



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

Committee outputs

Energy efficiency regulations for ships: EEDI and SEEMP

DCS regulations

Initial IMO Strategy on reduction of GHG emissions from ships

Revised procedure on assessment of Impacts on States
Consideration of mid-term measures

Short-term measure: EEXI, CII

2023 IMO Strategy on reduction of GHG emissions from ships

LCA guidelines
Biofuels circular

Comprehensive impact assessment

Review of short-term measure
Approval of basket of mid-term measures

40% reduction of CO₂ per transport work
5% uptake of zero-emission fuels, striving for 10%
Indicative checkpoint: 20% reduction of the total annual GHG, striving for 30%

Net-zero GHG emissions by or around, i.e., close to, 2050

2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025

2030

2040

2050

Implementation

3rd IMO GHG Study

EEDI and SEEMP

Fuel consumption report to DCS

4th IMO GHG Study

Aggregated results of the 2019 fuel consumption data

EEXI survey

Collection of carbon intensity data (CII) for existing ships

Indicative checkpoint: 70% reduction of the total annual GHG, striving for 80%

EEDI Phase 1

EEDI Phase 2

EEDI Phase 3 for certain ship types

EEDI phase 3 for remaining ship types

- mandatory measures and guidance
- evidence-based decision making
- strategic objectives





Ammonia Energy Conference 2021 – Australia

Future fuels and emissions



MAN Energy Solutions
Future in the making

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

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

By GAIL COOPER - 20/02/2024

f X in



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

Mer of Marine



NH₃ 25.000 DWT Chemical Tanker

CMB.TECH has ordered 6x 25.000dwt chemical tankers. The vessels has been designed considering future retrofiting for using NH₃ as a fuel.



NH₃ 6.000 TEU Container Vessel

6x 6.000 TEU ice class 1A high reefer container ships with a class notation to use NH₃ as fuel.



NH₃ 205.000 DWT Dry Bulk Carrier

CMB.TECH has 22x 210.000 dwt Newcastlemax bulkers on order. The vessels have a unique design as they will be able to use the zero-emission fuel of Ammonia.



Image of A-tug

But no vessels really run with ammonia engines until now

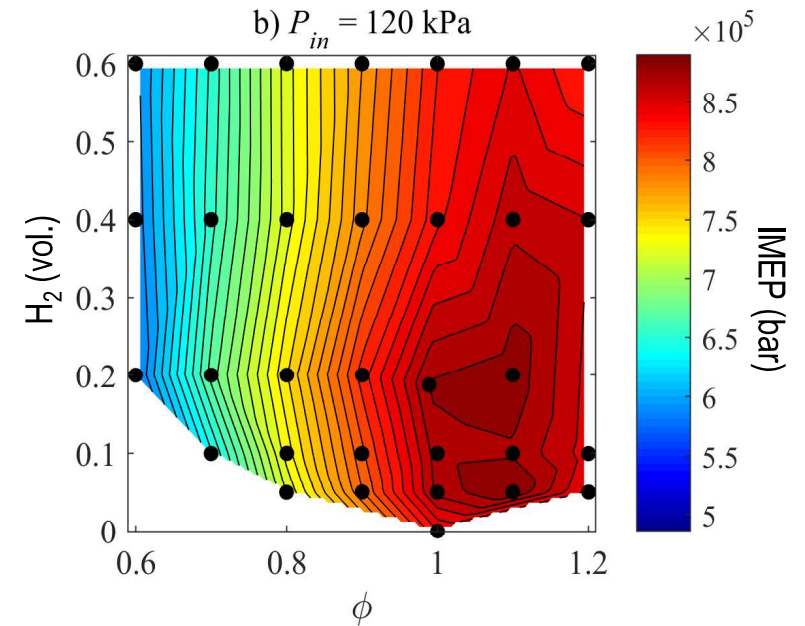
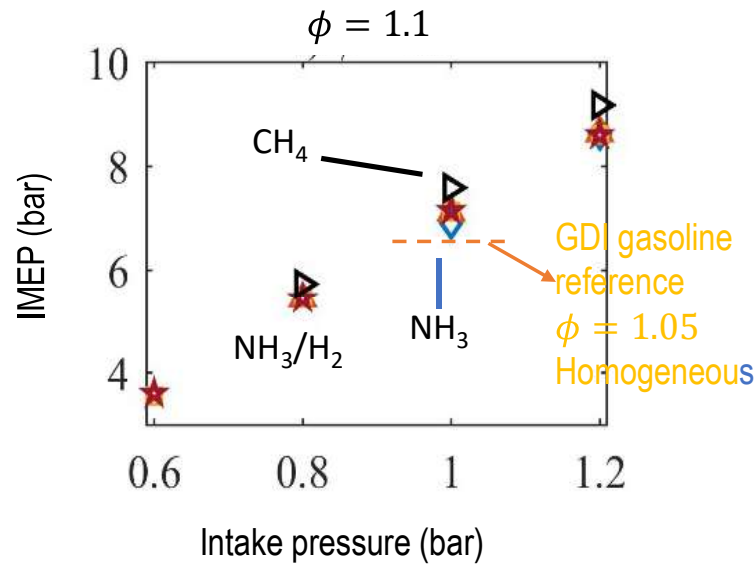
What Consequence on global environment if we consider all ships with ammonia engine ?



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



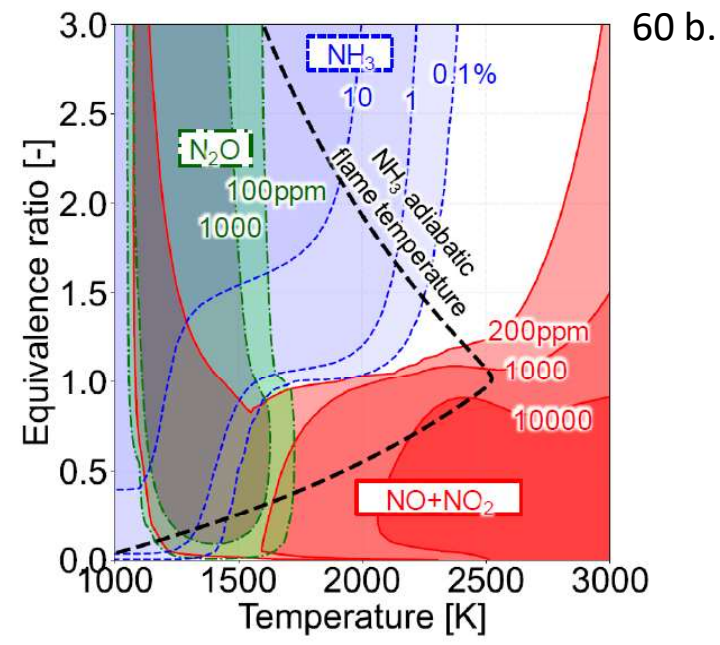
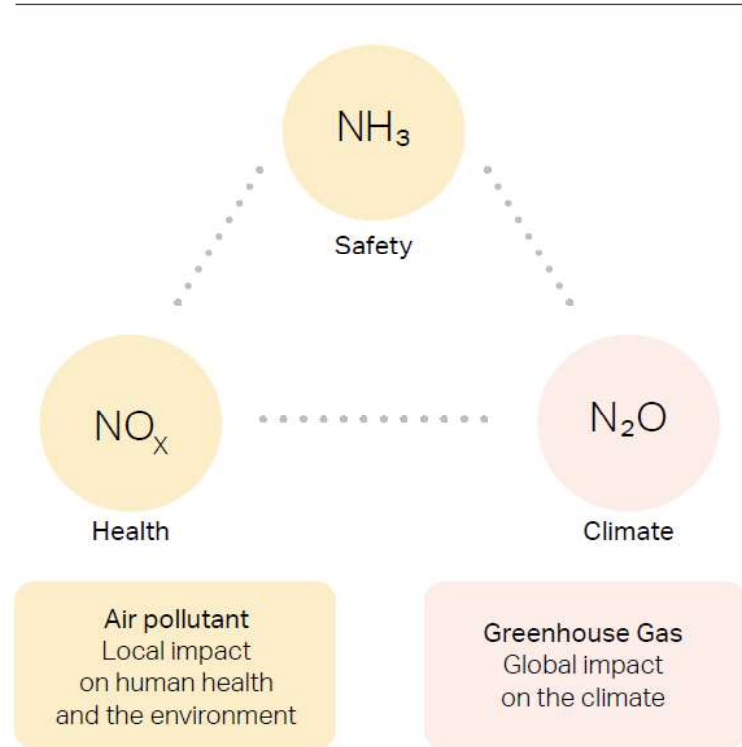
- Current igniter, CR,
- Piston geometry (GDI)
- Premixed gaseous NH₃/air intake (no injector)

- Similar IMEP than NG or Gas.
- Operation with NH₃ only for $P_{in} \geq 1$ bars
- H₂ = efficient combustion promoter

- Best work for slightly rich mixtures
- 5-10 vol.% H₂

IMPORTANT QUESTION : WHAT EMISSIONS FOR AMMONIA ENGINE

Ammonia combustion emission risk triangle



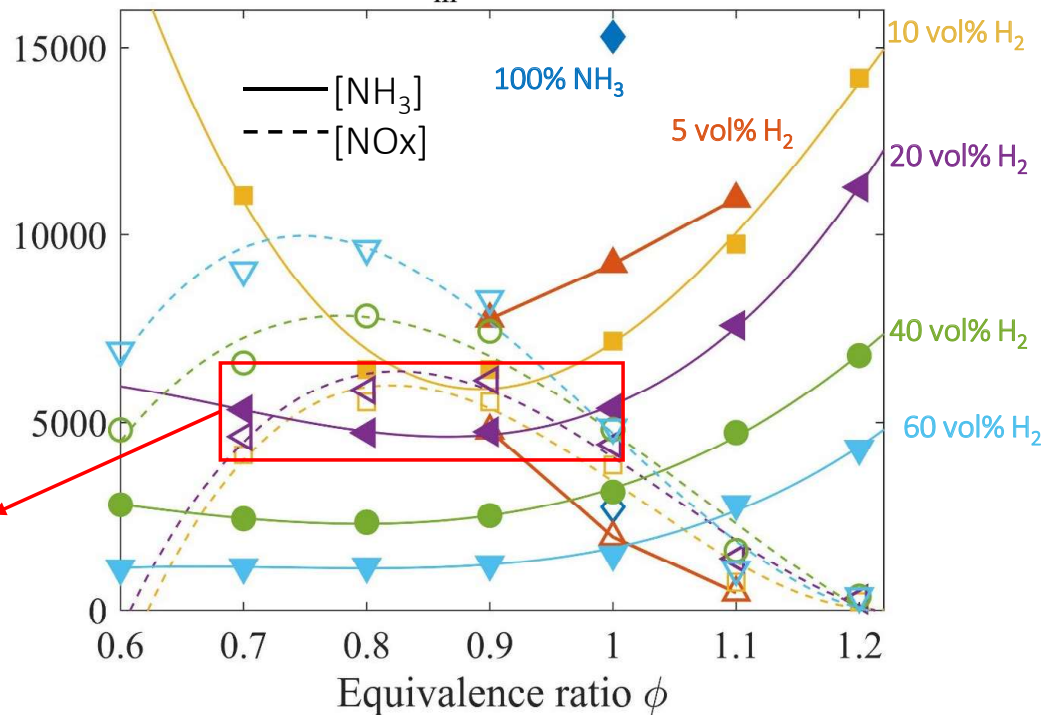
Hiraoka K, Matsunaga D, Kamino T, Honda Y, et. al. Experimental and numerical analysis on combustion characteristics of ammonia and diesel dual fuel engine. SAE Technical Paper 2023:2023-32-0102. <https://doi.org/10.4271/2023-32-0102>.



EMISSIONS OF SI ENGINE FUELED WITH NH₃/H₂

Exhaust emissions
(ppmw)

$P_{in} = 1.0$ bar



“Low” emission window

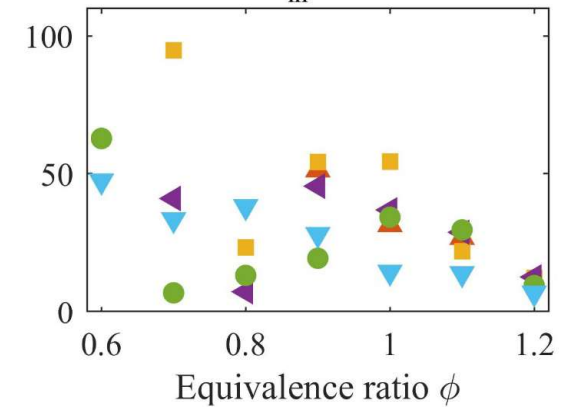
$$0.7 < \phi < 1$$

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

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

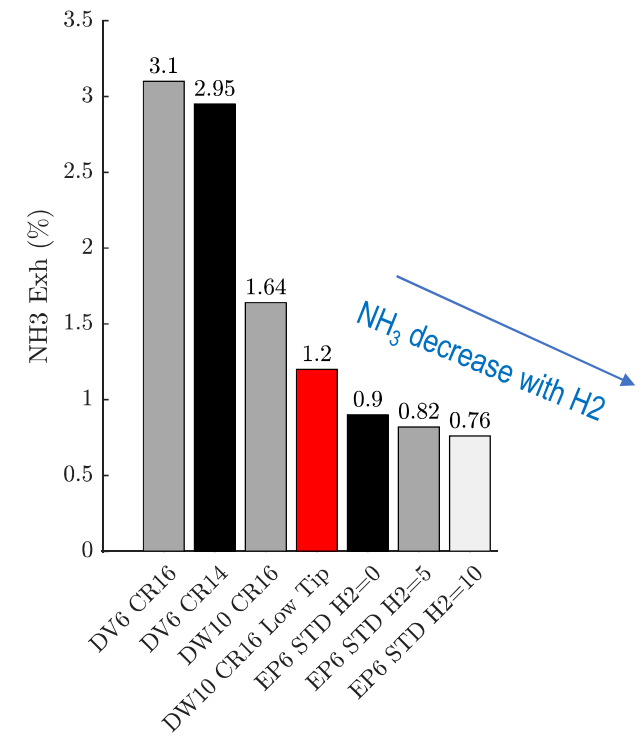
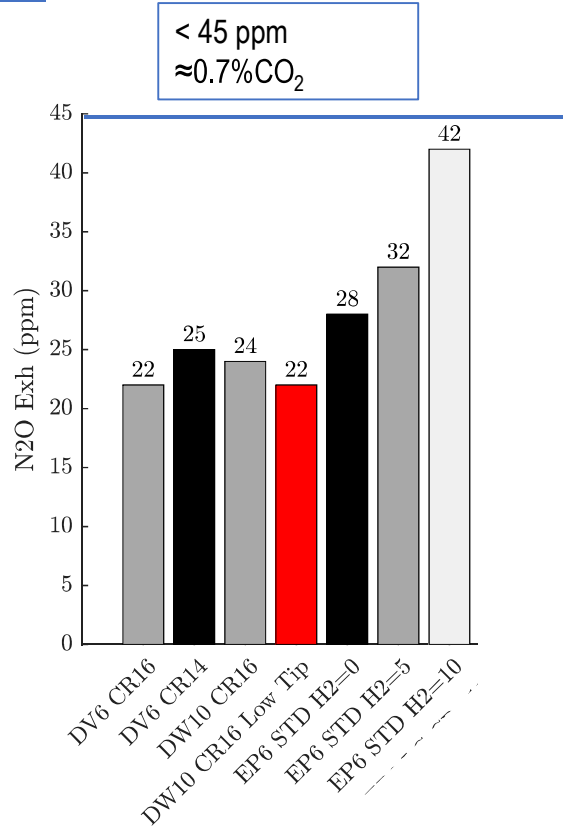
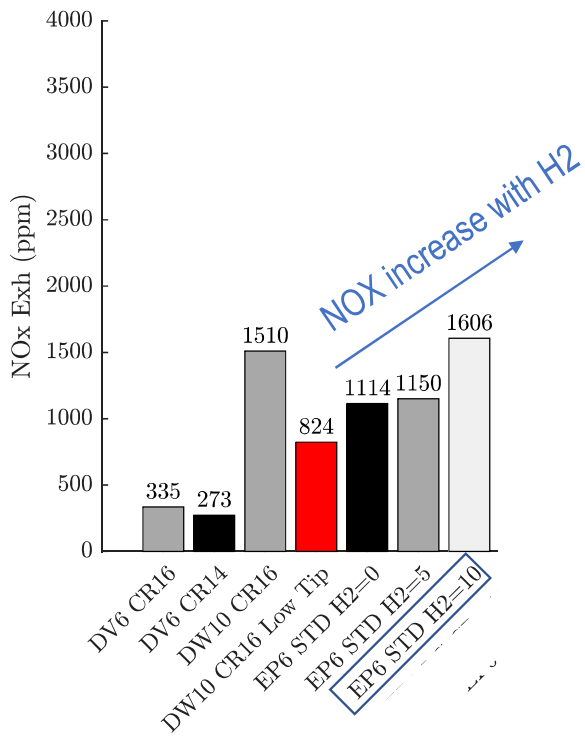
$$T_{exhaust} = 700\text{-}800 \text{ K}$$

[N₂O]
(ppmw) a) $P_{in} = 1$ bar



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

EXHAUST EMISSIONS : FUNCTION OF THE ENGINE DESIGN



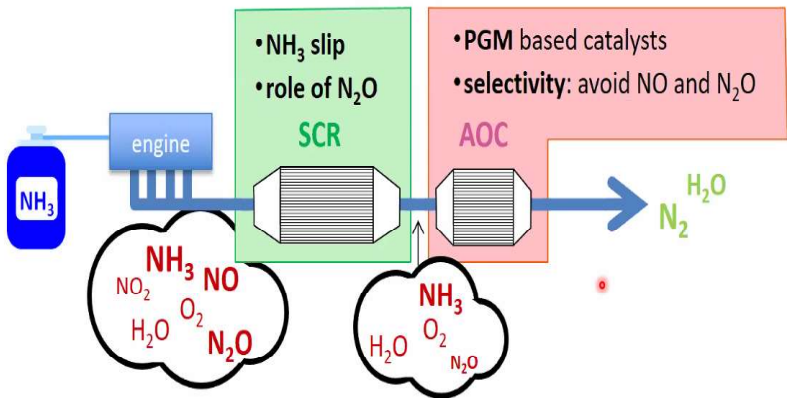
Operating conditions:

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

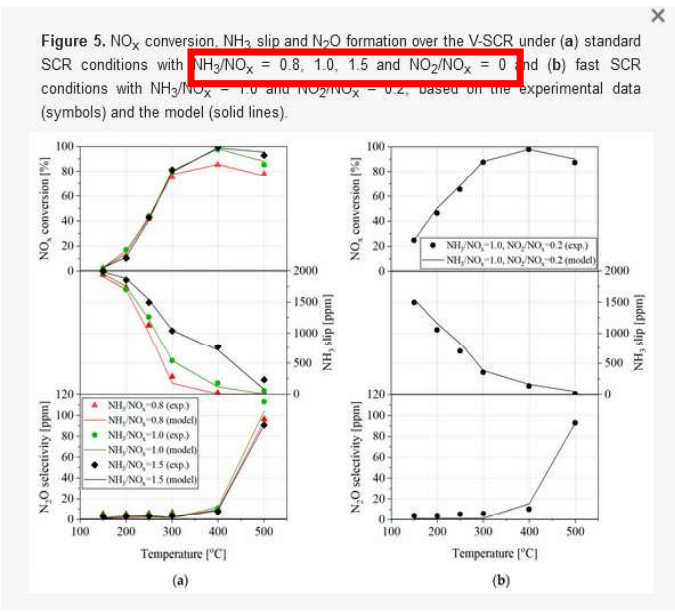
D= Diesel engine with spark plug and pure ammonia
 E= Gasoline engine
 CR = Compression Ratio

Mitigation strategy required for pollutants

- 🔗 SCR : mature for NH₃ engine ?
- 🔗 NO_x/NH₃ not constant for all operating conditions !
- 🔗 High H₂O : catalyst efficiency, life ?

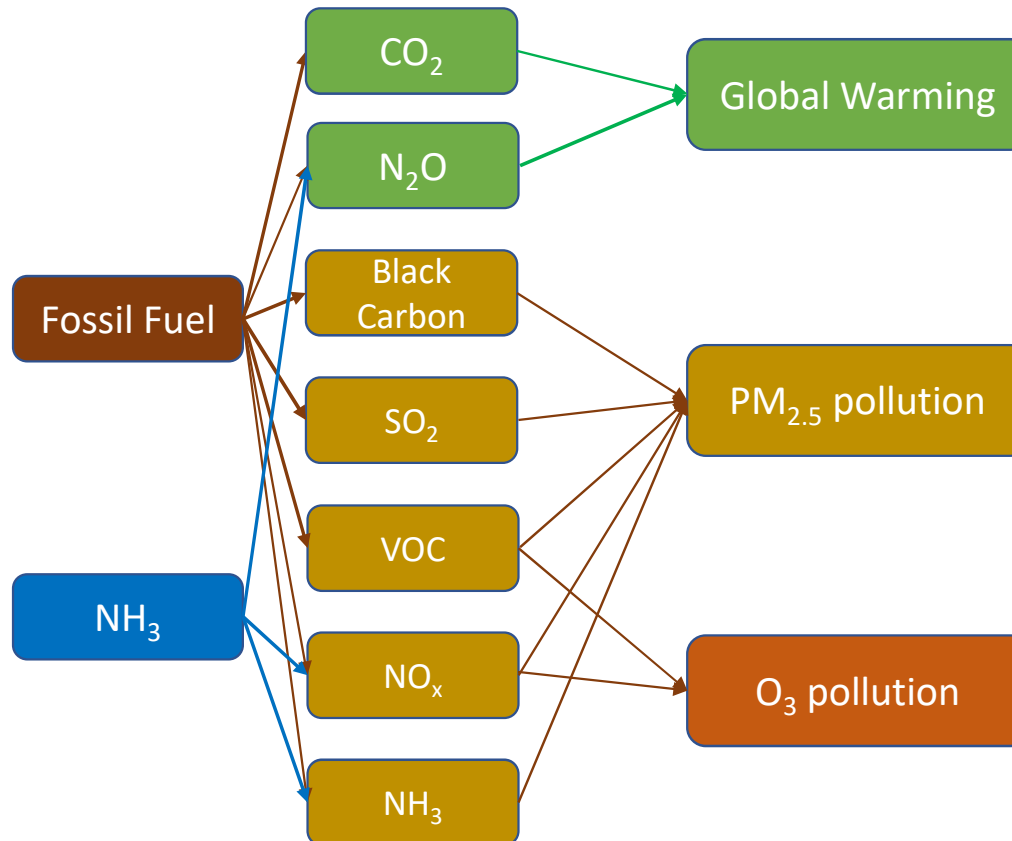


Ferri D., First Ammonia combustion Workshop, Feb. 2022



Voniati, G.; Dimaratos, A.; Koltsakis, G.; Ntziachristos, L. Ammonia as a Marine Fuel towards Decarbonization: Emission Control Challenges. *Sustainability* **2023**, *15*, 15665. <https://doi.org/10.3390/su152115665>

NH₃ VERSUS FOSSIL FUEL: ADVANTAGES FOR GLOBAL ENVIRONMENT ?



Combustion exhaust gases from ammonia fueled engine will include ...

NH₃ : Strong pungent smell, highly toxic to human body

NO_x : Photochemical smog, acid rain, air pollution

N₂O : GHG about 300 times more potent than CO₂, ozone depleting gas

