Getting Ready for Clean-Produced, Carbon-Free Ammonia and Well-to-Wake Emissions

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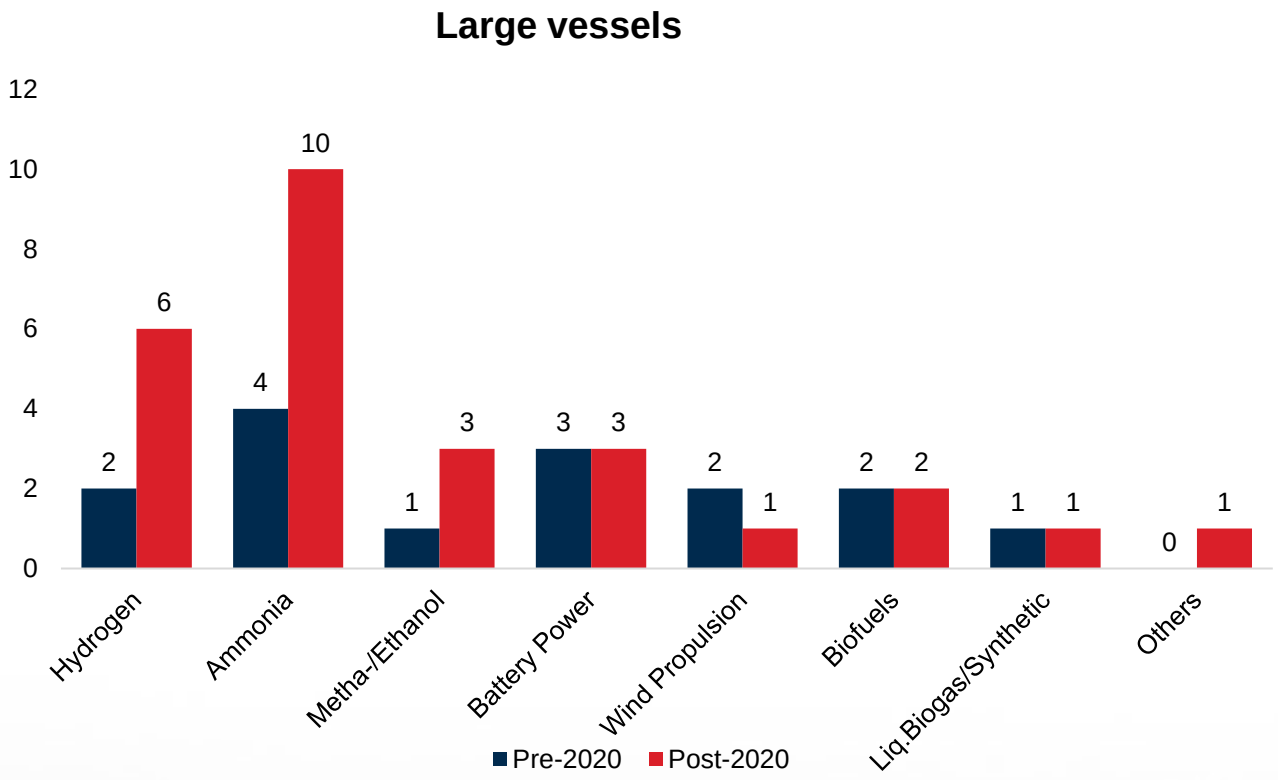
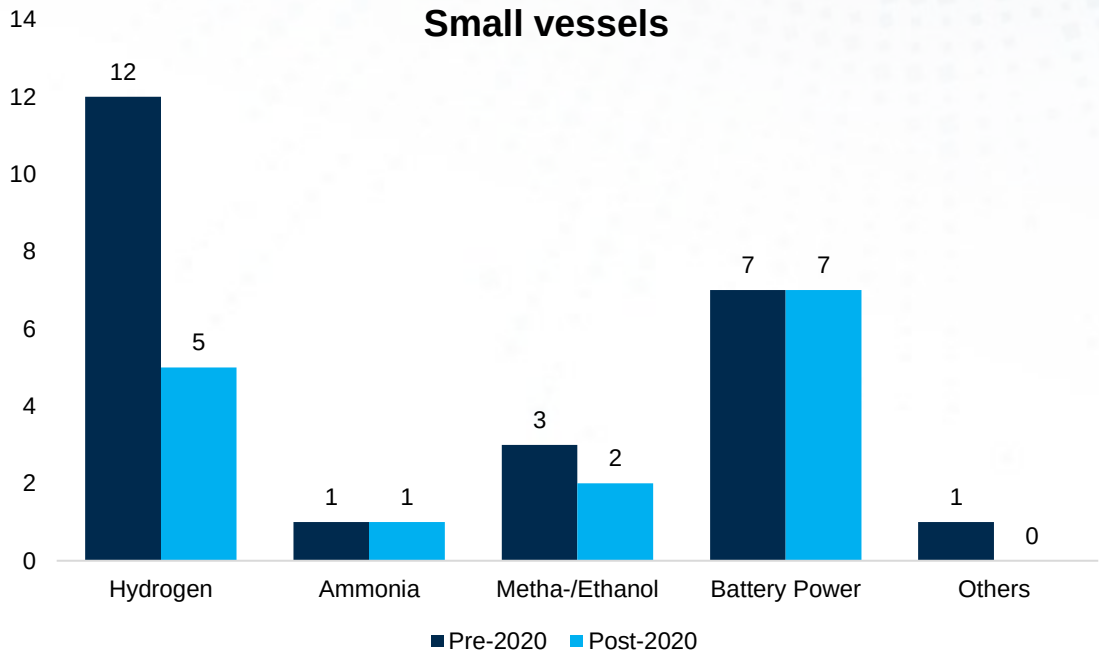
Joint Development Projects



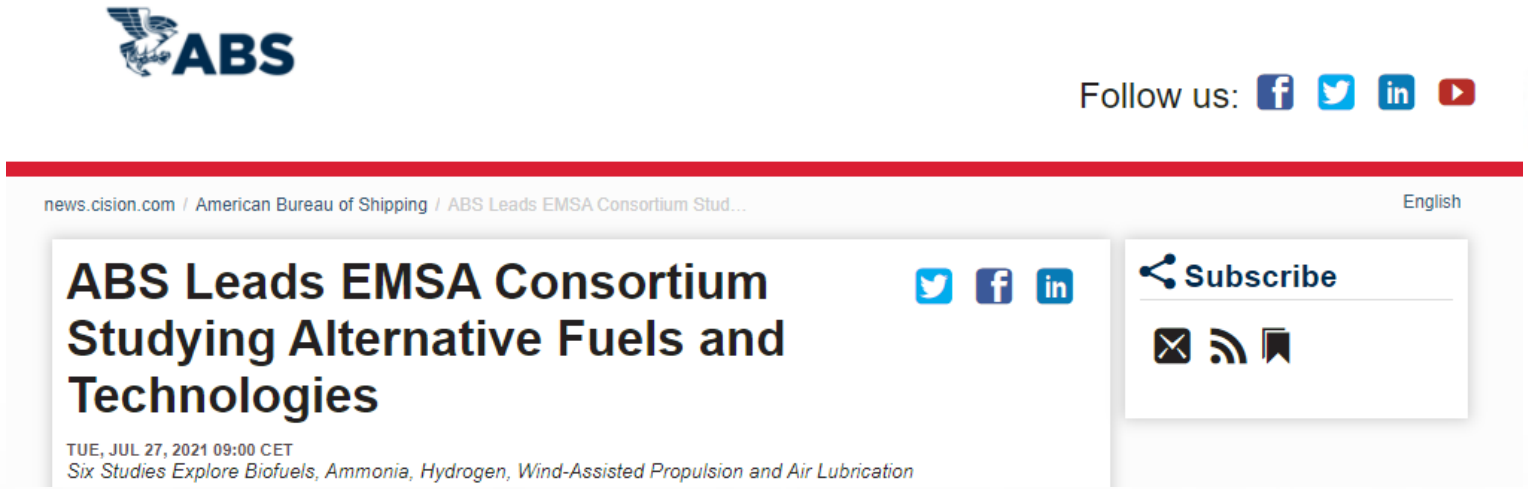


AVIN Suezmax Tanker - World's First Ammonia/LNG Ready Design

- The 3 x Suezmax vessels to be built at New Times Shipyard, comply with both the ABS Ammonia Ready Level 1 and the LNG ready level 1 requirement

EMSA Consortium

- EMSA Consortium Studying Alternative Fuels and Technologies
  - Biofuel, **Ammonia**, Hydrogen, Wind Assisted Propulsion, Air Lubrication + Extra (TBD)
  - Availability, life-cycle emission characteristics and economic aspects
  - Current regulatory framework, identify any gaps and include safety assessments for the application of each fuel and power source to cargo as well as passenger vessels

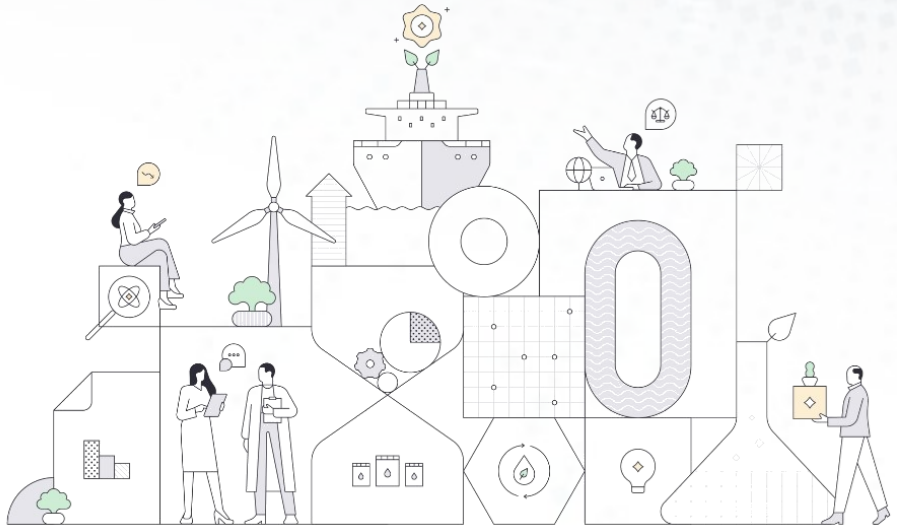


Ammonia Fueled Container Feeder

- Joint Development Project
- 2019 – 2020: Phase 1
  - ABS, SDARI and MAN
  - Conceptual design
  - HAZID
  - AIP
- 2020 – 2021: Phase 2
  - Ship design developped according to a specific route
  - Space and cost optimization
  - Electricity produced from Ammonia
  - HAZID/HAZOP
  - AiP Q1-2022

Mærsk McKinney Møller Center – Zero Carbon Shipping

- ABS is a founding partner
- Studies covering:
  - SOFC study
  - Retrofit studies on many fuel types:
    - LNG
    - Ammonia
    - Methanol
    - CCS
    - Wind Assisted Propulsion
    - Air Lubrication
  - Ammonia bunkering



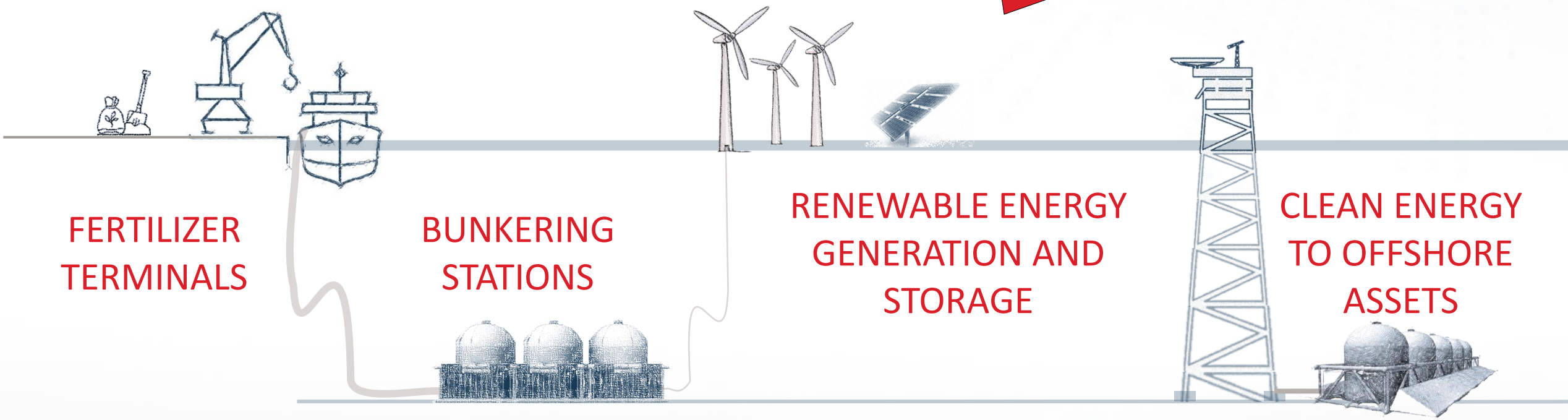
Mærsk Mc-Kinney Møller Center
for Zero Carbon Shipping

https://zerocarbonshipping.com/#

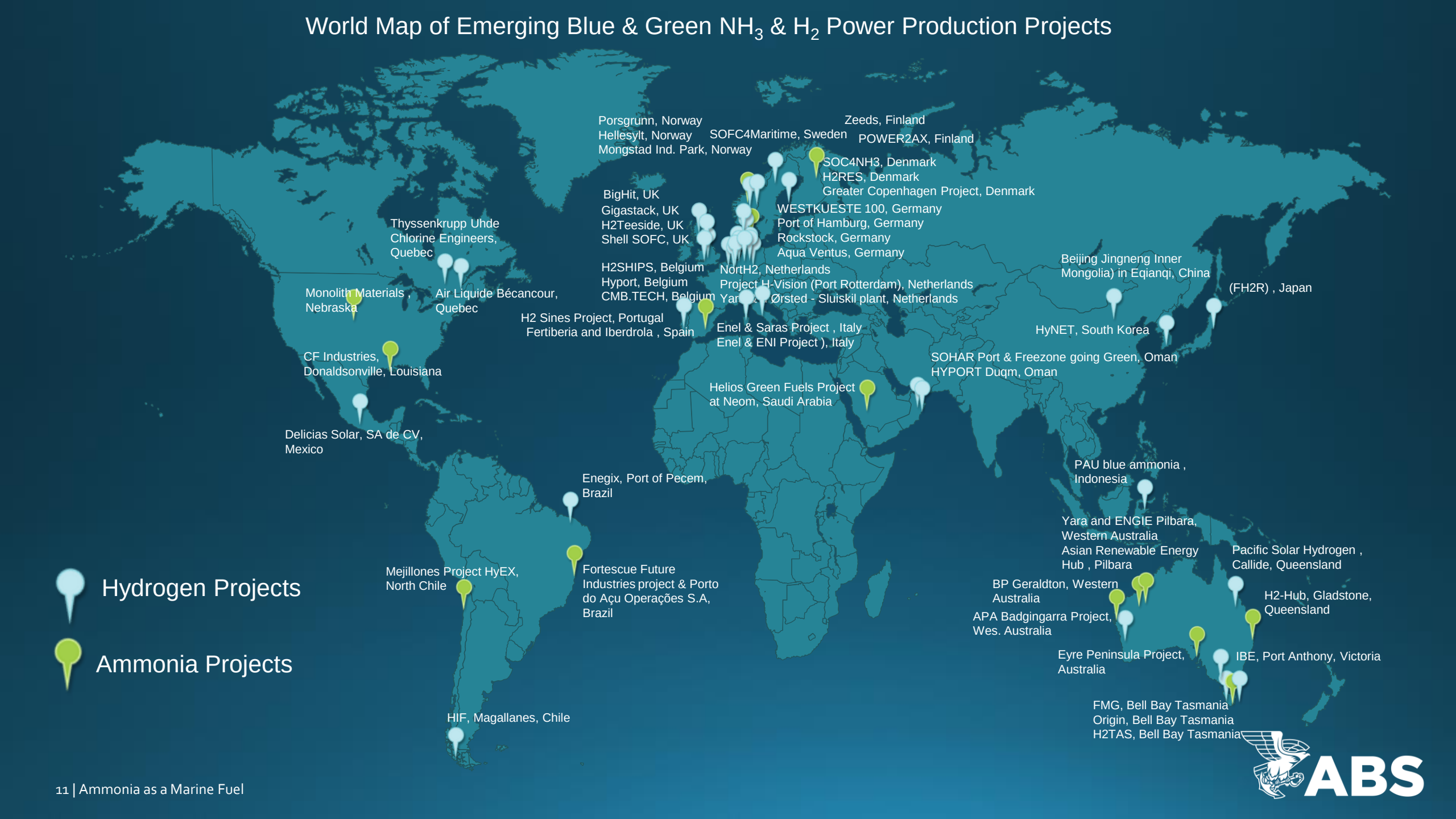
JIP with NOV

- Safe storage of large volumes of ammonia subsea

SAFE AND ZERO ENERGY STORAGE SUBSEA FOR ALL, POPULATED AND NON-POPULATED AREAS



World Map of Emerging Blue & Green NH_3 & H_2 Power Production Projects



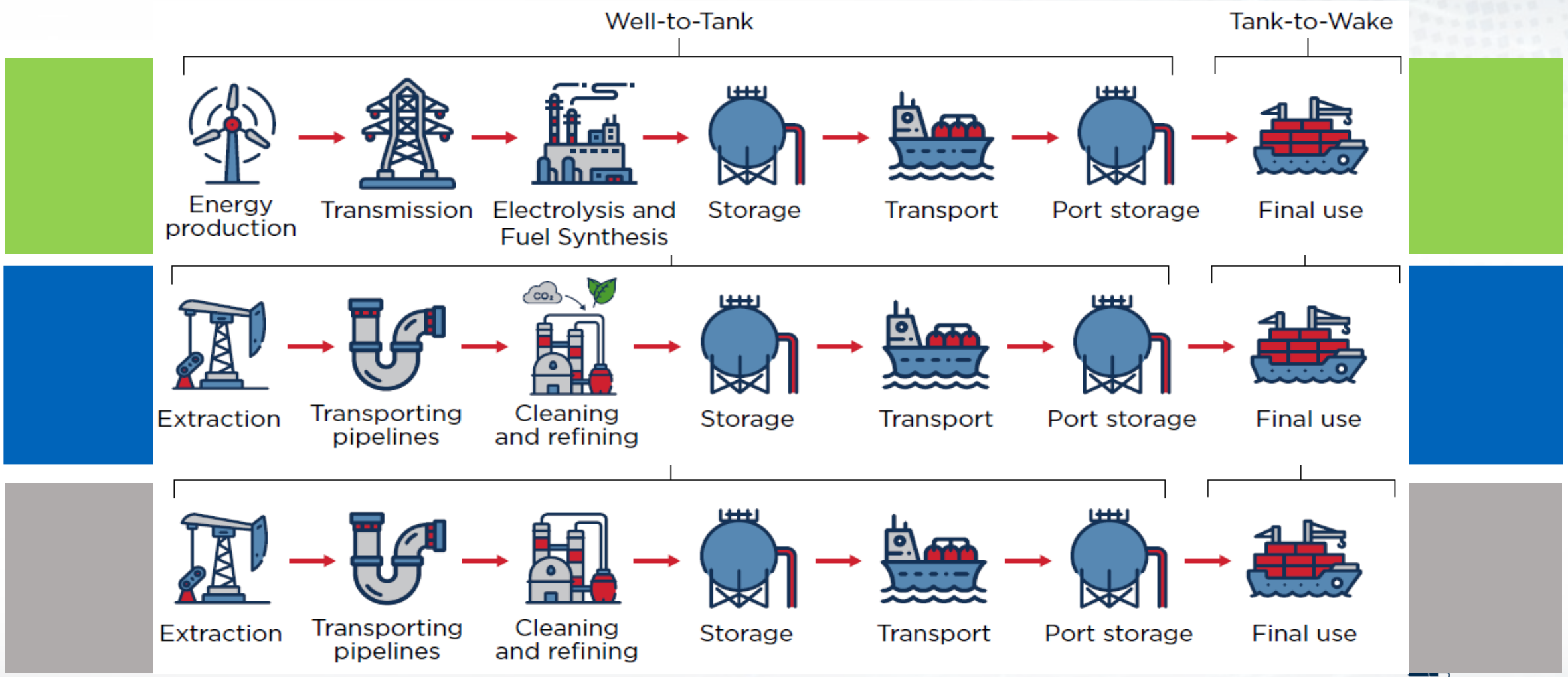
Regulatory Framework

- IMO accounts only for Tank-to-Wake emissions
  - Unreacted CH_4 and N_2O not included
- **ISWG-GHG 9 Agenda**: “further consider concrete proposals to encourage the uptake of alternative low-carbon and zero-carbon fuels, including the development of lifecycle GHG/carbon intensity guidelines for all relevant types of fuels and incentive schemes, as appropriate;”
- Discussions will be held at MEPC 77 on the Well-to-Wake emissions (including fugitive emissions)
- Potential proposal as a replacement of current Cf used at IMO / MEPC.308(73)
- Pre-defined values for different types of fuels with different production pathways

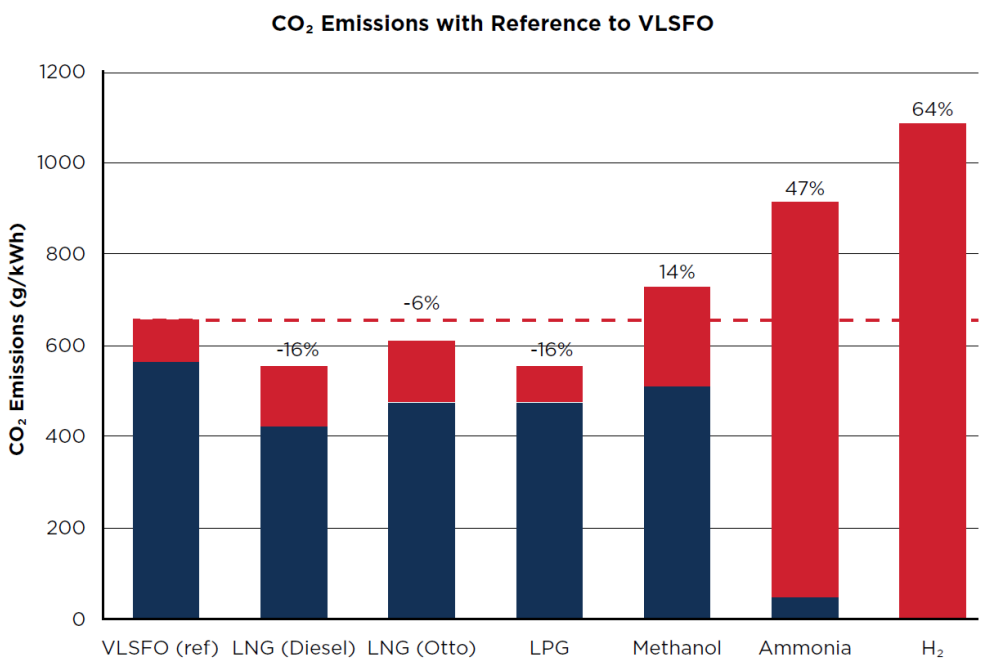
$$\text{Total WtW Emissions (t } CO_2\text{eq)} = \sum_{i}^{n\text{-engine}} \sum_{j}^{m\text{-fuel}} \underbrace{(M_{ij} * LCCF\_WtW\_fuel_{ij})}_{\text{Onboard fuel Well-to-Wake emissions}} + \sum_{i}^{n} \underbrace{(E_i * LCCF\_electricity_i)}_{\text{Shore electricity Well-to-Wake emissions}}$$

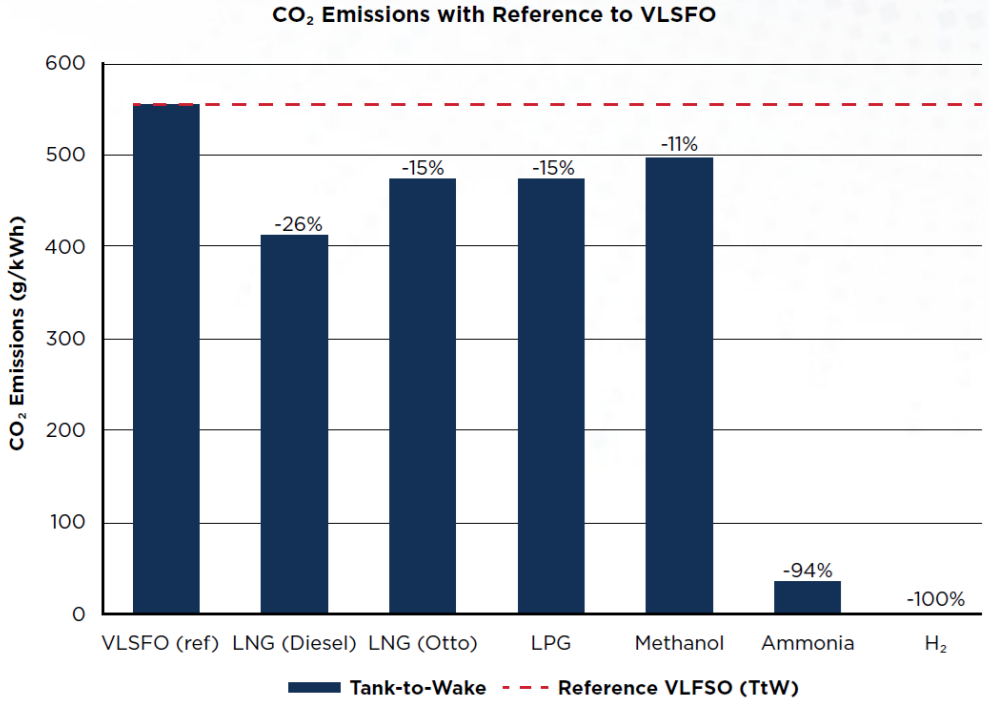
Life-Cycle Fuel Schemes

Green and Blue Life-cycles Are Preferred Among Three Color-coding Fuel Schemes



Well-to-Wake Emissions





Well-to-Wake Emissions

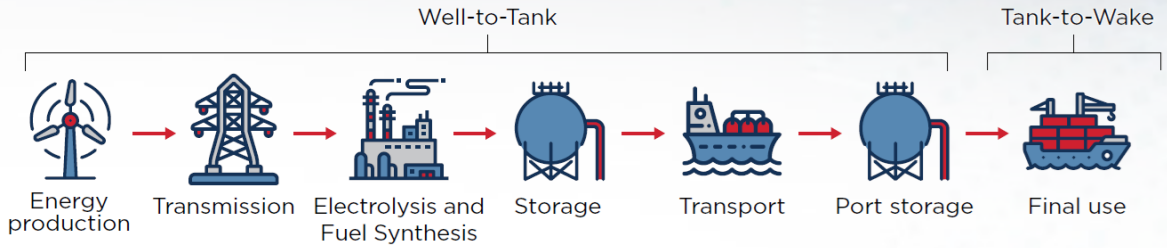
NH_3

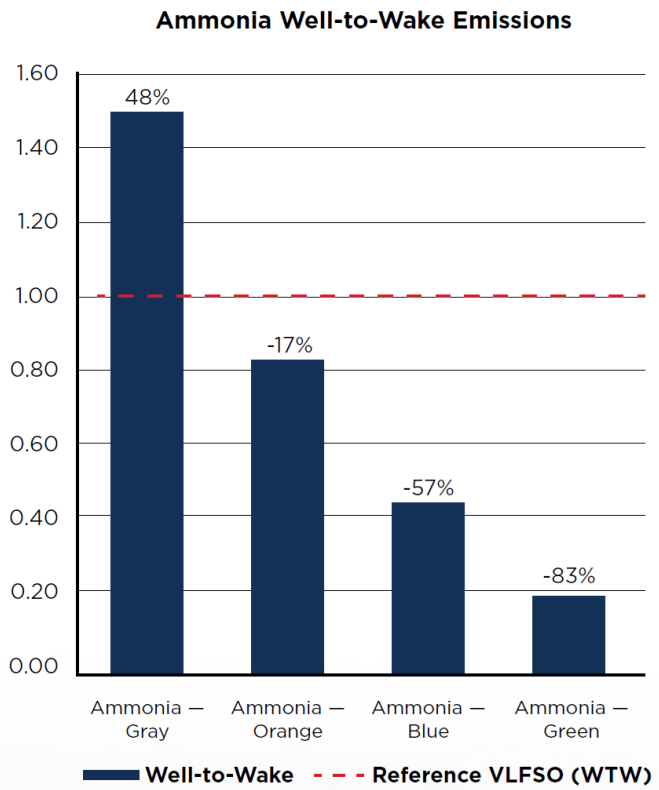
Grey*:
- Produced from CH_4

Blue**:
- Produced from CH_4 + CCS

Green***:
- Produced from green Electricity

Orange***:
- Mix of green and gray 50/50





gCO2 eq / kWh		Grey	Orange	Blue	Green
WtT	Subtotal	874	437	175	0
TtW	N2O[1]	75	75	75	75
	Pilot Fuel[2]	35	35	35	35
	CO2eq	0	0	0	0
	Subtotal	110	110	110	110
WtW	**Total**	**984**		**285**	**110**

[1] Use of equivalent emissions for Methane Slip values from 4th GHG IMO Study
[2] Estimated value based on engine manufacturer data

* Based on H_2 produced via steam reforming and then used to produce NH_3. GHG Emissions model by SINTEF is benchmarked against known sources (Spoof-Tuomi, 2020; Alfa Laval, 2020; MITACS., 2017, Singh et al, 2018)

** Assumption: CCS offsets 80% of the WtT emissions (Thinkstep,2020; Gilbert et al, 2019)

*** Based on H_2 produced via electrolysis and then used to produce NH_3

Recent Publications

Sustainability Whitepaper 2021: Hydrogen as Marine Fuel

Sustainability Whitepaper 2021: Biofuels as Marine Fuel

View of the Value Chain (2021): Low Carbon Shipping

Advisory on Decarbonization Applications for Power Generation & Propulsion Systems

Sustainability Whitepaper 2021: Methanol as Marine Fuel

Sustainability Whitepaper 2021: Ammonia as Marine Fuel

Please visit: www.eagle.org/sustainability