Keynote: The Impact of Ammonia Engines on Global Atmospheric Pollution

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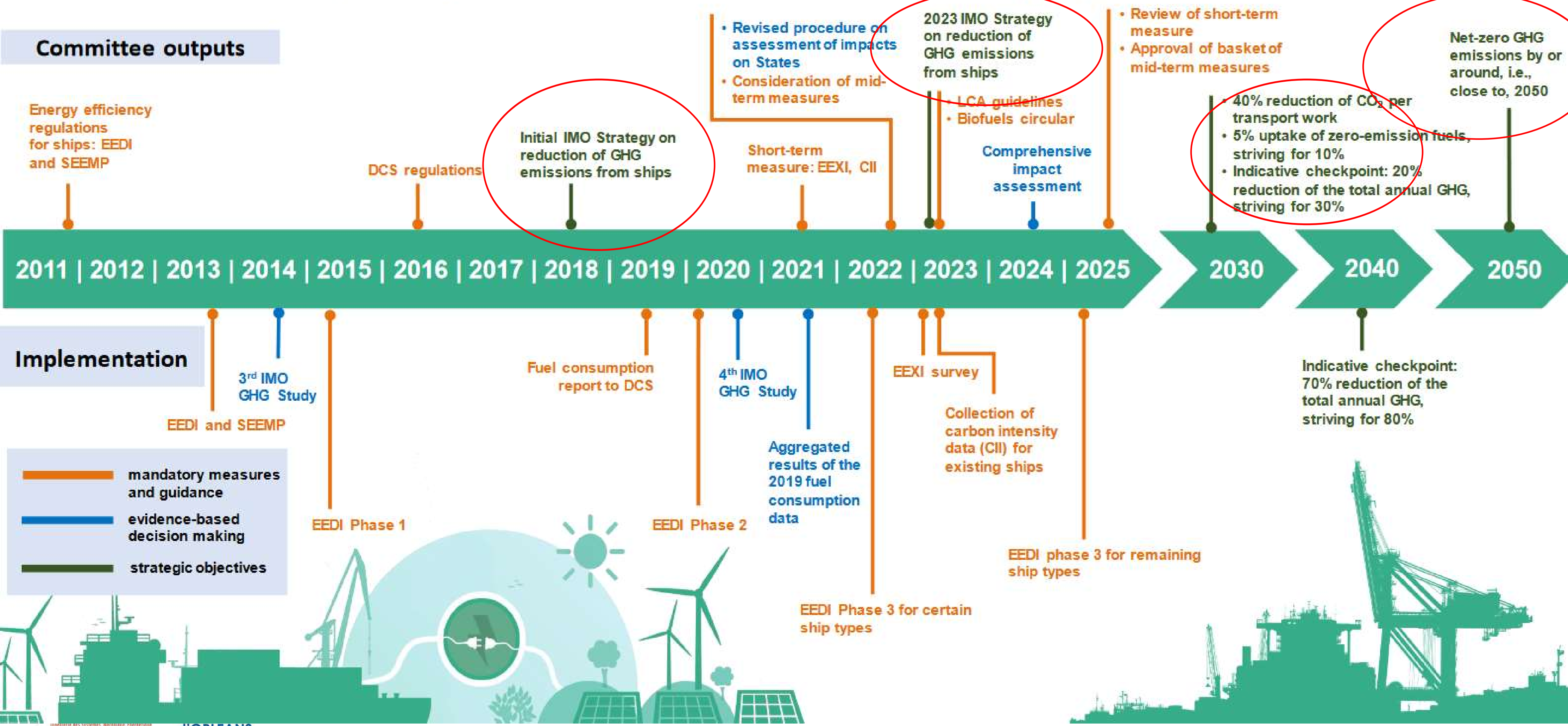
MariNH3

Clean, green ammonia engines for maritime

Addressing climate change

Over a decade of **regulatory action** to cut GHG emissions from shipping



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Ammonia Energy Conference 2021 – Australia

Future fuels and emissions

Kjeld Aabo
Director New technologies
Sales and Promotion Two stroke Marine
Member of WG ISO 8217 & Chairman CIMAC Fuel

MAN Energy Solutions
Future in the making

CMB.Tech, Yara et North Sea Container Line font construire un porte-conteneurs à ammoniac

Par GAEL COGNE - 20/02/2024

Premier porte-conteneurs utilisant de l'ammoniac comme carburant, le navire d'une capacité de 1400 EVP sera construit à Qingdao, en Chine.

Mer et Marine

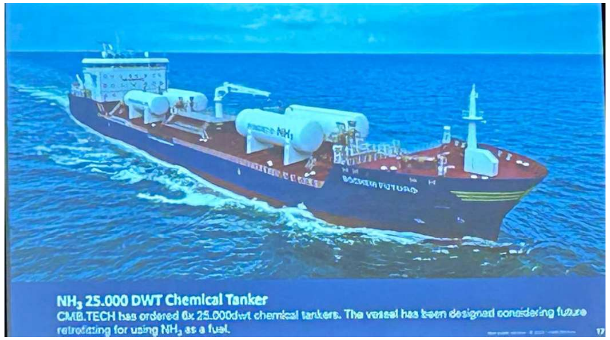

Image of A-tug

But no vessels really run with ammonia engines until now

What Consequence on global environment if we consider all ships with ammonia engine ?

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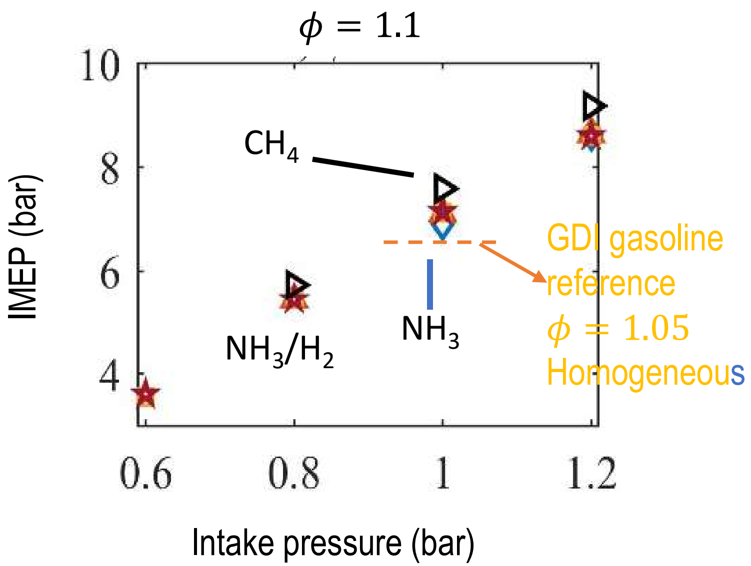
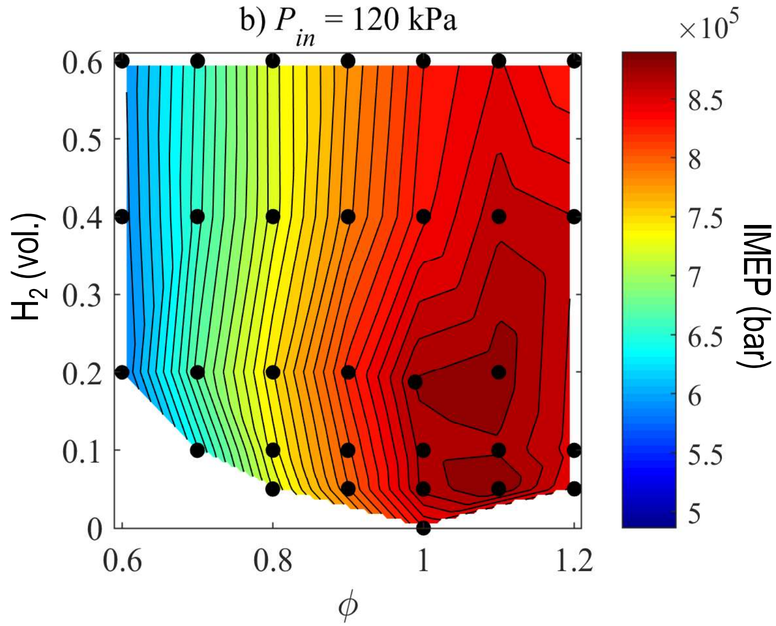
EXAMPLE : AMMONIA IN 'GDI' ENGINE

Engine Characteristics	
Engine Type	**Current 'GDI SI engine' PSA -EP6DT**
Bore	77 mm
Stroke	85 mm
Connecting Rod Length	138.5 mm
Displacement Volume V_{cyl}	395.81 cm^3
Compression Ratio	**10.5**

- Current igniter, CR,
- Piston geometry (GDI)
- Premixed gaseous NH_3/air intake (no injector)

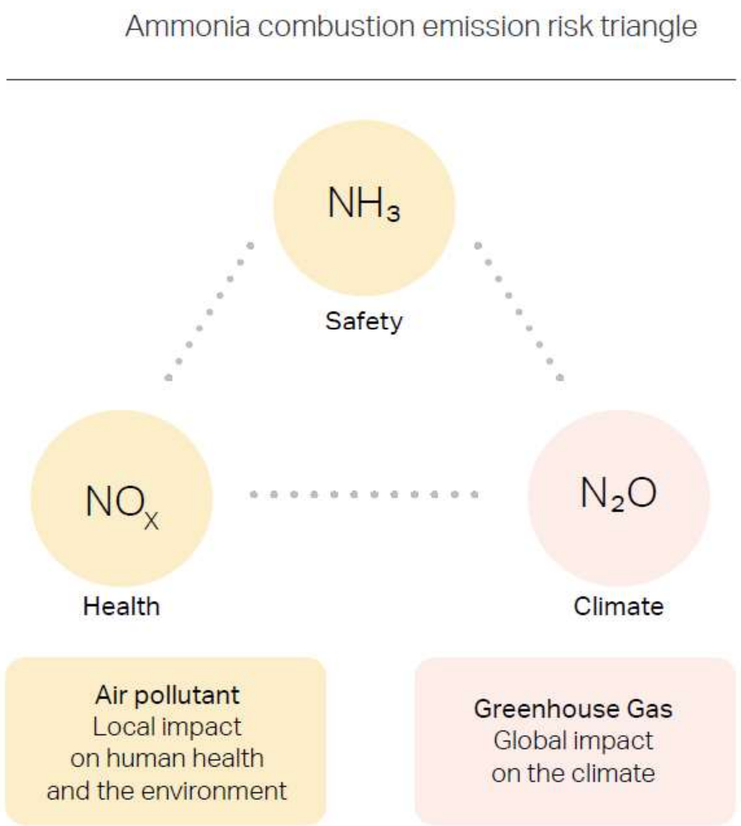




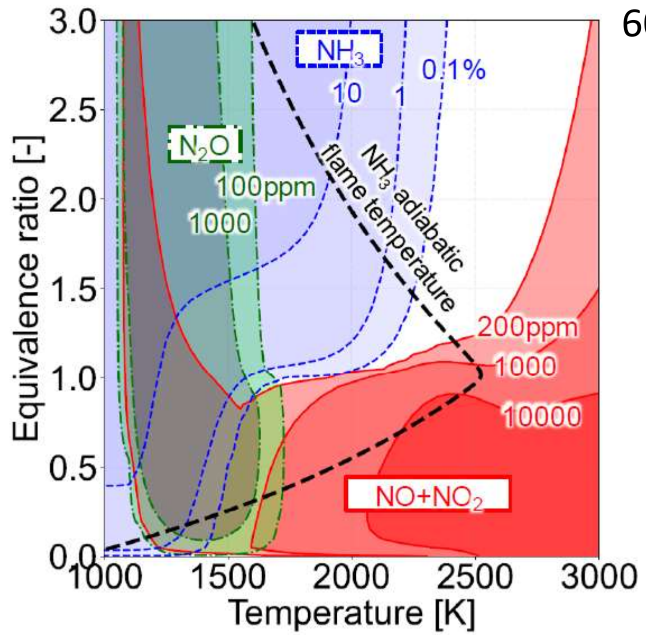
- Similar IMEP than NG or Gas.
- Operation with NH_3 only for $P_{in} \geq 1$ bars
- H_2 = efficient combustion promoter

- Best work for slightly rich mixtures
- 5-10 vol.% H_2

IMPORTANT QUESTION : WHAT EMISSIONS FOR AMMONIA ENGINE



Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping



60 b.

Hiraoka K, Matsunaga D, Kamino T, Honda Y, et. al. Experimental and numerical analysis on combustion characteristics of ammonia and diesel dual fuel engine. SAE Technical Paper 2023:2023-32-0102. https://doi.org/10.4271/2023-32-0102.

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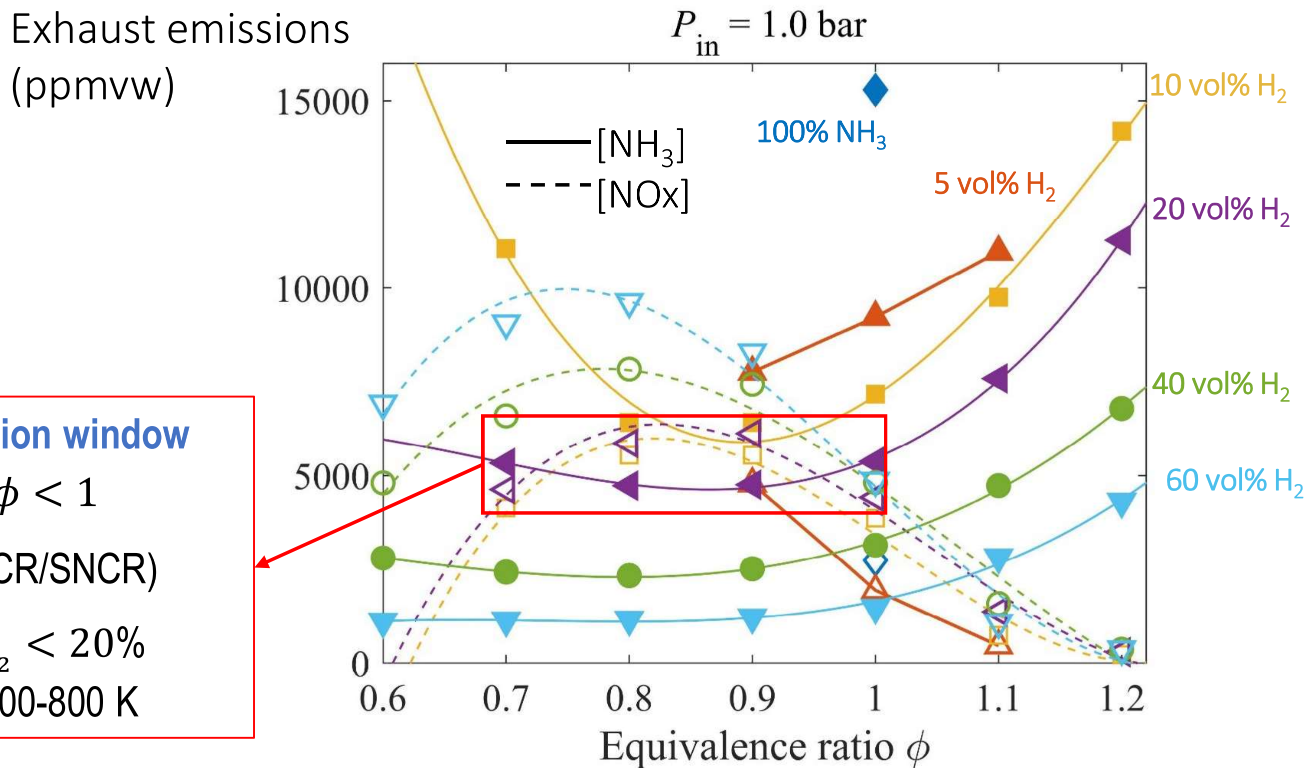
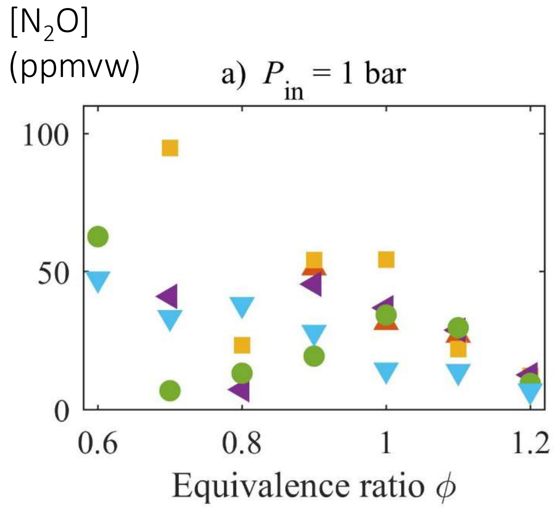
EMISSIONS OF SI ENGINE FUELED WITH NH_3/H_2





"Low" emission window

$0.7 < \phi < 1$

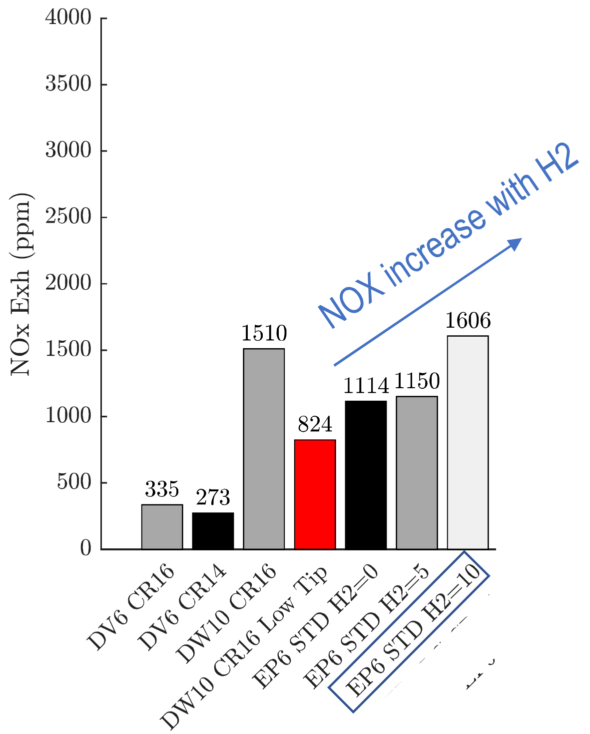
$\frac{NOx}{NH_3} \sim 1$ (SCR/SNCR)

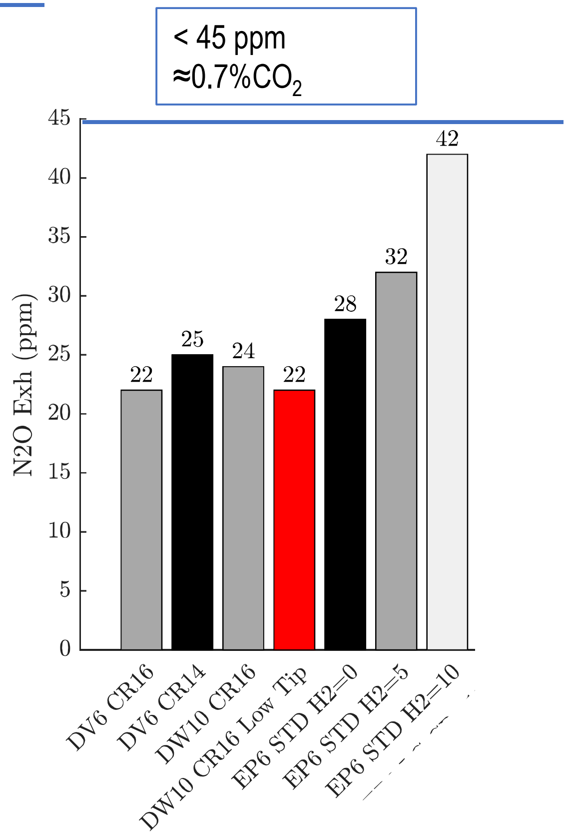
$5\% < x_{H_2} < 20\%$

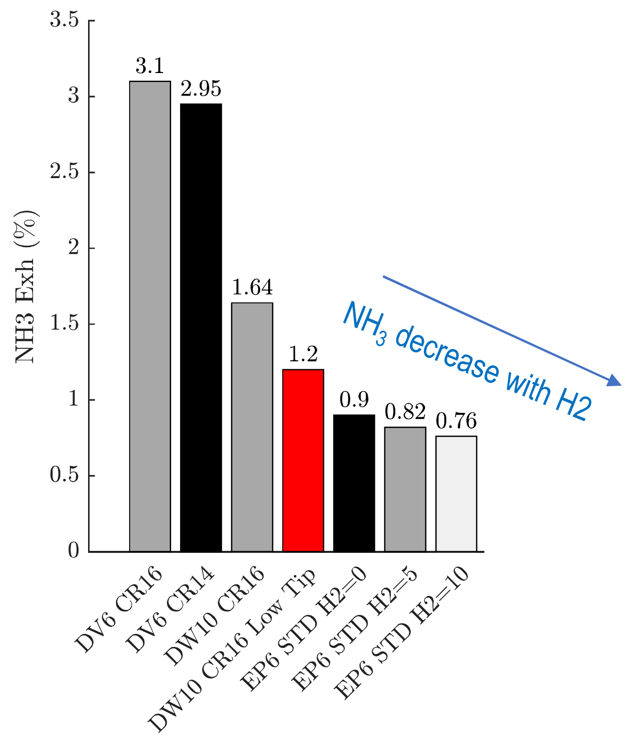
$T_{exhaust}$ = 700-800 K

Pollutants require after-treatment
(not unlike conventional fuel operation)

EXHAUST EMISSIONS : FUNCTION OF THE ENGINE DESIGN







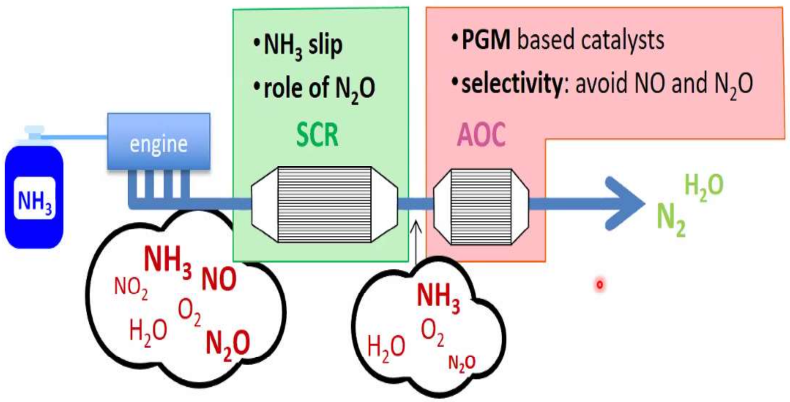
Operating conditions:

- N=1000rpm
- Pin=1bar, Tin~50°C
- SIT opti, **Phi = 1**
- **8 bar IMEP**

D= Diesel engine with spark plug and pure ammonia
E= Gasoline engine
CR = Compression Ratio

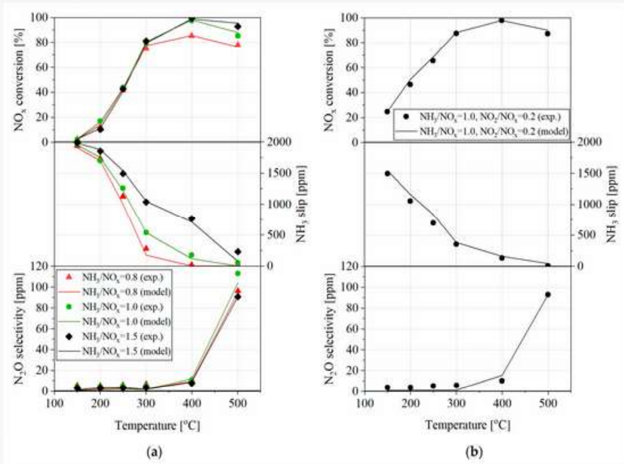
Mitigation strategy required for pollutants

- SCR : mature for NH_3 engine ?
- NOx/NH_3 not constant for all operating conditions !
- High H_2O : catalyst efficiency, life ?



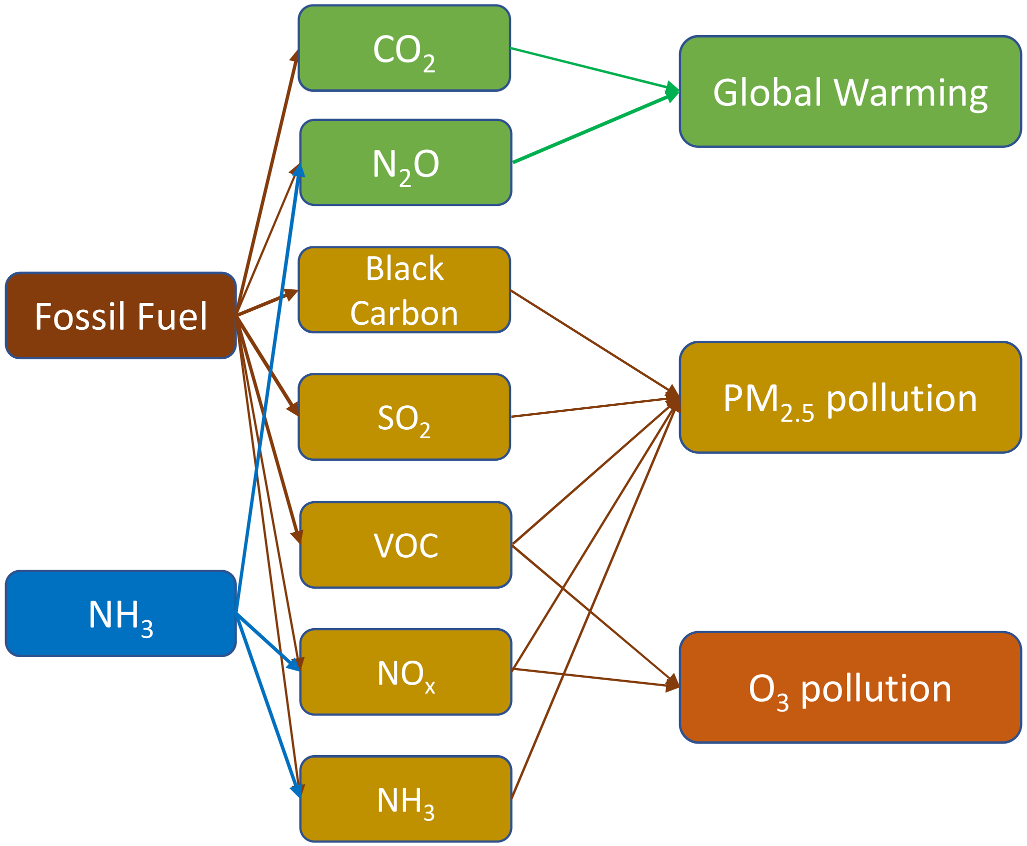
Ferri D., First Ammonia combustion Workshop, Feb. 2022

Figure 5. NO_x conversion, NH_3 slip and N_2O formation over the V-SCR under (**a**) standard SCR conditions with NH_3/NO_x = 0.8, 1.0, 1.5 and NO_2/NO_x = 0 and (**b**) fast SCR conditions with NH_3/NO_x = 1.0 and NO_2/NO_x = 0.2, based on the experimental data (symbols) and the model (solid lines).



Voniati, G.; Dimaratos, A.; Koltsakis, G.; Ntziachristos, L. Ammonia as a Marine Fuel towards Decarbonization: Emission Control Challenges. *Sustainability* **2023**, *15*, 15565. https://doi.org/10.3390/su152115565

NH_3 VERSUS FOSSIL FUEL: ADVANTAGES FOR GLOBAL ENVIRONMENT ?



Combustion exhaust gases from ammonia fueled engine will include …

- **NH_3 : Strong pungent smell, highly toxic to human body**
- **NO_x : Photochemical smog, acid rain, air pollution**
- **N_2O : GHG about 300 times more potent than CO_2, ozone depleting gas**

$$4NH_3 + 3O_2 \rightarrow 2N_2 + 6H_2O \; (+ NH_3 + NOx + N_2O)$$