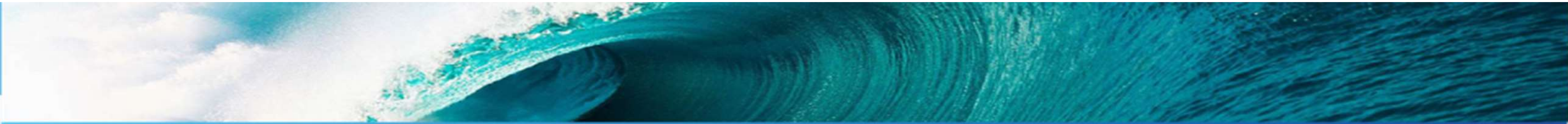

Biofuels and Ammonia studies: overview of production pathways, availability, scalability & sustainability

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EMSA

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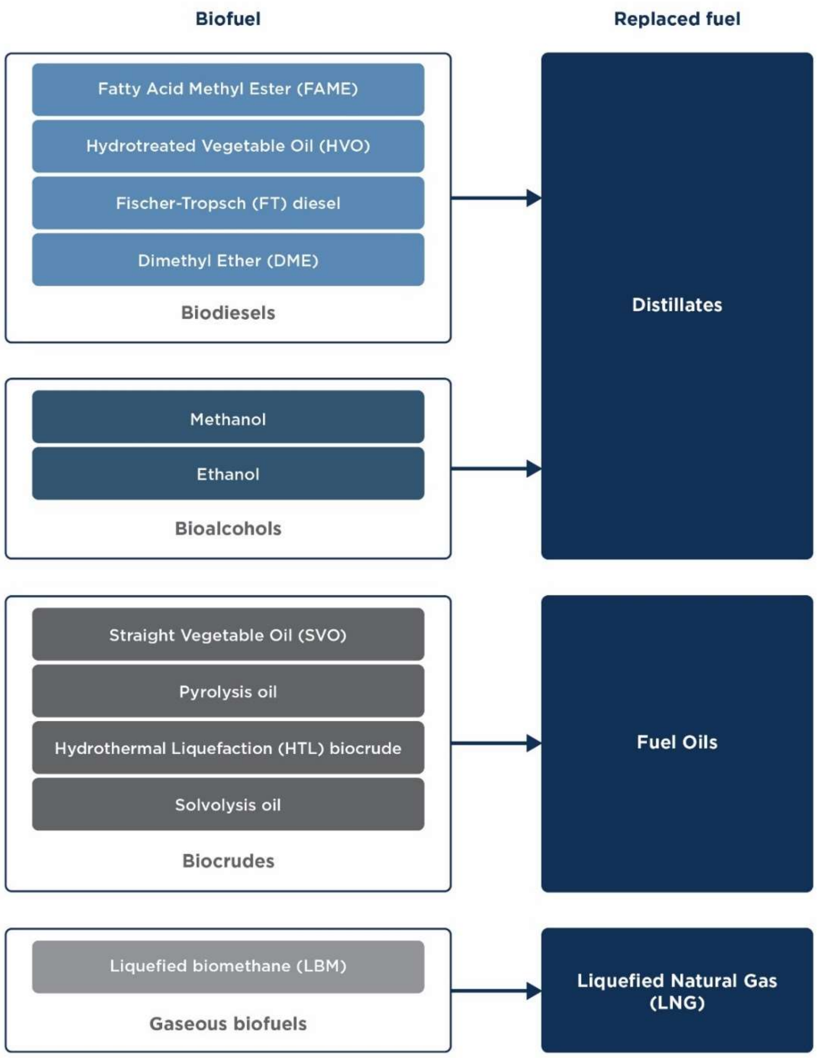
Agenda

1. Biofuels
   - Production pathways
   - Availability and scalability
   - Sustainability
   - Conclusion
2. Ammonia
   - Production pathways
   - Availability and scalability
   - Sustainability
   - Conclusion
3. Overall conclusion

Biofuels production pathways

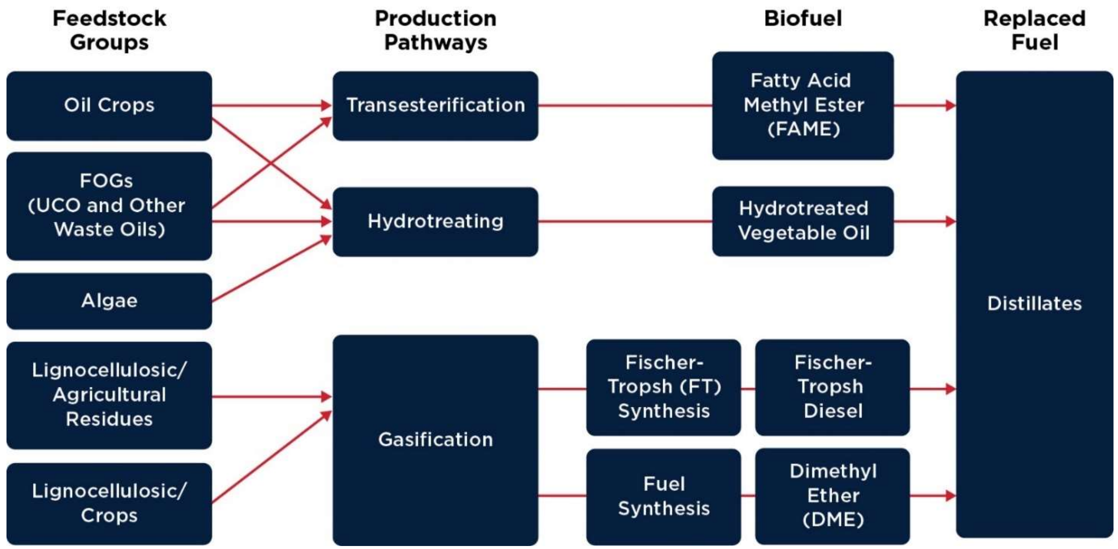
- There is a wide range of biofuels, which in principle can replace all fossil fuels currently used in shipping
  - Fuel oils
  - Distillates
  - LNG
  - Methanol



Biofuels production pathways

- Most fuels can be produced from a range of feedstocks with several production pathways
- The report provides high-level descriptions of the production processes for 11 most promising biofuels.

Example for biodiesels



Biofuels production pathways – TRLs

- There are many pathways available
- The current more developed pathways tend to provide less GHG reduction potential
- Promising pathways still require further development

Fuel category	End product	Production pathway	Fuel production	
			TRL 2019	TRL 2030
Biodiesels	FAME	Transesterification	10	10
	HVO	Hydrotreatment	10	10
	HVO (from wood)	Wood extractives pulping/ catalytic upgrading	8/9	8/10
	HVO (from algae)	Algae/oil extraction / catalytic upgrading	4/5	4/5
	FT diesel	FT synthesis	6/8	8/9
	DME	Lignocellulosic Gasification	6/8	8/9
Bio-alchohols	Bioethanol	Fermentation	10	10
		Waste based	8/9	10
		Lignocellulosic hydrolysis	8/9	9/10
		Waste based	8/9	10
	Bio-methanol	Black liquor gasification	6/8	8/9
		Lignocellulosic gasification	6/8	8/9
Biocrudes	SVO		10	10
	Pyrolysis oil	Lignocellulosic Pyrolysis/ catalysed upgrading	5/6	6/8
	HTL biocrude	Lignocellulosic Hydrothermal liquefaction/ catalytic refining	2/4	4/5
	Solvolysis oil	Lignocellulosic hydrolysis / solvolysis	4/5	6/8
Gaseous biofuels	Liquefied biomethane	Sludge/maize/manure/residues Fermentation / digestion	10	10
	Liquefied biomethane	Lignocellulosic Gasification	6/8	8/9

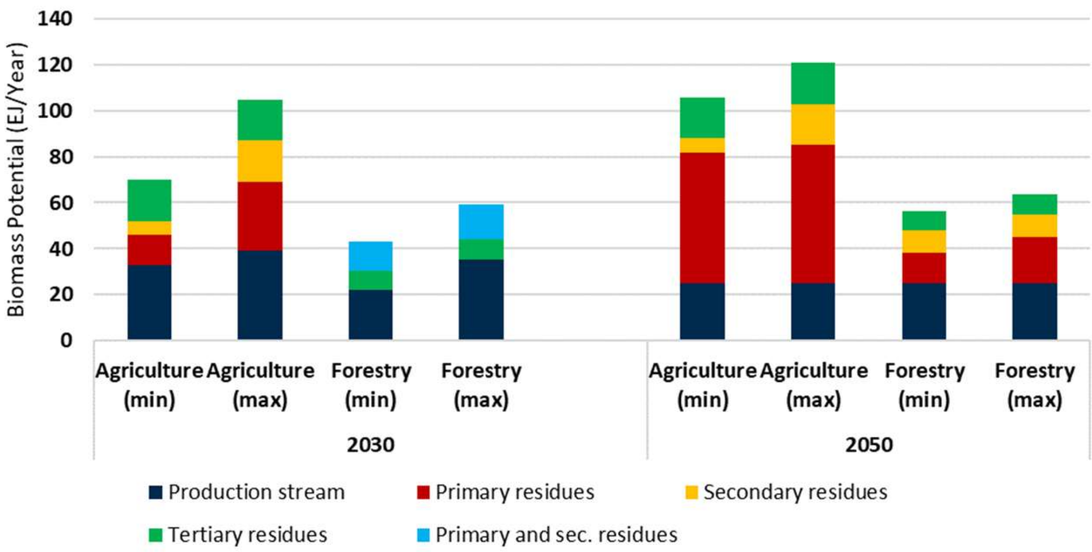
Biofuels availability and scalability

- Biofuel availability for the maritime sector is determined by
  - The availability of feedstocks; and
  - Competition with other sectors.

  - The availability of feedstocks depend on:
    - Sustainability criteria;
    - Type of feedstock: lignocellulosic / algae / carbohydrates / bio oils & fats.

  - Competition with other sectors depends on:
    - Alternative sources; and
    - Policy measures.

Global sustainable biomass potential



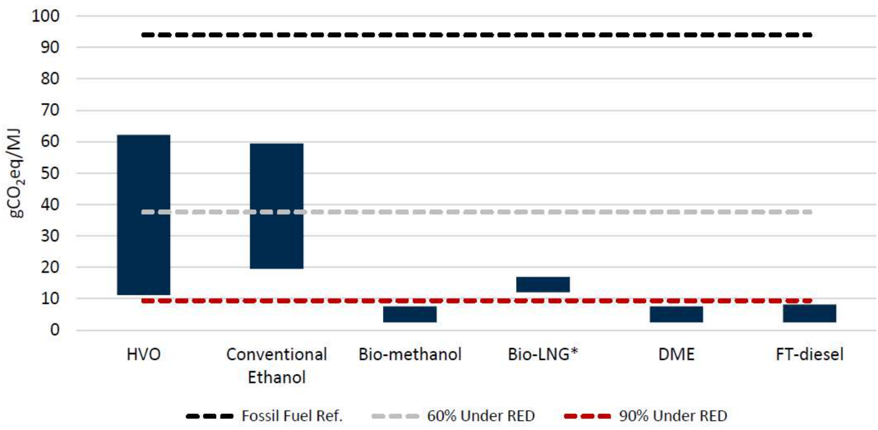
Energy demand from shipping: 18 EJ in 2018

Biofuels sustainability

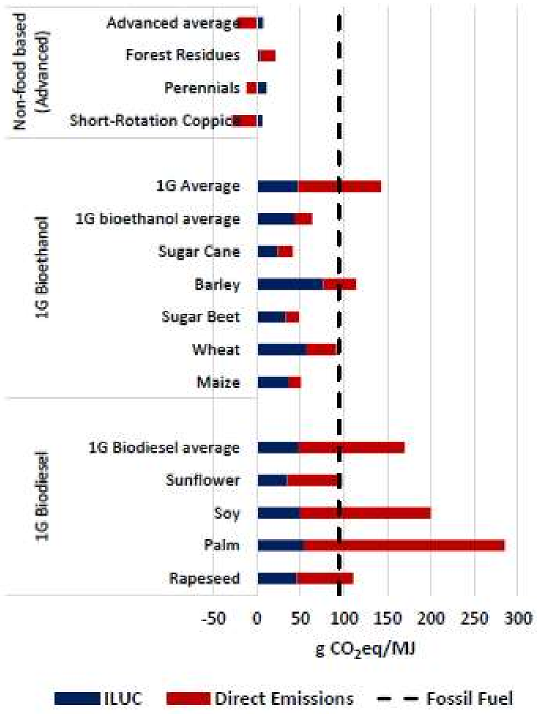
TtW is well known

Fuel	Carbon Content (%)	Combustion CO_2 Emissions (g/MJ)
HFO	86	69-76
MDO	86	71-74
Diesel	86	72-74
Gasoline	87	67-73
Propane	82	60-65
Natural gas	75	50
Bioethanol (1st Gen)	52	72-81
Bioethanol (2nd Gen)	52	72-81
FAME	77	75
HVO	77	75

WtT Variations



ILUC could significantly add to WtW emissions



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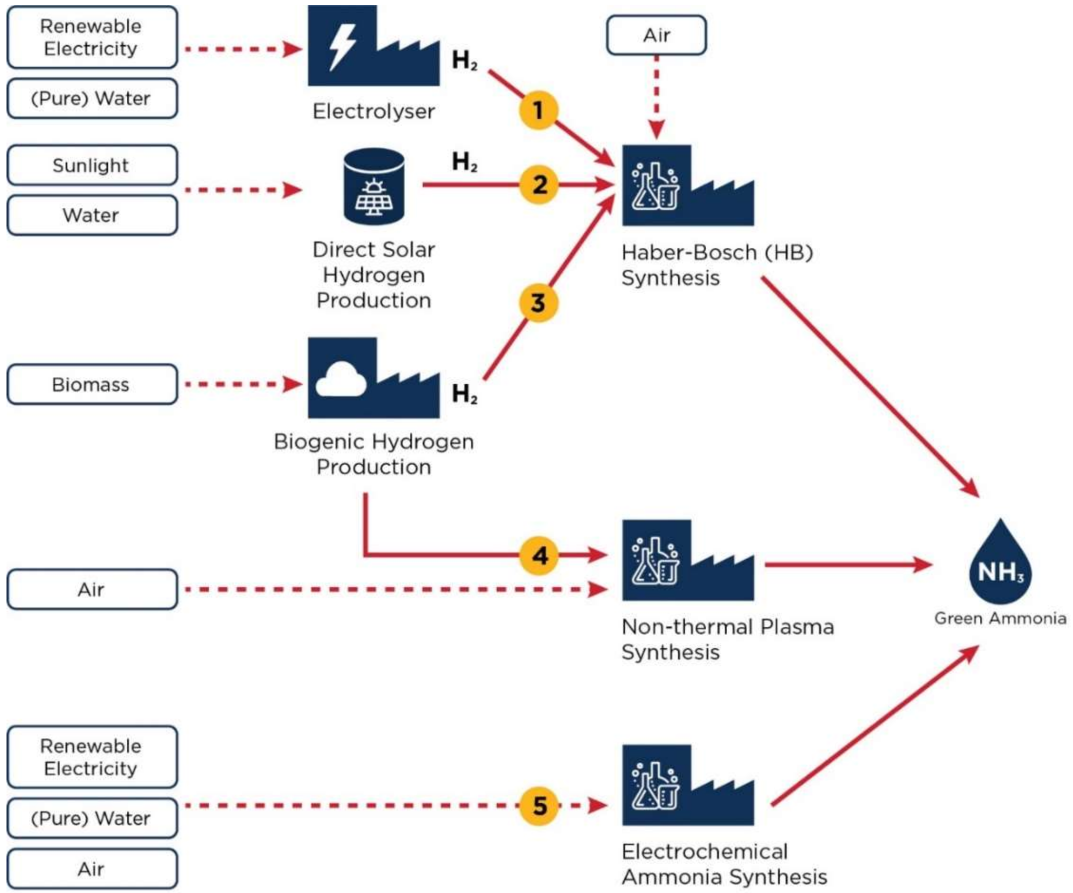
Biofuels conclusions

Pathway	Maturity	Current availability	GHG Reduction Potential	Scalability
Sugars, starches and vegetable oils	↑↑	High	Low Medium	Limited
Lignocellulosic (woody) inputs and algae	↓ TRL 9-10 by 2030	Low	High	Potentially High

Ammonia production pathways

- There is one technically mature pathway to produce green ammonia: Electrolysis + Haber-Bosch Synthesis
- There are other 4 pathways in a less mature stage of development



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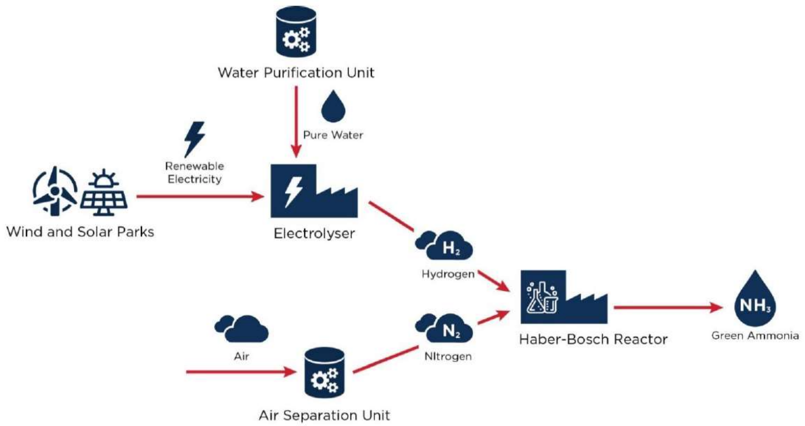
Ammonia Availability and Scalability

NH_3 HB is the most mature process



Process Type	Expected Efficiency [up to]
Pathway 1 Electrolysis and Haber-Bosch synthesis	~72%
Pathway 2 Direct solar hydrogen production	9% [up 70%]
Pathway 3 Biogenic hydrogen production	~57%
Pathway 4 Non-thermal plasma synthesis	12-37% [up to 45%]
Pathway 5 Electrochemical ammonia synthesis	14-62% [up to 90%]

Grey NH3 Production

235 Mtons/year

2019

Green NH3 Announced

>133 Mtons/year

*annouced blue and green ammonia production

What are the challenges ?

- Many sectors will have demand for green or blue ammonia.
- Green electricity will also be in high demand
- Demand depends on policy, many of which are not yet confirmed
- Green production needs to be efficient, utlized at maximum capacity and this poses challenges:
  - Location, pipelines, access to ports
  - Connection to grid (sustainable?)
  - Potentially oversized

Ammonia sustainability

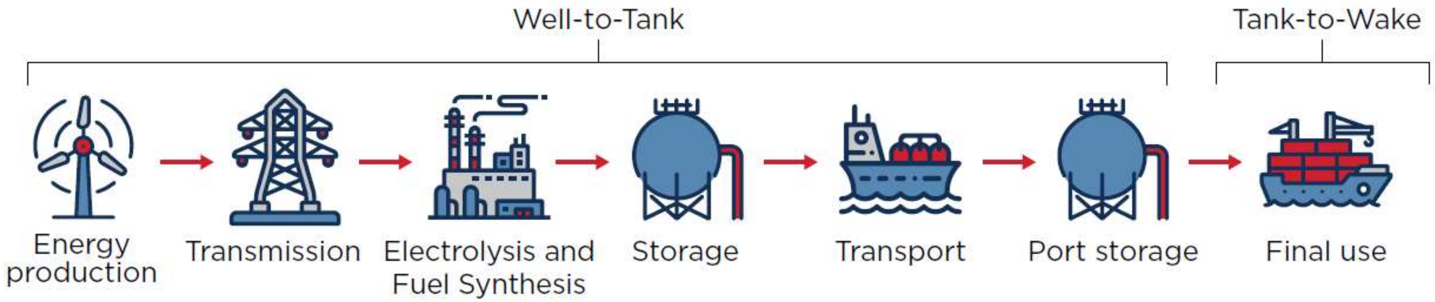
NH_3 The challenge is green electricity

- Certification mechanisms
- If connected to the grid, need to ensure the source of that energy
- Transportation, if not decarbonised, may lead to increased footprint

Engine still under development

- NOx & N2O slip uncertain
- Pilot fuel usage

Pollutant	HFO, MGO	LNG	Ammonia (combusted in engines)
SO_2 and metals	Present	Not present	Not present
Carbon monoxide and hydrocarbons	Present	Present or increased	Not present
VOCs and PAHs	Present	Reduced	Not present
NO_x **	Needs SCR for Emission Control Area	Otto engines meet Emission Control Area without SCR	Needs SCR for Emission Control Area
Direct particulate matter	Present	Reduced	Reduced
Ammonia (NH_3) ***	Low	Not present	Unknown
N_2O	Present	Present	Present or increased****
CH_4	Low	Present at Otto engines	Not present
CO_2*****	Present	Present	Not present



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Ammonia sustainability

NH3

Other Environmental Impacts (production of Ammonia)

- Production of hydrogen requires pure, deionized water. The amount of (fresh) water can increase water scarcity. Desalination and rejection of brines can be detrimental to ocean biodiversity and marine life
- Generating green electricity will require land (solar or onshore wind)
- Production of Solar should avoid using land used for crops

Where Solar ?

- Northern Chile
- Western Australia
- Northeast Brazil
- Northern Africa
- Pats of US and China

Where Wind ?

- Avoid land used for crops (Australia, Chile, etc)
- Using offshore may be an option in Western Europe and USA

- Inland transportation has been ongoing for many decades. Accidents happened and handling of ammonia is known.
- Ammonia spills can be harmful for marine life, need for further evaluation

Ammonia conclusions

	Maturity	Current availability	GHG Reduction Potential	Scalability
Green ammonia	↑↑	Low	High	High

Overall conclusion

- Most low-carbon fuels used in maritime shipping are currently biobased and produced from vegetable oils.
- Scalability of these fuels is low and GHG emissions reductions limited.
- Effective decarbonisation of maritime transport requires, amongst others:
  - Biofuels from lignocellulosic biomass or algae;
  - Green ammonia.
- The technical challenges are surmountable: TRLs for production of green ammonia and lignocellulosic biofuels are high or are projected to reach 8-9 by 2030.
- The financial challenges appear to be surmountable: many projects in the pipeline for green ammonia production.
- Main remaining challenges: availability of green electricity and a stable policy framework

Thank You

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