Biofuels and Ammonia studies: Suitability & Regulations

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ABS

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EMSA
European Maritime Safety Agency

Studies on Alternative Fuels/Power for Shipping

Ammonia and Biofuels

Suitability & Regulations

EMSA Alternative Fuels Workshop
Lisbon, 18/10 – 20/10

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Suitablility - biofuels

Bio-fuels

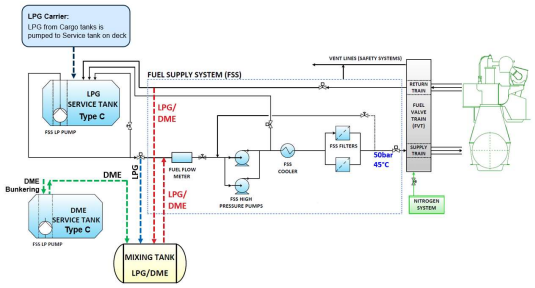
Note: Bio-methane and bio-methane are chemical identical with methane and methanol – no change

Fuel Property	Units	MGO – Diesel (Petroleum based)	FAME (Biodiesel)	HVO (Renewable Diesel)
Cetane Number	-	40 – 55	50 – 65	80 – 99
Density at 15°C	Kg/m^3	0.82-0.85	0.88	0.77-0.78
Kinematic viscosity at 40°C	mm^2/s	2.5-4.5	4.5	2.5-3.5
LHV	MJ/Kg	42-44	37-38	34-44
Oxygen content	%	0	11	0
Sulphur content	ppm	< 10	< 10	< 10
NOx Emissions (from combustion)	%	Baseline	+10%	-10% to 0
Lubricity	-	Baseline	Good	Poor (may require additives)
Oxidative Stability / Storage stability	-	Baseline	Poor (Antioxidants to increase storage life or stability, or frequent bunkering is more likely)	Good
Cold Flow Properties	-	Baseline	Poor	Good (only with isomerisation)

FAME and HVO: can be used in exsisting marine engines with a few pre-caution.

Fuel Property	Units	MGO – Diesel (Petroleum based)	DME	LPG	
				Propane	Butane
Cetane Number	-	40 – 55	55 – 60	5	10
Density at 15°C	Kg/m^3	0.82-0.85	0.66	0.5	0.61
Kinematic viscosity at 40°C	mm^2/s	2.5 – 4.5	0.12–0.15	0.2	0.2
LHV	MJ/Kg	42-44	28	46	45
Oxygen content	%	0	34.8	0	
Sulphur content	ppm	< 10	0	0.01	
Expected NOx Emissions (from combustion)	%	Baseline	- 20%	- 10% to 15%	
Lubricity	-	Baseline	Poor	Between Baseline and Poor	

DME similar to LPG, but LHV is lower - new engine development is required



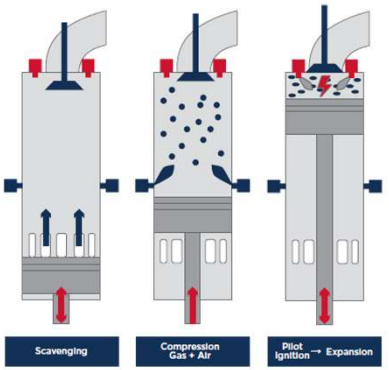
Suitability: Engine Technology – burning ammonia

NH_3 Bio-fuels

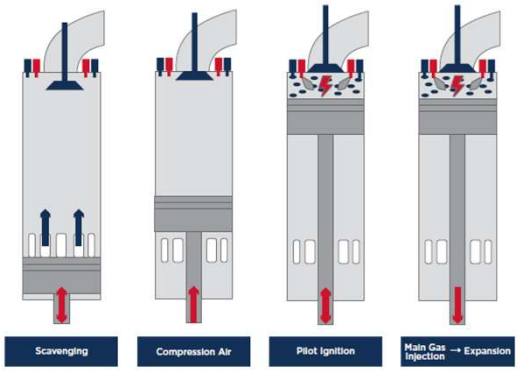
Ammonia is resistant to autoignition, it requires an ignition source through out the period where it burns

	Low-Pressure (LP)		High-Pressure (HP)	
Gas mode cycle type	Otto		Diesel	
Gas injection / Combustion principles-methane and ammonia	LP gas admission valves located on the cylinder for pre-mixed gas/air and in-cylinder compression (diesel pilot fuel required for start of combustion)		HP gas injection valves located on the cylinder cover for direct gas injection into the cylinder for diffusion combustion (diesel pilot fuel required for start of combustion)	
Fuel	Methane gas	Ammonia (guid. values)	Methane	Ammonia (guid. values)
Fuel supply pressure	~5 bar (4-stroke) <13-16 bar (2-stroke)	5-16 bar	300 bar	~80 bar
Injection pressure	Same as supply pressure	Same as supply pressure	Same as supply pressure	500-700 bar
Liquid pilot % @MCR	0.5 – 1.0	15 - 30	0.5 – 1.5	5-10
BMEP [bar]	17.3	~17	21.0	21.0
Min load for DF mode [%]	~5	~30	~5	~15
IMO NOx Compliance	Tier II (oil mode) Tier III (gas mode)	Tier II (oil mode) Tier II (ammonia mode)	Tier II (oil mode) Tier II (gas mode)	Tier II (oil mode) Tier II (ammonia mode)
Fuel Quality Sensitive	Yes - Requirement for Methane Number	Yes	No	No
Fuel Slip	Yes	Yes	Insignificant	Insignificant
Knock/Misfire Sensitive	Yes	Yes	No	No
Load response	reduced	reduced	unchanged	unchanged

Low Pressure Gas Injection



High Pressure Gas Injection



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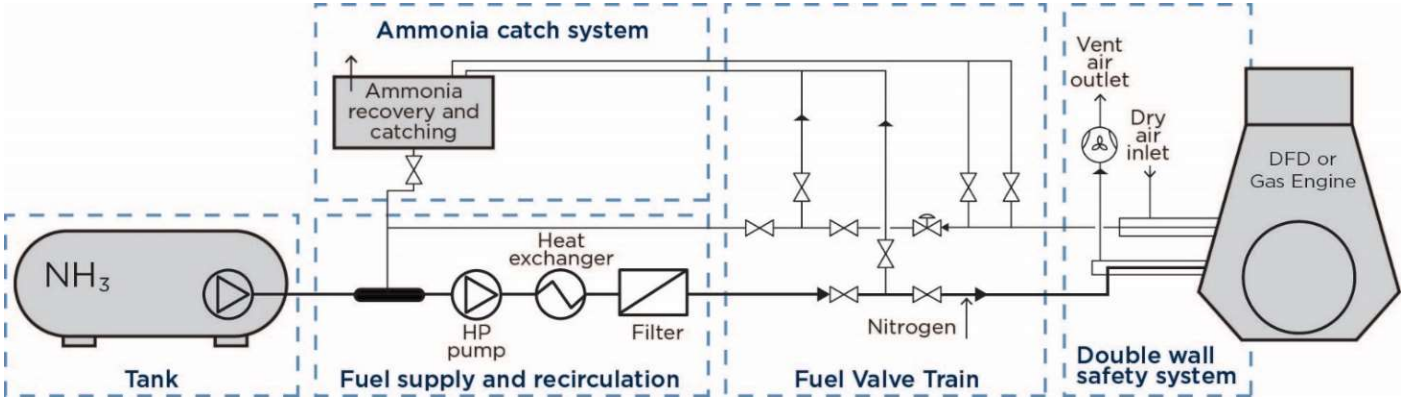
Suitability – Ammonia fuel supply system

NH_3

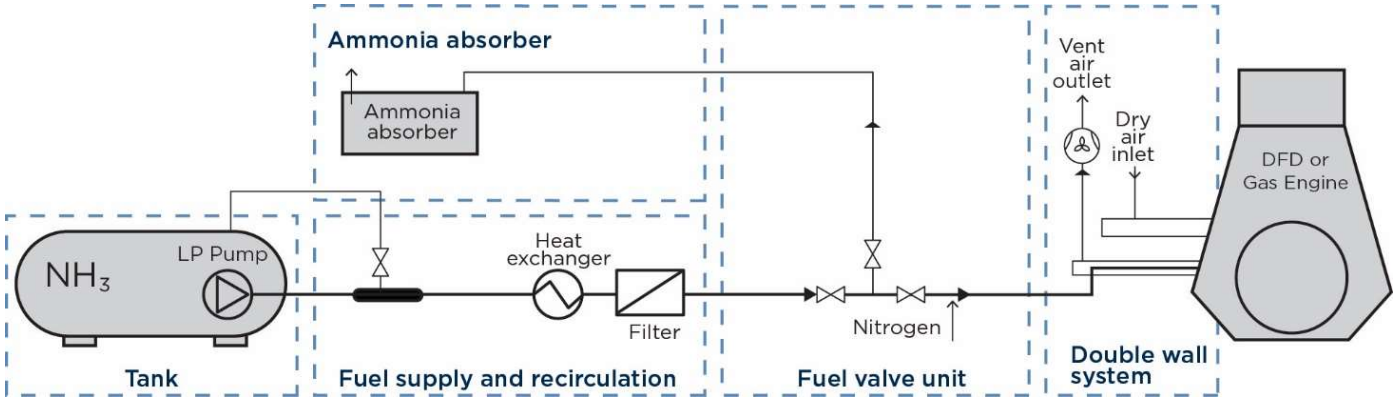
What is needed ?

1. Tanks, either Type A or Type C
2. Ammonia supply pumps
    1. High pressure ~ 80 bar
    2. Low pressure~ 5-15 bar
3. Temperature control
4. Filters
5. Double block and bleed
6. Vent system incl. a collection & treatment system for ammonia vapor
7. Double wall pipe system

High Pressure Gas Injection



Low Pressure Gas Injection



Drop-in biofuels

- Fully drop-in
  - FAME
  - HVO
  - FT Diesel
  - Bio-methanol
  - Bio-ethanol
  - Bio-methane
- Not fully drop-in
  - DME
  - SVO
  - HTL Biocrude
  - Pyrolysis oil
  - Solvolysis oil

Biofuel	Replaced fossil fuel	Drop in properties/blend %	Remarks
FAME	Distillates	Up to 100% v/v	Subject to confirmation by Engine Designer for blends above 7% v/v FAME
HVO	Distillates	Up to 100% v/v	Subject to confirmation by Engine Designer
FT diesel	Distillates	Up to 100% v/v	Subject to confirmation by Engine Designer
DME	Distillates – LPG in dual fuel engines	Up to 20-30% v/v – up to 100% v/v	Subject to confirmation by Engine Designer
Bio-methanol	Methanol	Up to 100% v/v	For Methanol DF Engines and Fuel Supply System
Bio-ethanol	Distillates in Otto engines – Methanol in dual fuel 2-stroke engines.	Up to 100% v/v	Not enough information about use in marine engines – probably doable by introducing minor modification to the methanol fuel injection system
SVO	Fuel oil	Up to a limited share	Subject to confirmation by engine Designer
Pyrolysis oil	Fuel oil	Not a drop-in fuel	Properties vary widely and change with ageing. Acidic and corrosive. Can be upgraded to a drop-in fuel.
HTL biocrude	Fuel oil	Up to a limited share	Little information about use in blends in marine engines. Can be upgraded to a drop-in fuel.
Solvolysis oil	Fuel oil	Up to a limited share	Little information about use in blends in marine engines. Can be upgraded to a drop-in fuel.
Liquefied biomethane	LNG	Up to 100% v/v	For DF and Gas Engines, and Fuel Gas Supply System

Regulatory Overview

International

- **ISO & ASTM** Standards
- **IMO** - International Maritime Organisation
  - Safety of Life at Sea (SOLAS)
    - ISM CODE
    - SOLAS IGC Code
    - SOLAS IGF Code
    - STCW
    - ISM Code
  - Prevention of Pollution from Ships (MARPOL)
    - NOx & SOx
    - EEDI/EEXI/CII/SEEMP/DCS
    - Guidelines
- **IBIA, SIGTTO, SGMF, CIMAC, IMPCA,**
- **IACS** Unified Requirements and Recommendations

Regional & National

- **European Union**
  - EU ETS, FuelEU Martime, RED II, ETD, EU MRV, CEN/CENELEC
- **United States:**
  - EPA, Clean Water Act, Emissions Control
- **Canada:**
  - Ozone depletion and fuel quality specs
- **China:**
  - Domestic Emission Control Areas
- **Japan:**
  - Roadmap to zero emission from international shipping
- **South Korea:**
  - Domestic Emission Control Areas

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International – ISO and ASTM

What is the role of ISO and ASTM ?
Develop and publish unified standards for technology design, materials, testing and certification

Fuel Type (ISO 8217 Ref.)	ISO-F- Fuel Grade	FAME Allowed v/v
Distillate Marine Fuels (Table 1)	DMX	0%
	DMA, DMZ, DMB	*De minimis*
	DFA, DFZ, DFB	7%
Residual Marine Fuels (Table 2)	RMA, RMB, RMD, RME, RMG, RMK	*De minimis*

NH_3

- Available for **land-based industrial** applications
- Some ISO standards applicable for marine environment are available
- There is a need to develop **marine-fuel** standards for couplings and bunkering

Bio-fuels

- Many available for **fossil** equivalent that need to be expanded to their bioequivalents
- Some land-based ISO can be extended/applicable to marine environment
- ISO's may be revised to allow higher than 7% blend percentages

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CIMAC, IMPCA, IBIA, SIGTTO, SGMF,

Bio-fuels

NH_3

CIMAC:

- Has been producing guidelines for biofuels (oils and gas)
- Constantly updates as information is made available
- Needs to work on NH_3 as a gas fuel. WG17 is expected to expand scope of activities to cover for alternative fuels

IMPCA:

- Has issued specification for Methanol
- Guidelines on methanol cargo handling on shore and ship tend to provide an end to end standardized process for sampling

SIGTTO:

- Has been instrumental developing IGC Code (including Ammonia)
- Has a series of recommendations and guidelines for carriage, STS transfer, bunker, etc, of NH_3

SGMF:

- BASiL developed for LNG could be expanded to NH3 and other gas fuels
- Series of relevant publications and guidance on LNG, expanding to NH_3 would be necessary

IBIA:

- Currently working on a future fuels assessment, results to be released

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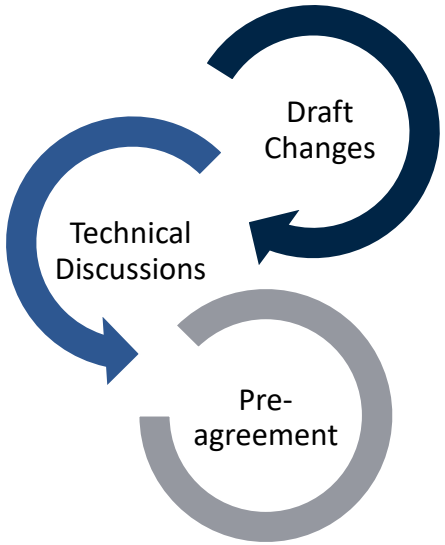
International – SOLAS (IMO)

What is the role of SOLAS ?

SOLAS covers Safety of Ships and focuses on oils. It makes reference to the IGC and IGF codes which in turn are used as reference for the International Safety Management (ISM) code.

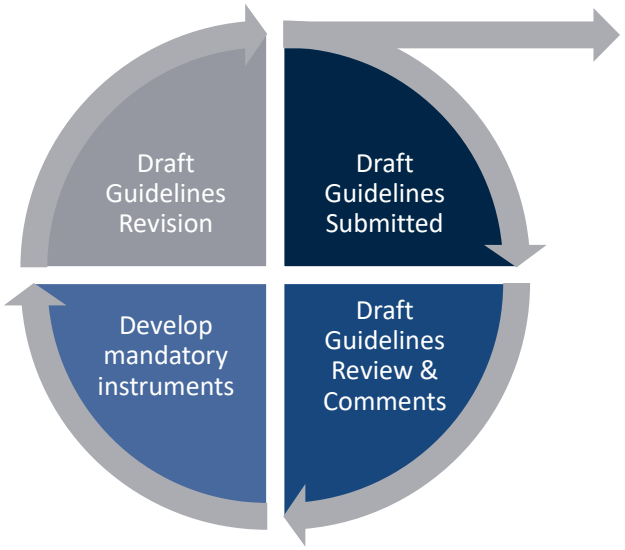
Correspondence. & Working Groups

Discuss and prepare the content to be addressed and agreed upon by the sub-committee



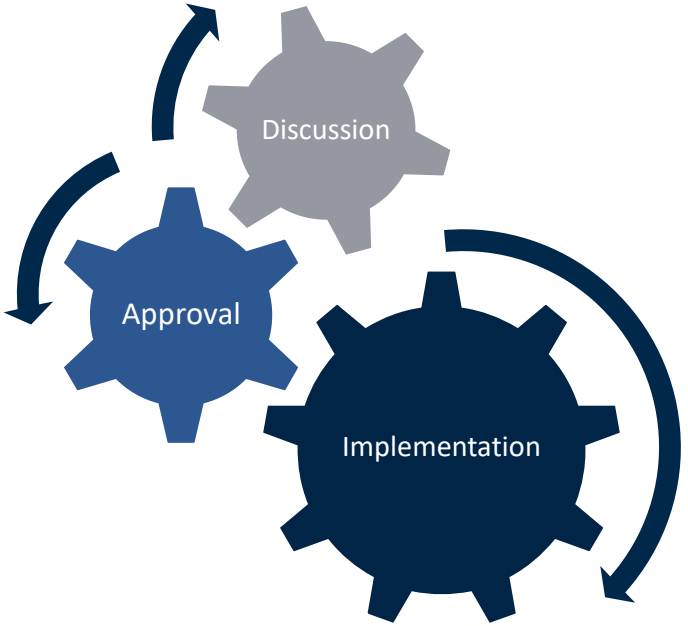
Subcommittees

Create & Review Content to Adopt into or Amend IMO Codes



Committees

Adopt and Implement Guidelines or Recommendations



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International – SOLAS (IMO)

NH_3 **Main challenge is its toxicity. IGC needs to be revised and IGF to be developed/adapted**

Toxicity
Corrosion

IGC:
- Covers important aspects such as storage, corrosion.
- Does not currently allow for using toxic cargoes as a fuel.

20 Mtons / year transported by Shipping

IGF:
- Alternative design procedure applies
- IGF needs to be revised to accomodate Ammonia

Alternative Design:
- This procedure is applied today by JIP/JDP ongoing
- Risk-based approach increases resources needed and burden

Timeline: CCC8 set as tentative to have a set of guidelines agreed by **2025**

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Applying SOLAS to biofuels

Bio-fuels

Application of SOLAS to biofuels is an area open for debate and interpretation

SOLAS I/Regulation 11

"*The condition of the ship and its equipment shall be maintained to conform with the provisions of the present regulations …*"

SOLAS II-1/Regulation 3-1

"*… ships shall be designed, constructed and maintained in compliance with the structural, mechanical and electrical requirements of a classification society which is recognized by the Administration …*".

Deliberately vague to accommodate wide range of residual, distillates and blended fuels

How does it work in case of Biofuels ?
How this is reflected into class requirements ?

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International – SOLAS (IMO)

Bio-fuels

Due to their drop-in nature, most of the provisions can be 'adapted' for their bio equivalents. <u>But:</u>

Fully drop-in

- Most of the text from the fossil equivalents can be applied to the bio counterparts.
- Making specific reference in the text to this understanding could benefit the industry
- Fuels that could benefit:
  - Biomethane (i.e., bio-LNG), bio-methanol
- Need to account for such while adaptation of the IGF Code is considered for biofuels.

- Example: onboard demonstration of suitability typically required

Not fully drop-in

- Replaced (fully or partly) fuel supply
- Must meet same flashpoint requirements
- Compatibility may need to be verified with fuel system
  - Filters – due to fuel contamination and degradation
  - Piping & Fixtures – corrosion due to biofuel properties
  - Tanks – proper maintenance & cleaning for fuel degradation
- Onboard fuel procedures may need updating

ISM Code

- Risk assessment and mitigation plan (impact of new fuels)
- Fuel system modifications and tank cleaning (if needed)
- Fuel capacity and segregation capability
- Fuel changeover procedures
- Documentation and reporting

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IACS

What is the role of IACS ?

Ensures the application of mandatory intruments and acts as technical advisory to provide and propose Unified Interpretations and Requirements to IMO

Bio-fuels

Class rules follow /take after SOLAS codes

- Offered important UI's to IMO (ex: NOx Reg 18)
- Demonstration of (in testing) compatability (UR M51)
- Onboard demonstration on a case-by-case basis

Fully drop-in

- Application of rules for biofuels follow their fossil-based equivalent
- Less or no burden on compatibility issues
- Less need for interpretation on mandatory requirements

Not fully drop-in

- There are no class rules with specific requirements for biofuels
- Implicit assumption that compatibility is covered at design
- Some further safety requirements on a case-by-case basis

NH_3

Class societies have published a series of Guidelines

- **American Bureau of Shipping (ABS)**. ABS Guide for Ammonia Fuelled Vessels. Published September 2021.
- **Bureau Veritas (BV)**. Ammonia-fuelled Ships – Tentative Rules. Rule Note NR 671 DT R00 E. Published July 2021.
- **Det Norske Veritas (DNV)**. Rules for Ammonia in Part 6 Chapter 2 Section 14. Published July 2021.
- **Korean Register (KR)**. Guidelines for Ships Using Ammonia as Fuels. Published July 2021.
- **NKK (Nippon Kaiji Kyokai – ClassNK)**. Guidelines for Ships Using Alternative Fuels (Edition 1.1) (Methyl / Ethyl Alcohol / LPG / Ammonia). published September 2021.

Support application and interpretation of IGF Code

- Safety
- Bunkering
- Onboard power production (ICE and Fuel Cells)

International – MARPOL (IMO)

NH_3 Carbon & Sulfur Free, but may still emit NOx emissions

Discharge to Environment

- Anhydrous Ammonia must not be discharged, toxic to environment. Must be contained and treated or burned in the engine

Engine Emissions

- MARPOL scope is TtW: carbon-free with zero carbon factor (Cf = 0) in EEXI/EEDI/CII Calculation
- N_2O emissions may need to be regulated via improved NOx Code

NOx Technical Code

- NH_3 engines must follow the NTC testing and approvals regime

International – MARPOL (IMO)

Bio-fuels

Due to characteristics of feedstock, naturally low in sulfur, but may still produce NOx emissions

Blended	*Not blended*
• Reducing fossil-based carbon emissions • Partially degradable upon spill	• Eliminating fossil-based carbon emissions • More degradable upon spill

All Biofuels

- Reducing sulfur oxides from emissions
- Depending on biofuel type and engine characteristics, may generate the same or more NOx emissions than fossil-based fuel equivalent
- Challenge on the Cf for EEDI/EEXI/CII, needs further work by IMO (LCA Discussions)

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International – MARPOL (IMO)

Key recent changes and ongoing discussions

Bio-fuels

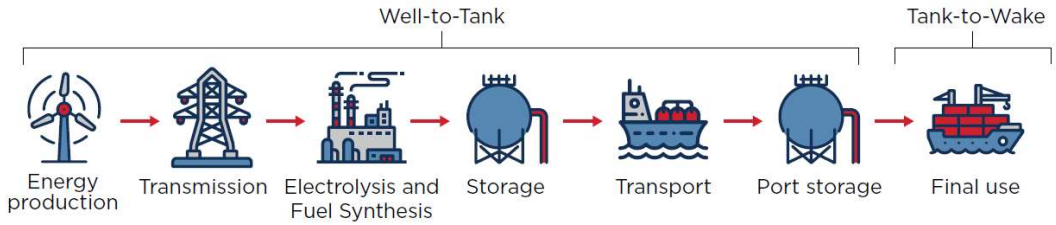
NOx

MEPC.1-Circ.795-Rev.6

Up to B30	Up to B100
• Assume to comply with Reg 18.3.2 • No NOx testing for engine required	• Comply with Reg 18.3.2 in case NOx Critical Settings are unchanged

LCA

- Multiple pathways
- WtT + TtW ?
- Which GHG's ?



Applicable to CII ? Tool for fuel levy/carbon tax ?

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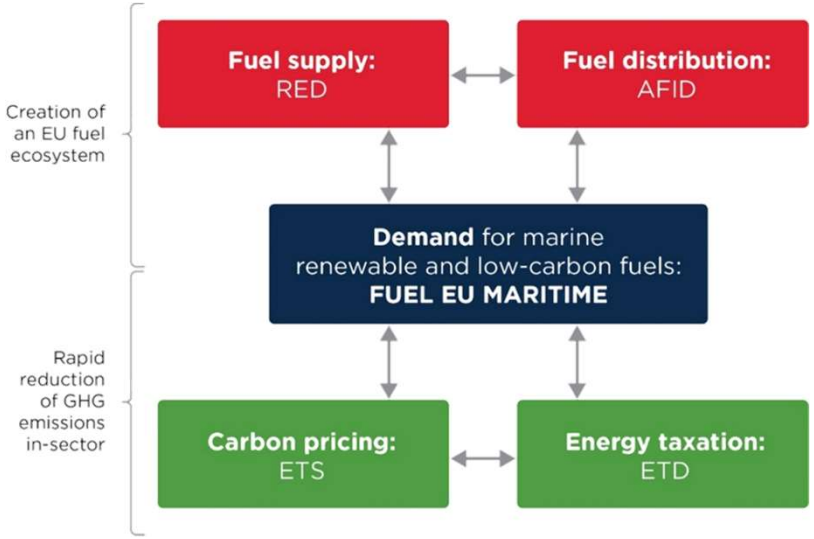
European Union

EU is implementing a series of levies to further promote alternative fuels



Other countries

NH_3 Bio-fuels

Land based

- Due to the extensive usage of NH3 for onshore application, there is an extensive list of national regulations:
  - Design criteria for systems handling ammonia
  - Environmental regulations
  - Safety and toxicity related directives
- A number of local requirements for storage and handling of some biofuels

Shipping

- There are some country specific regulations, guidelines for shipping anhydrous ammonia in bulk
  - Location of valves, tanks, flanges, and pipe fittings
  - Requirement for protection equipment
- DECA areas have been introduced (e.g., China and South Korea)
- National decarbonization strategies (e.g., Japan)

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Gap Analysis Results

NH_3	Bio-fuels	
4	6	No Gap or Changes needed
21	11	Small Gap or Minor Change
28	12	Medium Gap or Some Challenging Change
23	2	Large Gap or Many Challenging Changes

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Thank You

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