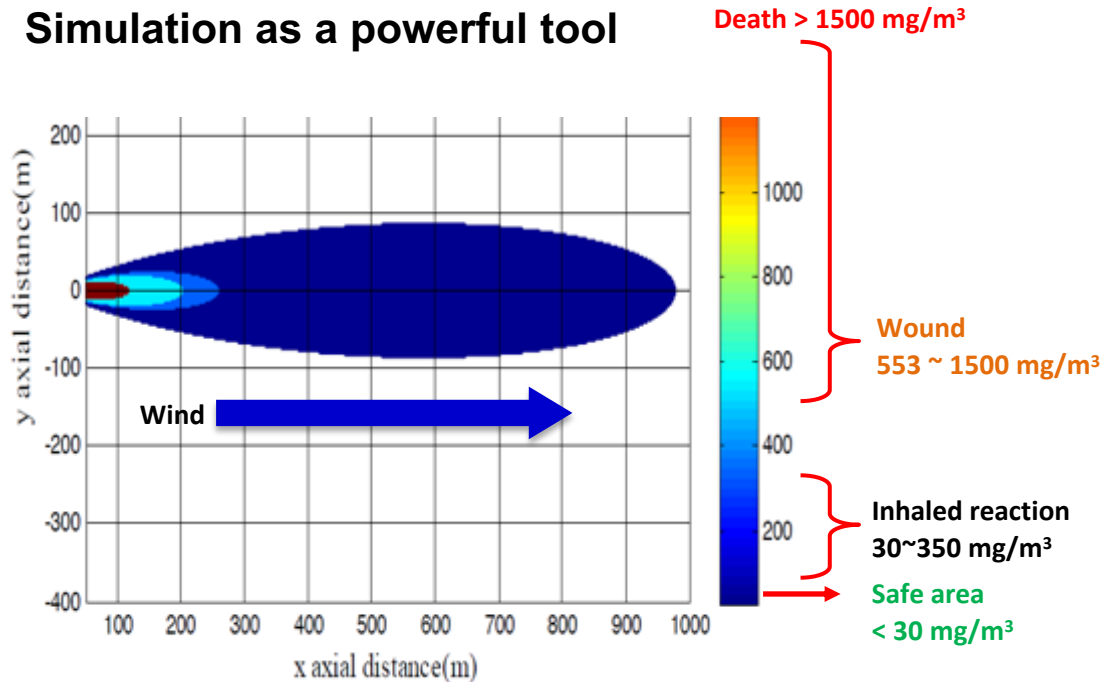
Ammonia Bunkering ?



Experience from environmental assessment provide good reference for predicting the safety zone during ammonia bunkering.

Ammonia Bunkering – Safety

Simulation as a powerful tool



Example: simulated ammonia leakage at 5 kg/s with wind speed of 4.5 m/s

Source: J. Jie, C. Xiaoxia, and H. Xuefeng, "Rapid simulation and visualization analysis of liquid ammonia tank leakage risk," *Procedia Engineering*, vol. 84, pp. 682-688, 2014.



Human

Exposure
Inhale
Acute effect
Chronicle effect
Training
PPE...



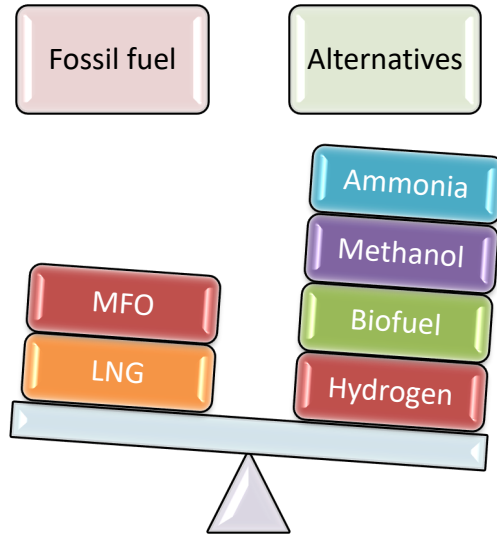
Environment

Atmosphere
Waterbody
Eutrophication
Recovery...

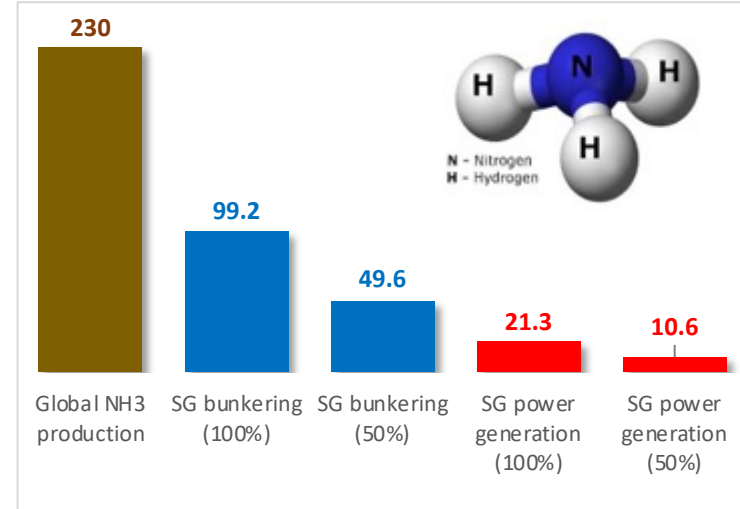


Machinery

Material integrity
Ventilation
Detection system
HAZOP...



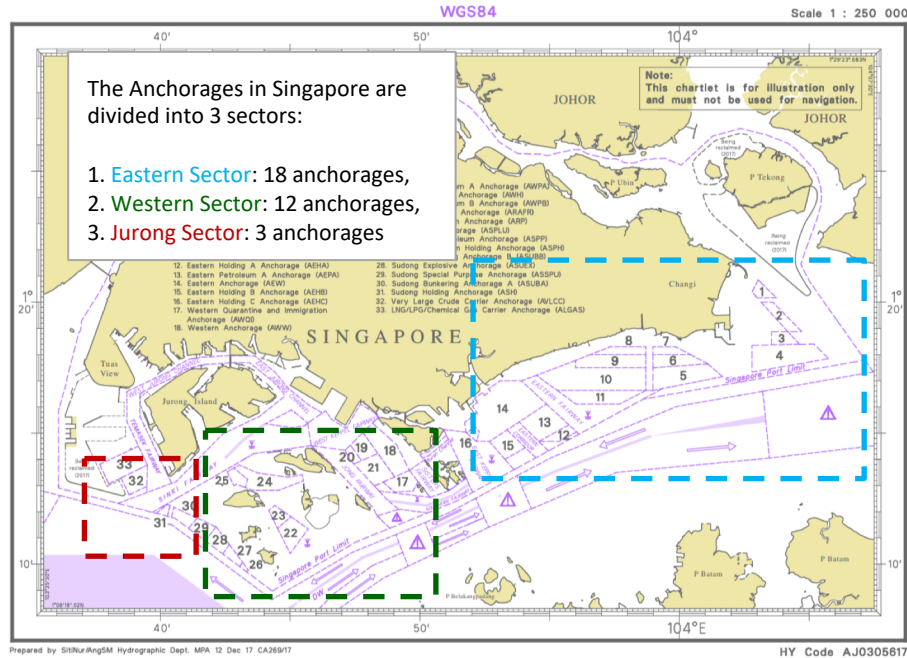
Potential future bunkering options in Singapore



Potential demand of ammonia as alternative fuel in Singapore (million tons)

- ❑ Singapore is one of the largest world bunkering hub with options of future alternative bunker fuels.
- ❑ Singapore will play a critical role as a strategic location to receive, store, consume or bunker ammonia.
- ❑ The potential demand of ammonia as an alternative fuel in Singapore is huge, either for power generation or bunkering purpose.

Anchorage



Aerial View



Source: https://www.reddit.com/r/singapore/comments/68rgot/birds_eye_view_of_singapore/

Bunkering activities are concentrated around designated anchorages and terminals.

Ammonia Bunkering – Further Considerations

Bunkering procedure, guideline and standard

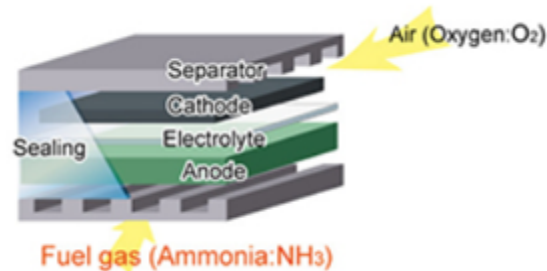
- MFM Metering
- Safety and risk analysis
- Crew training
- ...

Fuel Supply System

- Fuel storage
- ICE or FC?
- ...

Vessel Design

- Crew Safety
- Retrofit or new build
- ...



Ammonia SOFC
Source: Noritake



Ammonia carrier fuelled by its own cargo
Source: Maritime Executive, 2019



Thank you

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