MariNH3

Clean, green ammonia engines for maritime

Towards a Sustainable Decarbonised Future: Emissions formation and abatement from Ammonia Fuelled Engines

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- Introduction to emissions from NH_3 combustion.
- N-emissions formation.
- After-treatment systems and control for NH_3 exhaust.

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Introduction

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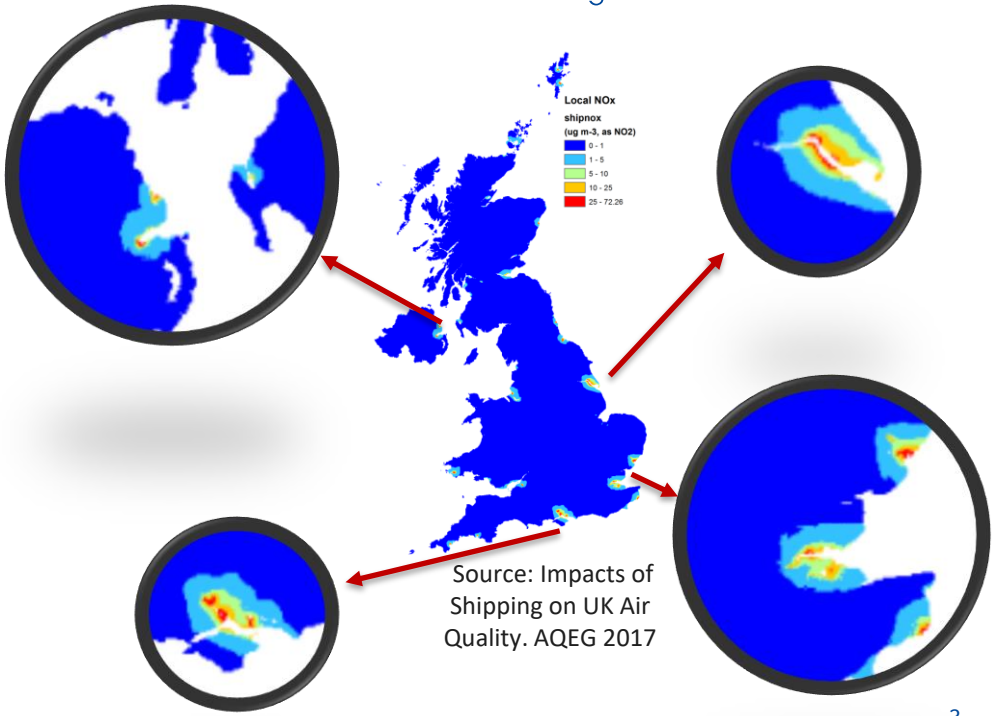
- NH_3: Characterized by a **strong Irritant odor** and is **highly toxic** to the human body.
- NO_X: Contributes to **photochemical smog, acid rain,** and **air pollution**; it is also **highly toxic**.
- N_2O: **A long-lived greenhouse gas (GHG)** and **an ozone-depleting substance**.

Zero carbon Fuels (H_2/NH_3)

CO + THC + NO_X

NH_3 + NO + NO_2 + N_2O

Conventional Fuel



Source: Impacts of Shipping on UK Air Quality. AQEG 2017

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Introduction

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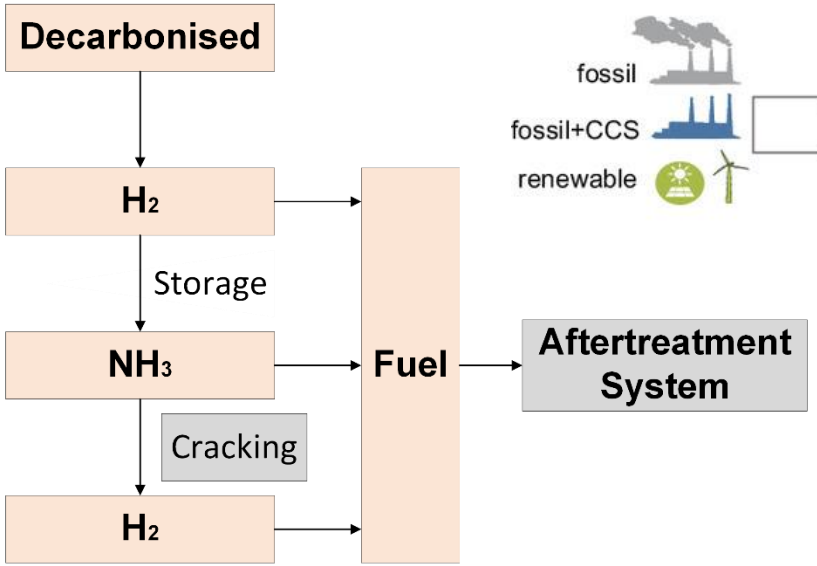

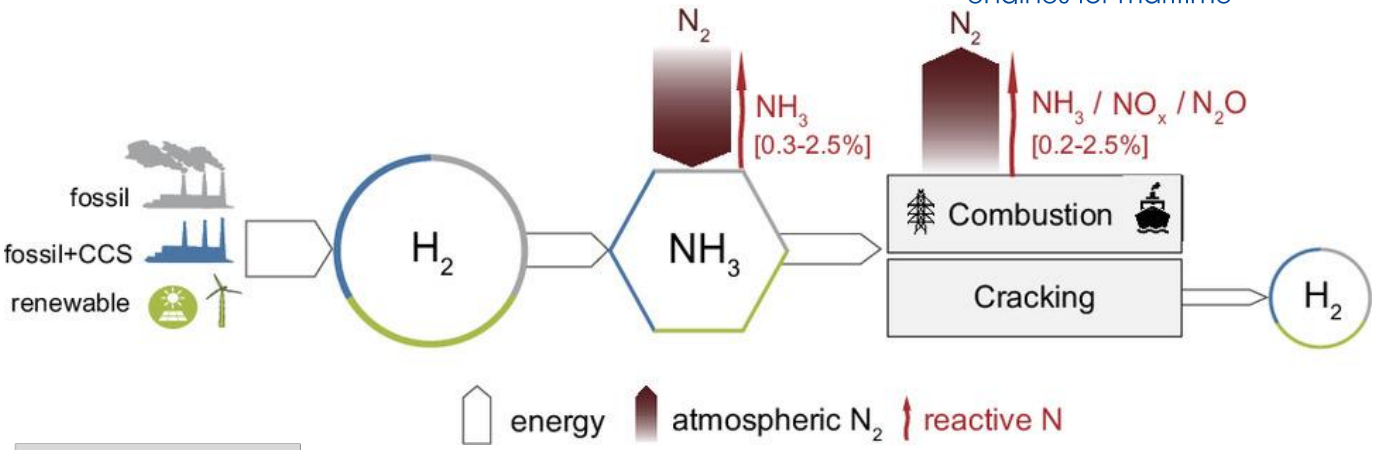

Schematic of the ammonia value chain and its potential impact on the nitrogen cycle. (https://doi.org/10.1073/pnas.2311728120)

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Experimental facilities

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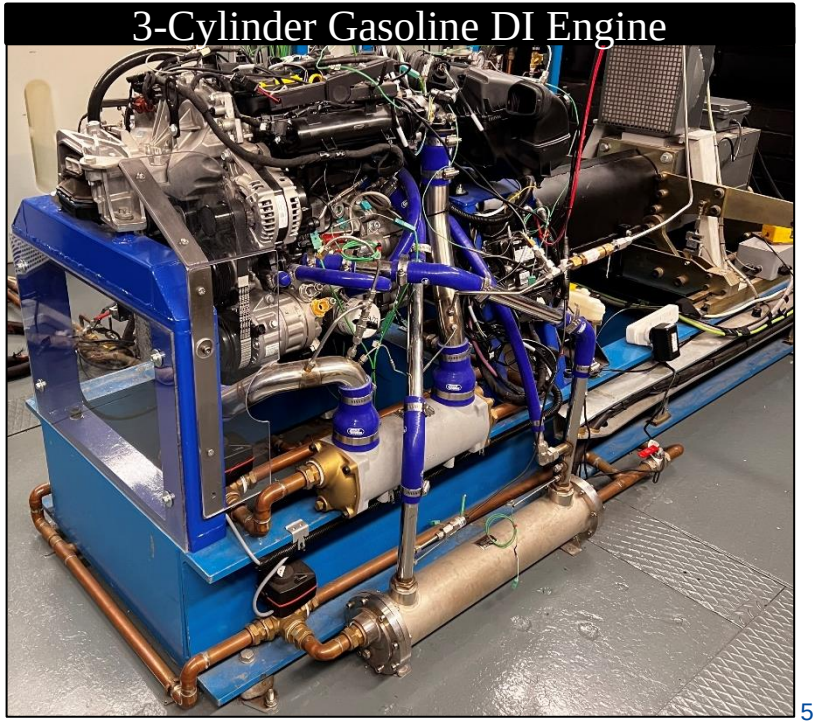
HSense (V&F)

Engines Control Room

3-Cylinder Gasoline DI Engine



Gas Analyser

Exhaust handling system

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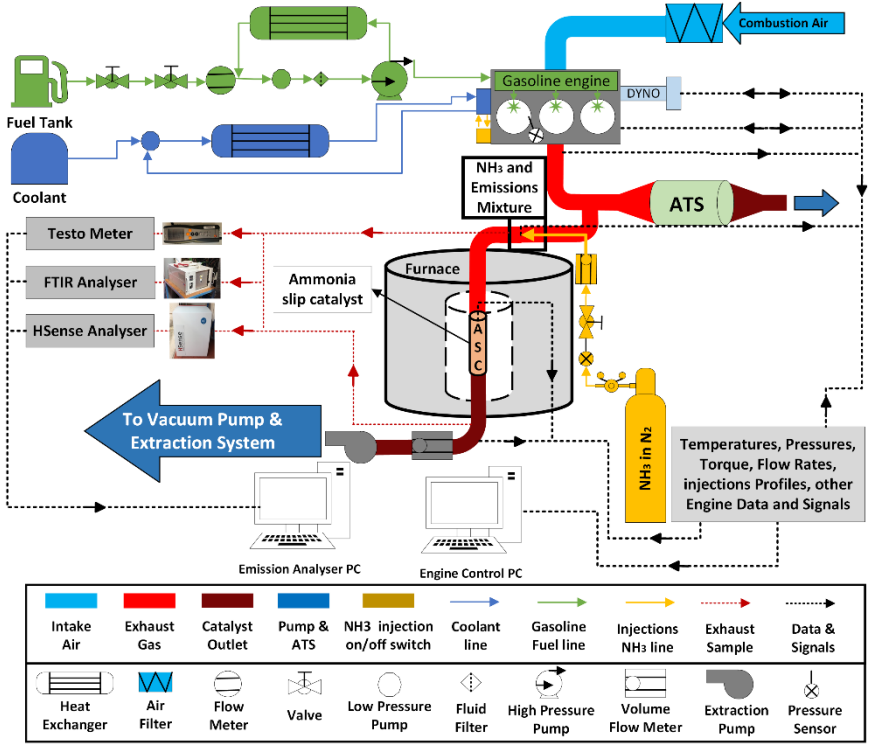

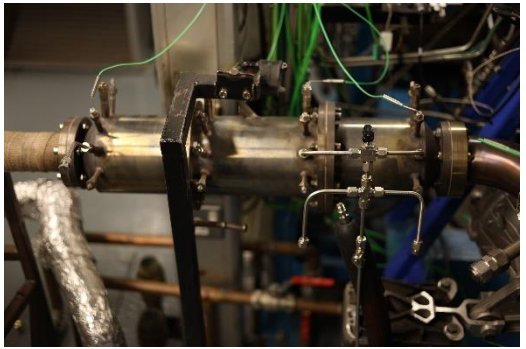

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Ammonia cracking

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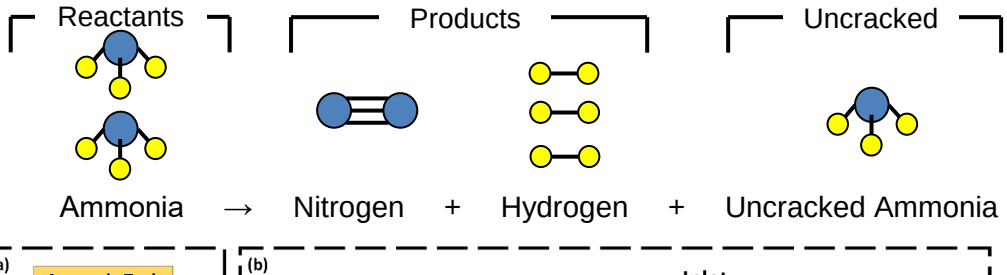
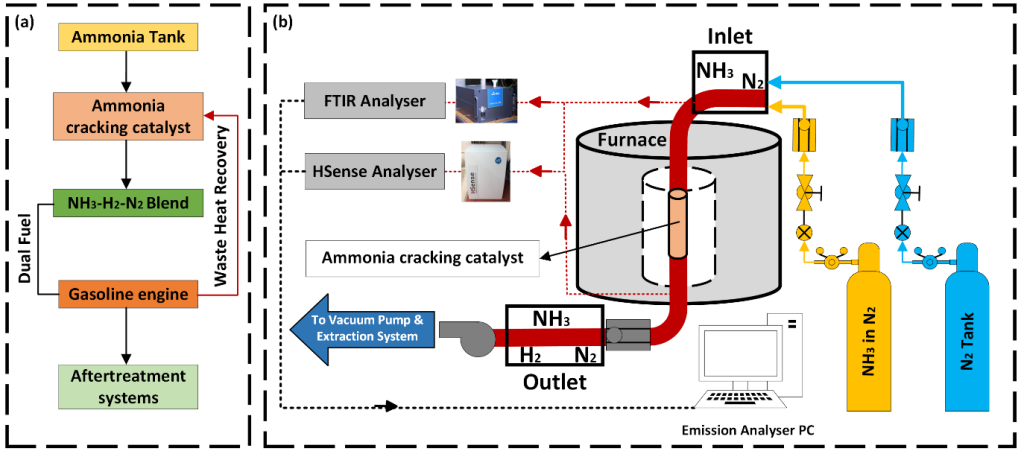
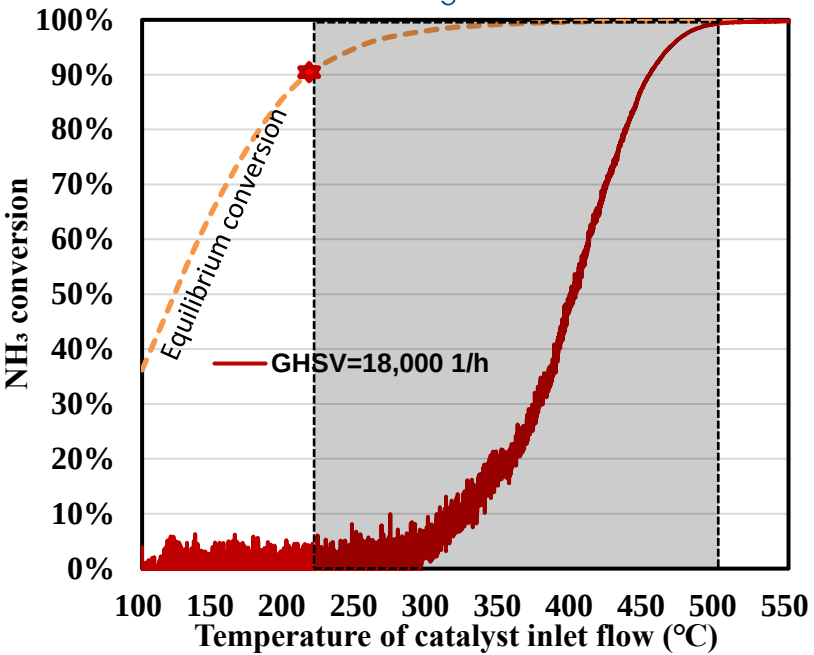




Ammonia cracking catalyst system scheme (Accepted for publication in Thiesel 2024)



Ammonia Conversion Laboratory Results for the University of Birmingham (Accepted for publication in Thiesel 2024)

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N-emissions formation

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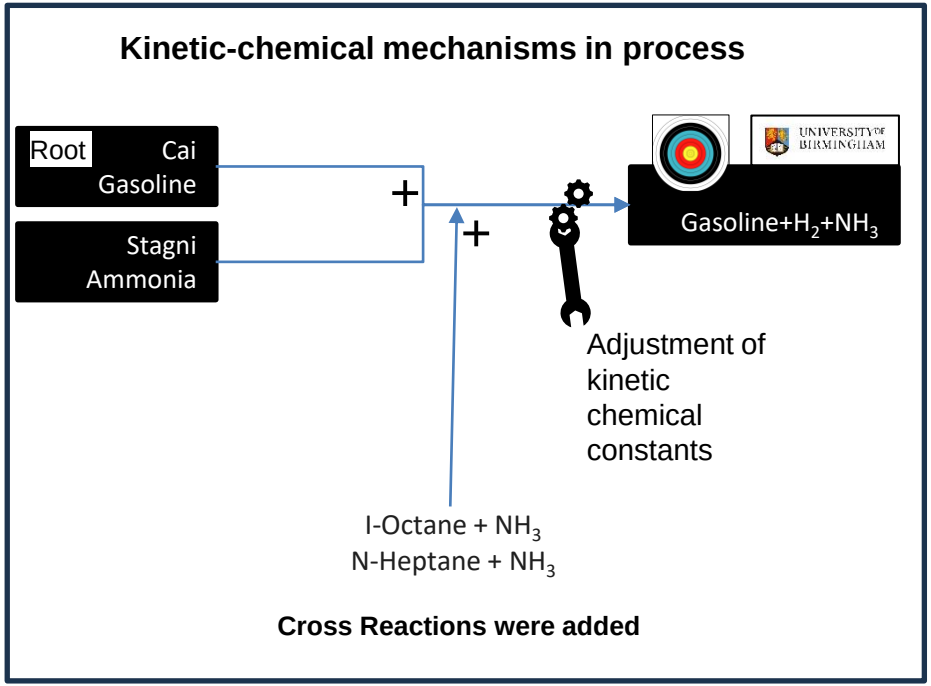
Fundamentals modelling

- Conditions (Po To, λ),
- P vs. CAD data,
- Engine geometric data

Two-zones Engine model

- Emissions (NO, N_2O, NO_2)
- Slip (H_2, NH_3)
- Engine Performance (Torque)



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N-emissions formation

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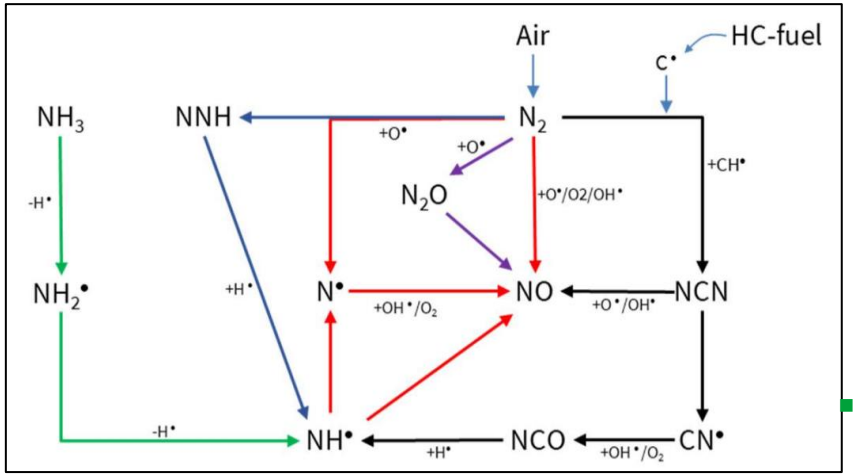

Simplified scheme of formation pathways of the NO species by different mechanisms

- NO_X production is done through 5 main pathways:
  - Thermal (T-sensitive)
  - Fuel (N in fuel sensitive)
  - Prompt (fuel rich, T < 1800 K)
  - N_2O intermediate (fuel lean, T< 1800 K, ↑ P)
  - NNH mechanism (H sensitive)
- Due to the nitrogen present within NH_3 the fuel NO_X pathway becomes important.
- The lower adiabatic flame temperature of NH_3 compared to gasoline reduces the contribution from thermal NO_X.

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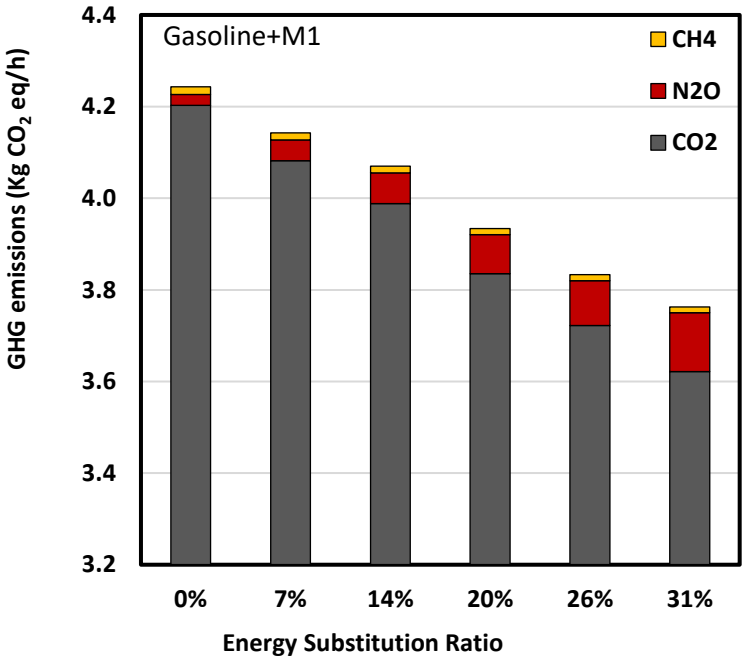

- CO_2 emissions continue to decrease.
- The potential contribution of the greenhouse gas **N_2O increases.**
- There was a consistent decrease in the total potential greenhouse gas emissions.

Green House Emissions as the ESR increases from a SI engine fuelled with Gasoliine+M1 (5%NH_3/70%H_2/25%N_2) (Accepted for publication in Thiesel 2024)

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After-treatment

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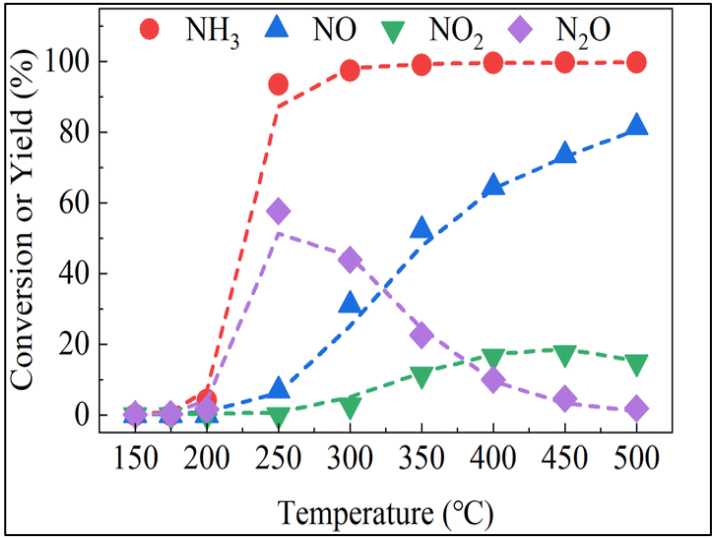
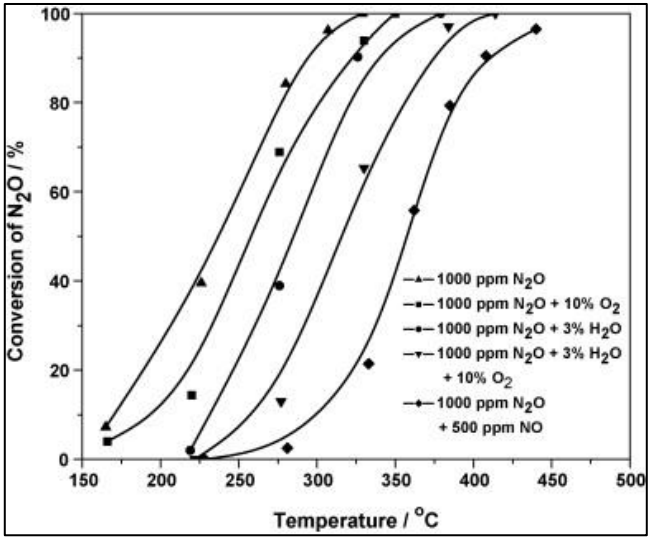
Ammonia slip catalysts (ASC)

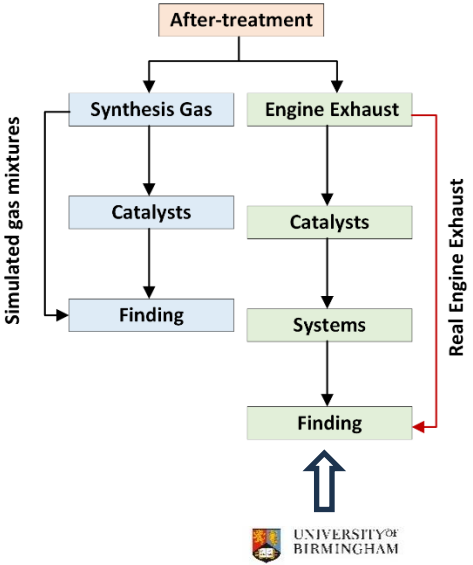


NH3 conversion and product yields under NH3 oxidation conditions. Yao D, Li Y, Wu F, et al. Reaction Chemistry & Engineering, 2023, 8(8): 2040-2051.

De-N_2O catalyst



N2O conversion – (Applied Catalysis B: Environmental 75, 167–174.)



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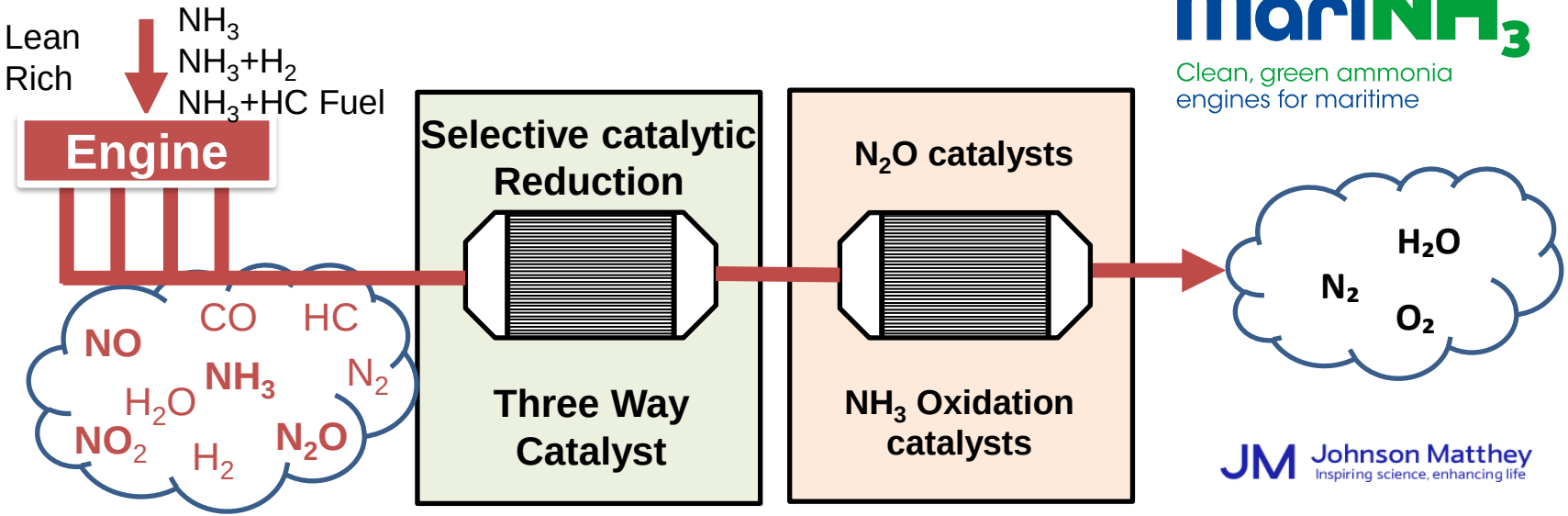

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- NH_3 as a fuel in ICE leads to complex unburnt NH_3 - NO_X – N_2O trade-offs.
- The different composition of NH_3 exhaust gas produces different challenges to aftertreatment systems than conventional gasoline exhaust gas.
- Exhaust after-treatment required to help with combustion trade-offs leading to combination of catalytic components.

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