

MariNH₃

Clean, green ammonia
engines for maritime

Reducing Non-Carbon Greenhouse Gas Emissions.

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Cambustion

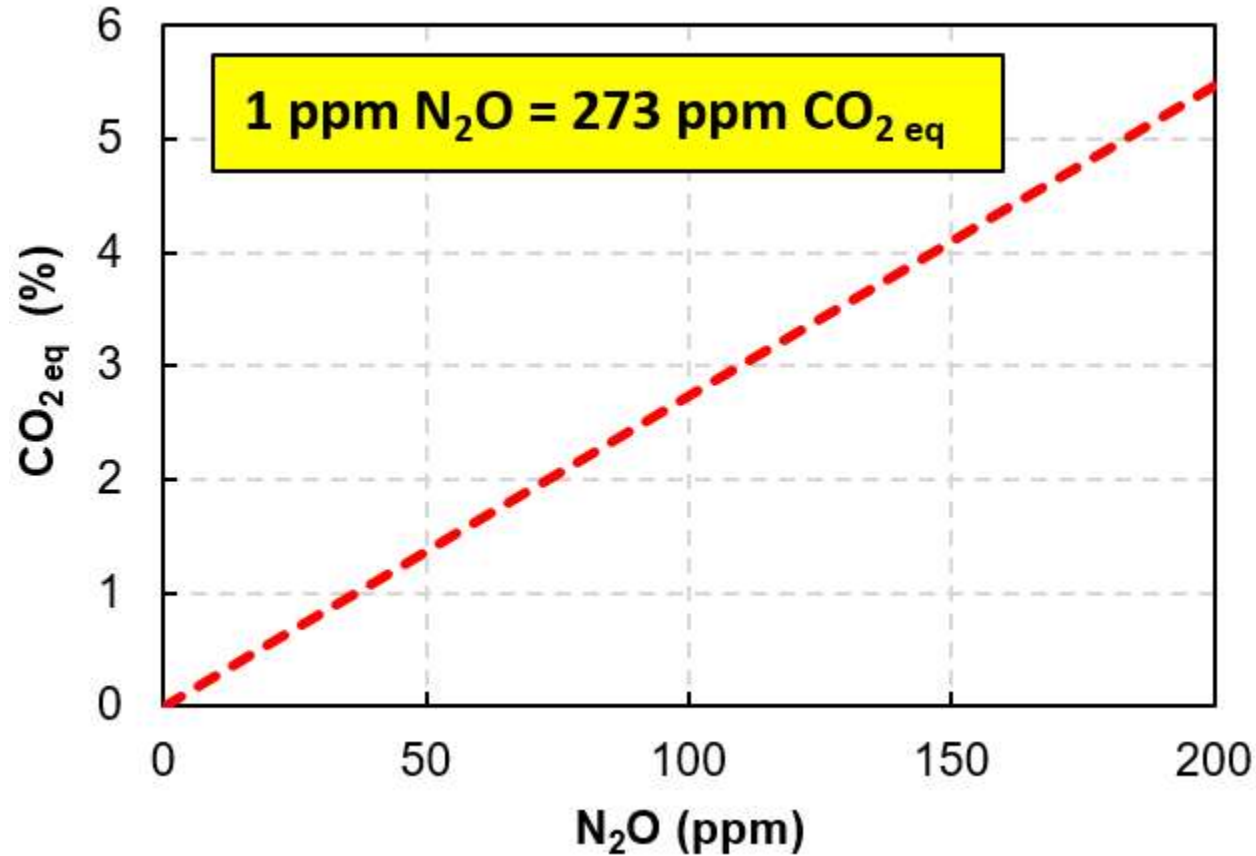
The
partnership



Funded by

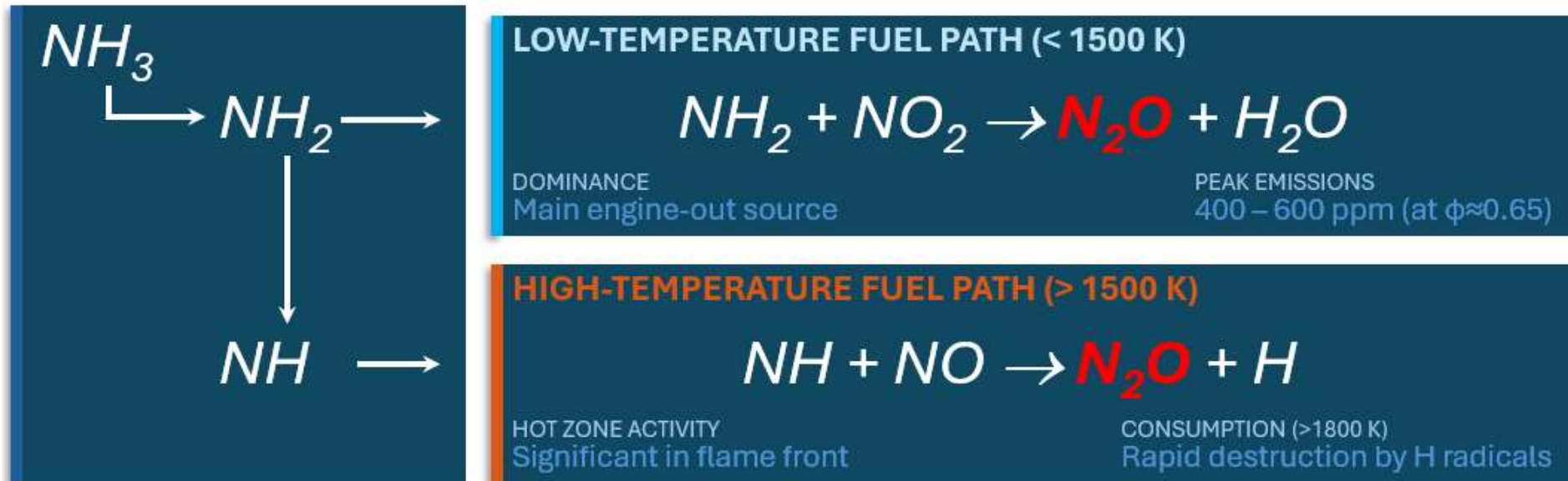


Non-Carbon Greenhouse Gas - N₂O



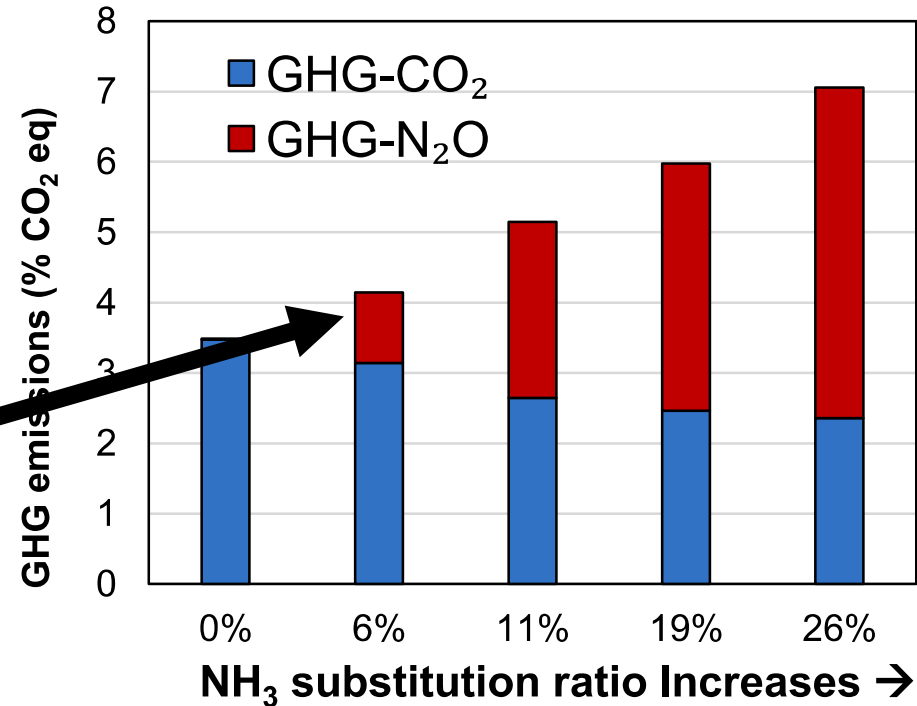
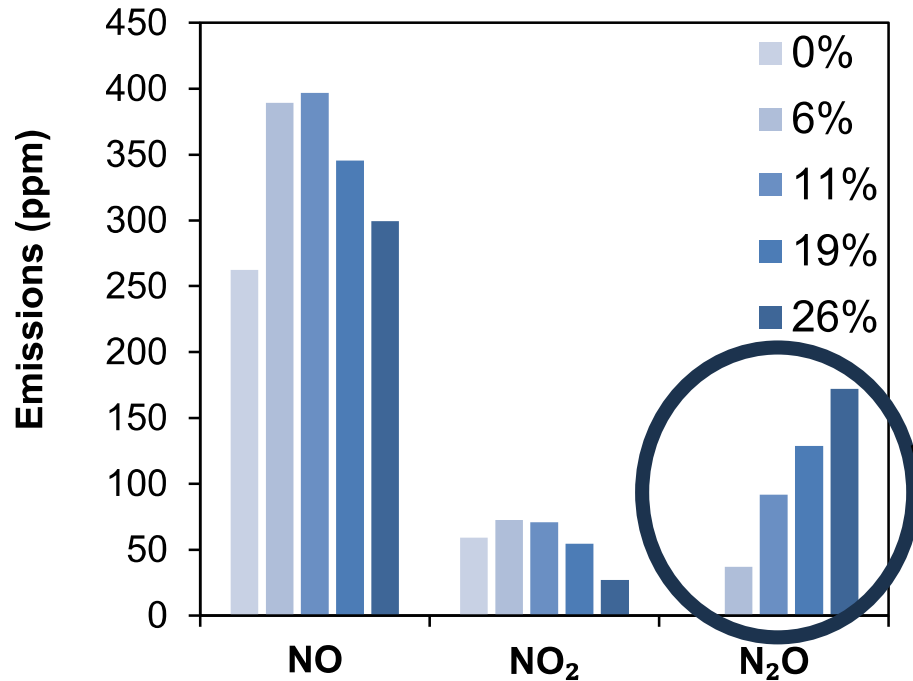
Typical engine out CO₂ levels of **2.3% to 5% range** for steady cruising

N₂O Formation During Combustion



Engine Non-Carbon Greenhouse Gas - N₂O **MariNH₃**

Clean, green ammonia engines for maritime



- Higher NH₃ ESR reduces CO₂ but can increase N₂O formation.
- Despite ~30% lower CO₂, increased N₂O can significantly raise the GWP₁₀₀-based CO₂-equivalent impact.

REGGAE- REducing Greenhouse Gases from Ammonia Engines



Objective

The **REGGAE** feasibility project designed a prototype after-treatment system consisting of optimised catalysts tailored for **REducing Greenhouse Gases** from **Ammonia Engines**.

Partners & Roles

Johnson Matthey (Project Lead) Catalyst development for DeN₂O and ASC & Well-to-Wake analysis



University of Birmingham Engine Emissions & Catalytic Aftertreatment Studies

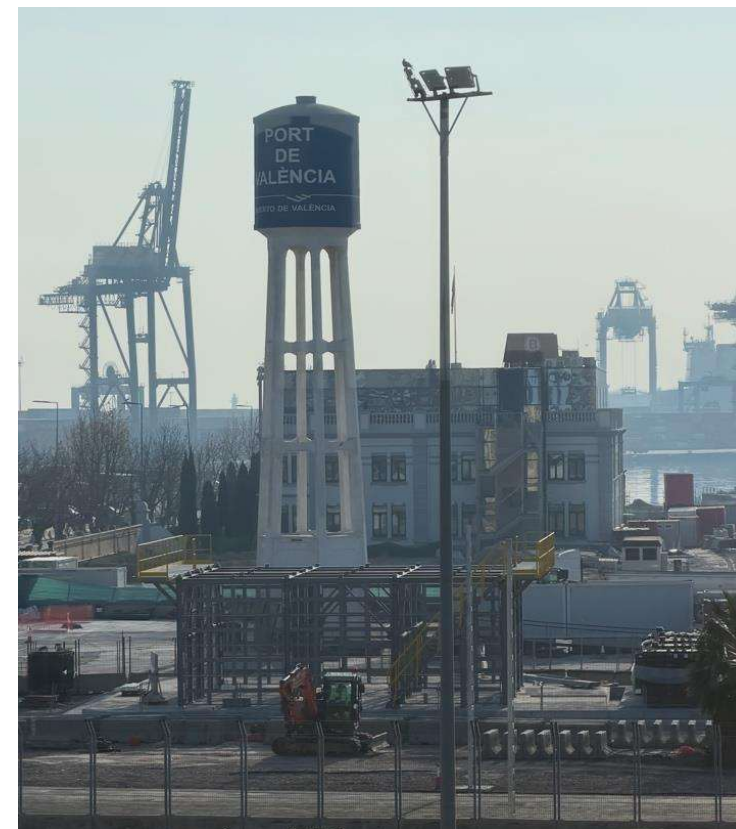


Fundacion Valenciaport End user. Impact and feasibility Studies



REGGAE - Success Criteria

- 90% catalyst activity below 450°C in N₂O reduction
- 25% reduction in GHG emissions (giving an absolute GHG emissions reduction higher than 90%, assuming pilot Diesel fuel is needed).



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De-N₂O Catalyst formulations

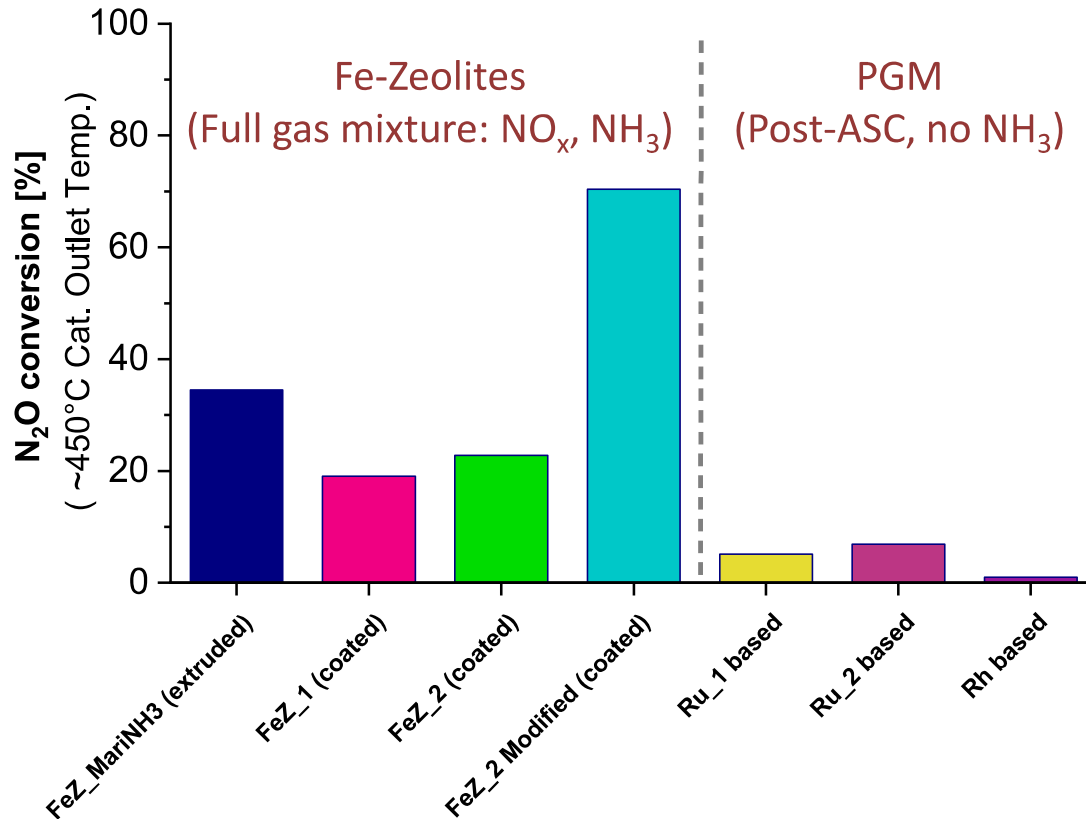
Sample	Form	CPSI
FeZ_MariNH ₃	Extruded	Medium
FeZ_1	Coated	High
FeZ_2	Coated	High
FeZ_2 Modified	Coated	High
Rh based	Coated	High
Ru_1 based	Coated	High
Ru_2 based	Coated	High

- ❑ **Aftertreatment catalyst** in monolith form produced by JM:
 - ❑ Fe-zeolite based
 - ❑ PGM based

PGM: Platinum-Group-Metals
CPSI: Cells Per Square Inch

7

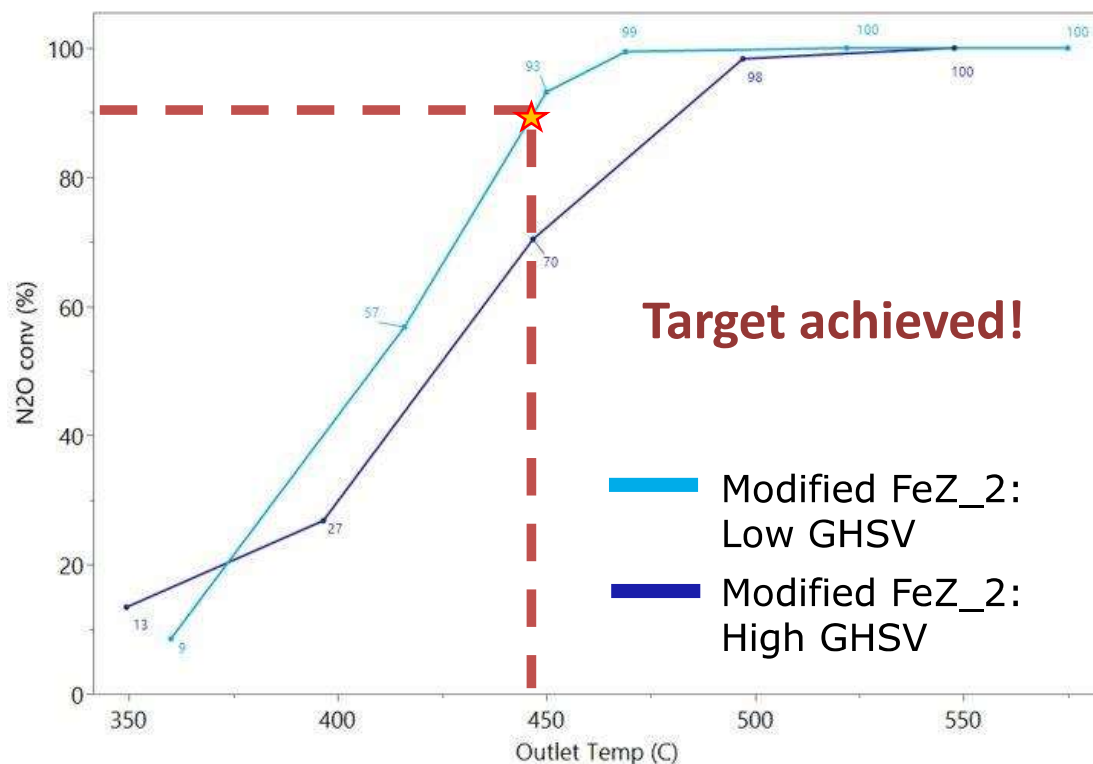
De-N₂O Catalyst Screening at JM



- ❑ Targets: N₂O conv. ≥90% (below 450°C)
- ❑ **FeZ_2 Modified catalyst outperforms** all other catalysts
- ❑ Modification of the synthesis method allows for improved activity



De-N₂O Catalyst Screening at JM



UoB Test conditions

- N₂O is 172 ppm
- NO~1220 ppm, NO₂ ~380 ppm, NH₃~1200 ppm, **NH₃/NO_x ≈0.75**
- O₂~15.2%, H₂O~10%
- Low/High GHSV
- Furnace Temp = 400,450,500,550 & 600°C

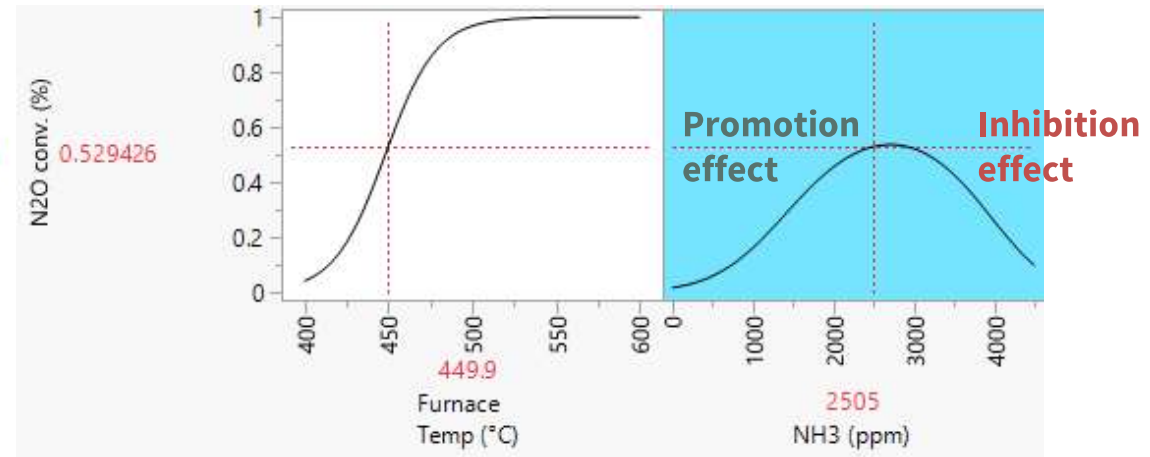
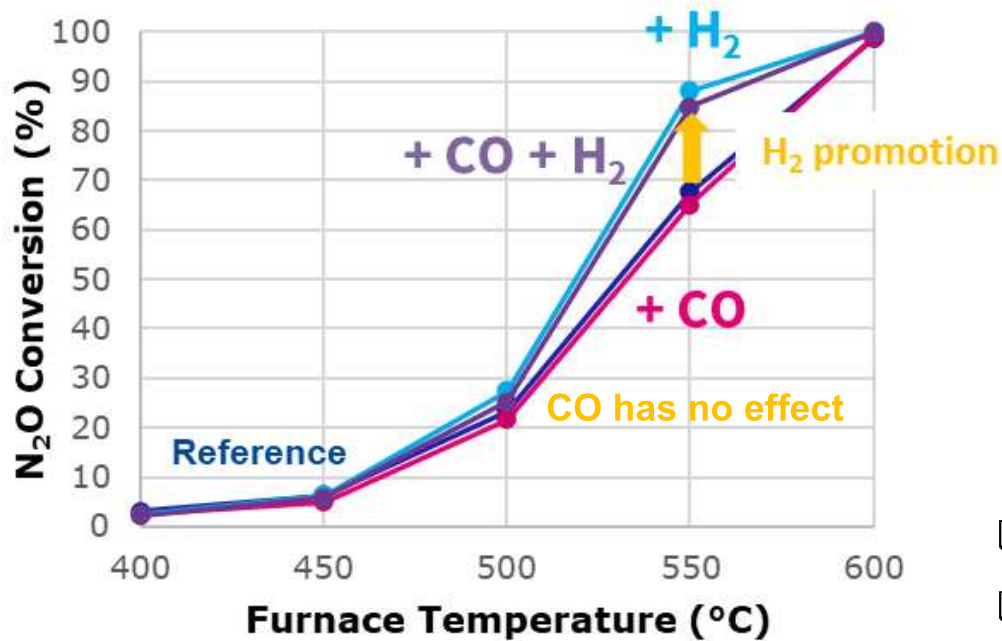
Target: N₂O conv. ≥90% (below 450°C)

Key observation

- ☐ Project target achieved when decreasing GHSV over the **FeZ_2 Modified**.

De-N₂O Catalyst Screening at JM

- Effect of reductants: H₂, CO and NH₃



- Promoting and inhibiting effects
- Effect of reductants strongly depends on reaction conditions and reductant concentration.

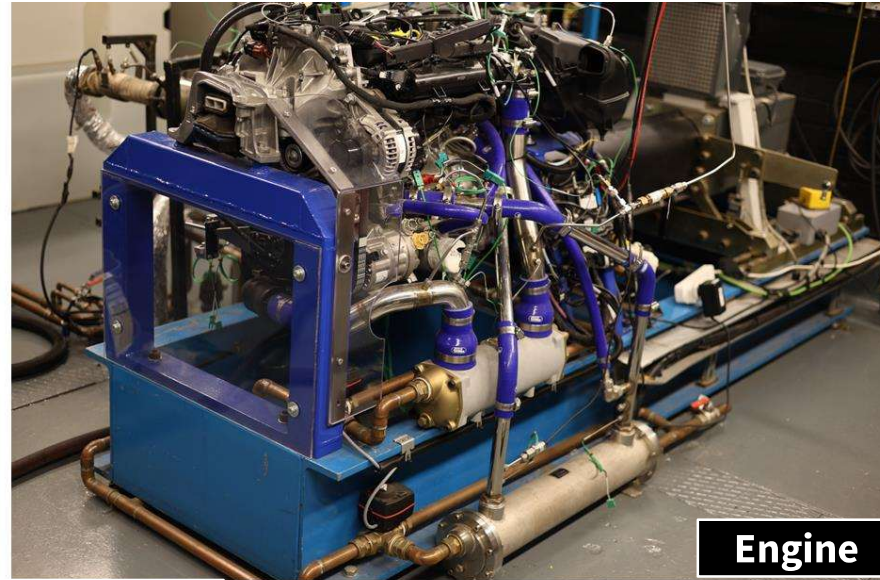
UoB Experimental Facilities

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Ammonia Storage



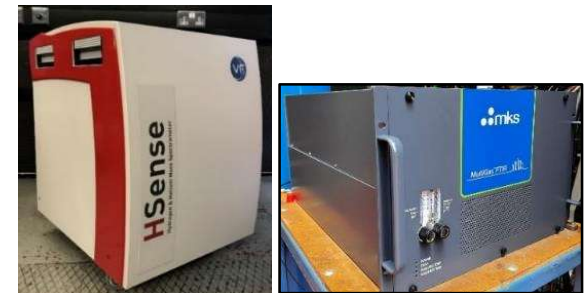
Engine



Catalyst



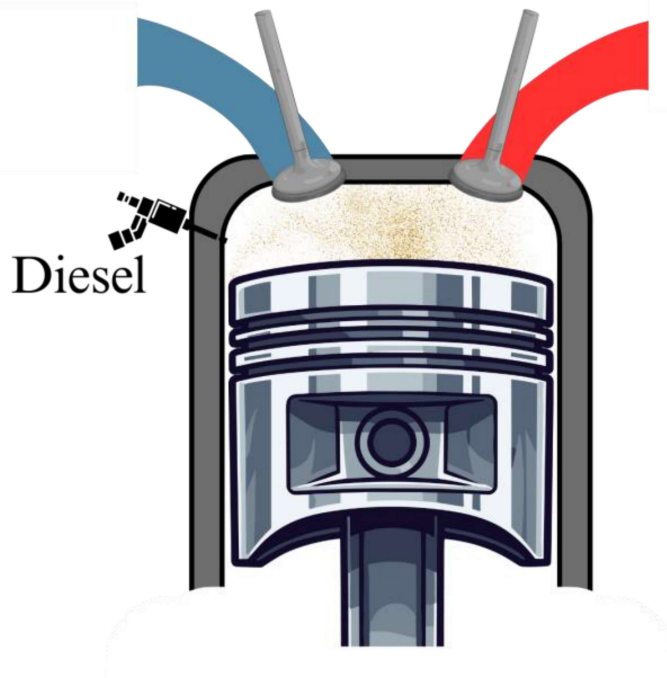
Ammonia flow control



Emissions Analysis

Engine Experimental Conditions

Air/NH₃+H₂



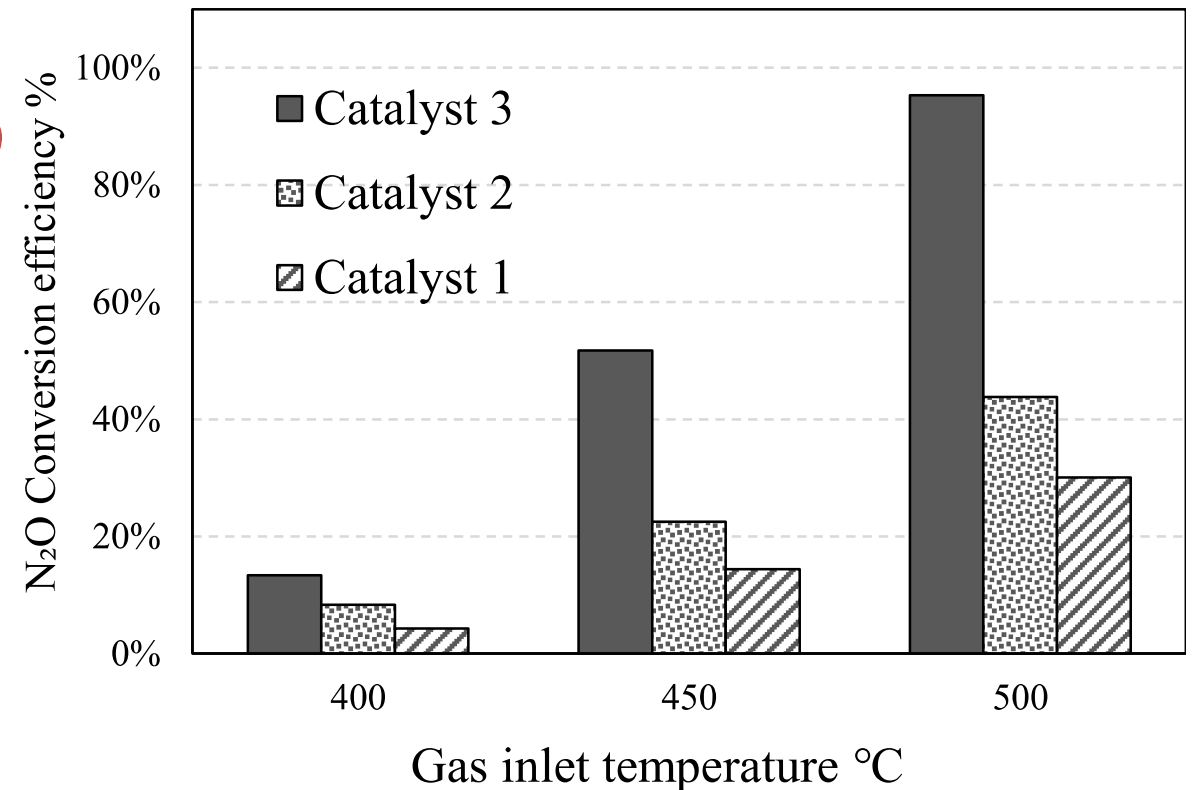
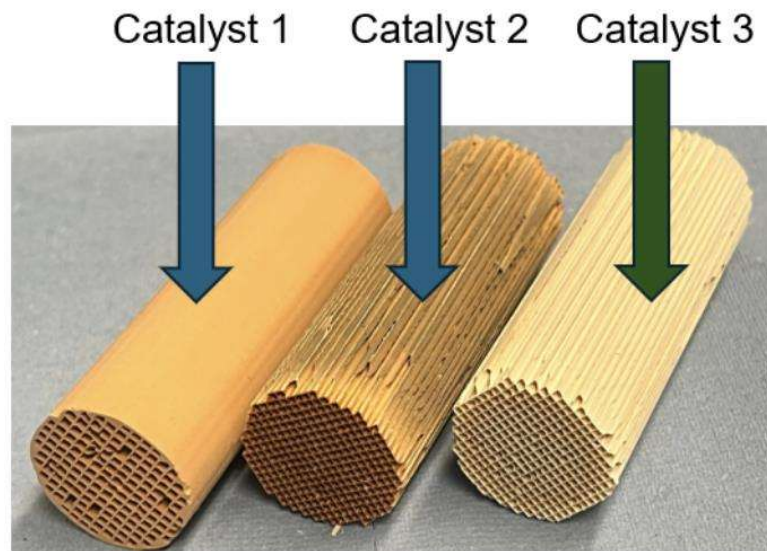
- Selection of engine operating conditions and fuel injection strategies
 - ✓ Pilot fuel injection strategies (multiple injections, pressure, duration)
 - ✓ Intake air temperature
- Effect of **Pure NH₃** and **mixture 10% NH₃ +70%H₂+20%N₂** on engine out emissions. Energy substitution ratio (ESR) of NH₃ mixture (up to 65%)

De-N₂O Catalyst Formulations – Engine

Catalyst 1: FeZ_MariNH₃ (extruded)

Catalyst 2: FeZ_2 REGGAE (coated)

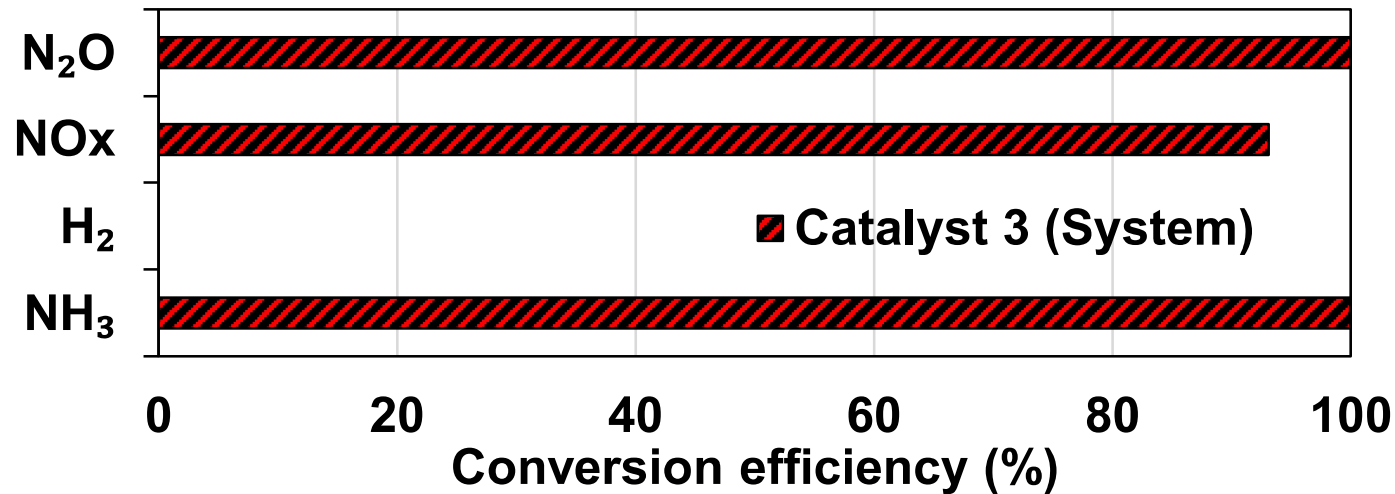
Catalyst 3: FeZ_2 Modified REGGAE (coated)



Aftertreatment Systems

Aftertreatment System active in:

- NH_3 -SCR for the reduction of NO_x emissions
- NH_3 Oxidation for NH_3 Slip
- N_2O reduction



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Fuelling Conditions

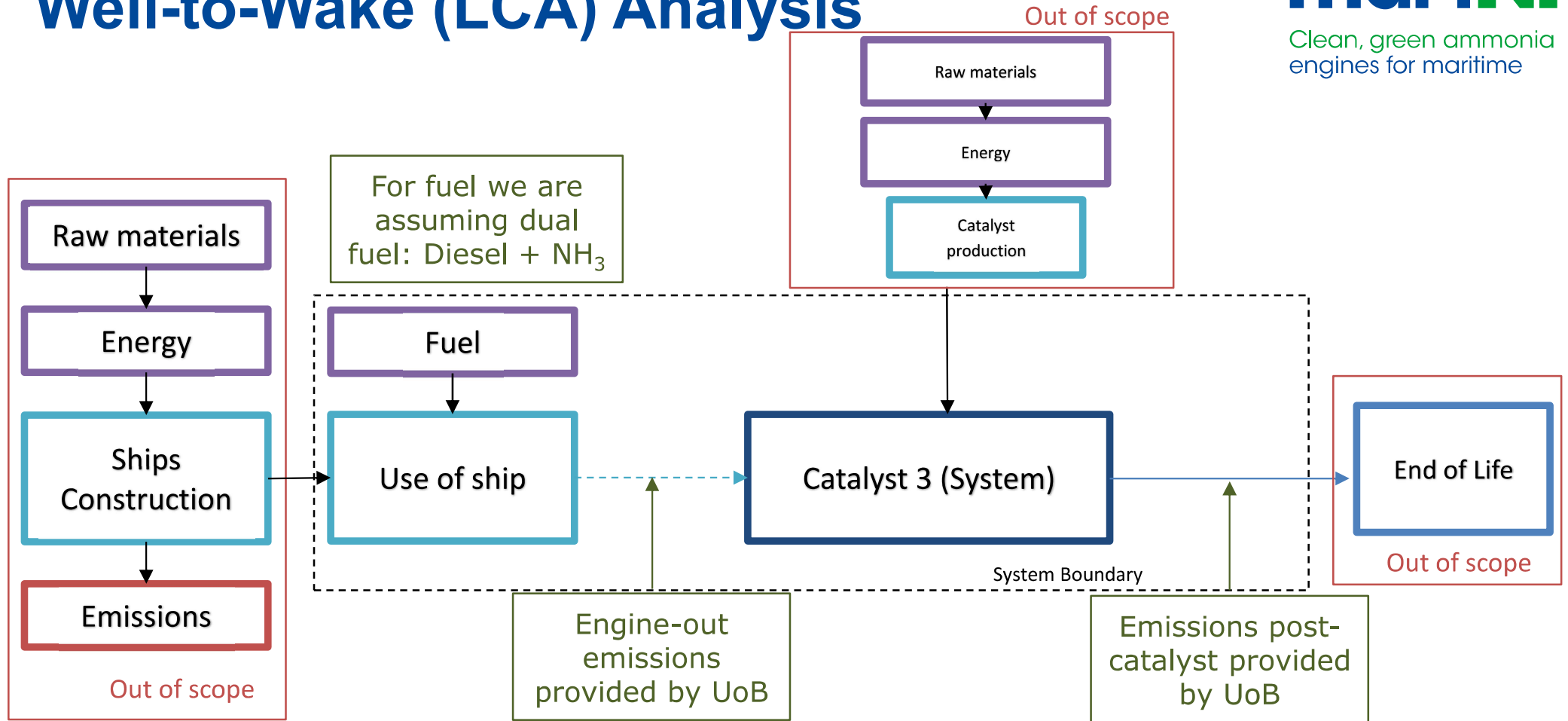
- Dual-fuel (Pure NH_3 + diesel)

Engine Exhaust Species

- N_2O ~ 184 ppm,

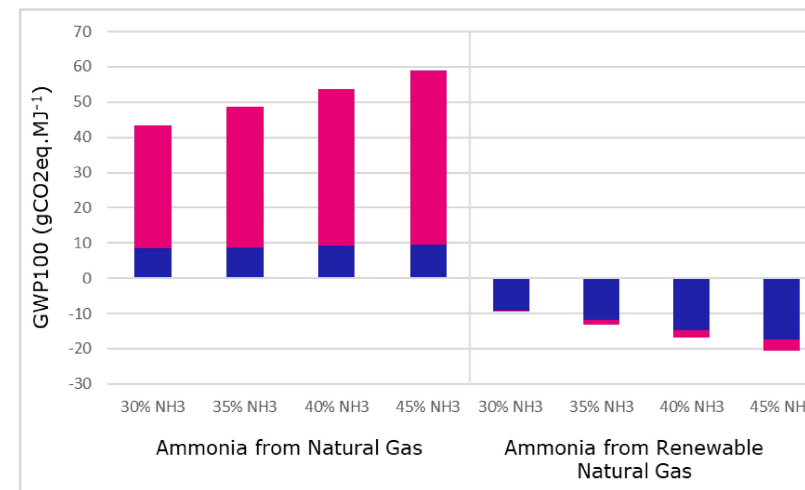
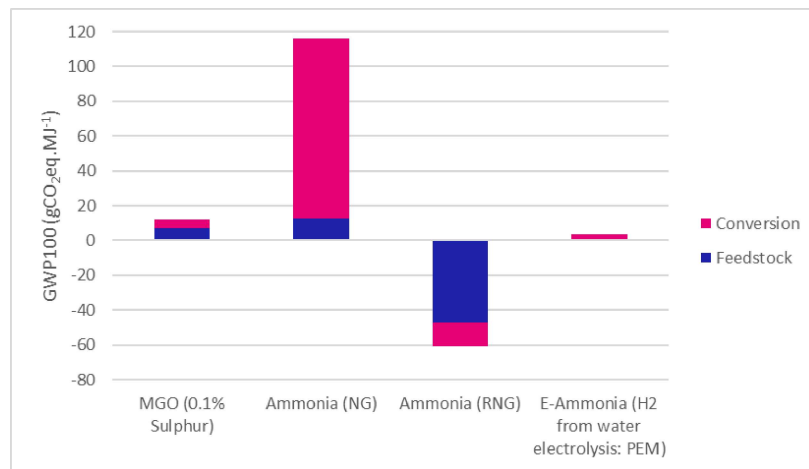
Temp. 400-450°C

Well-to-Wake (LCA) Analysis



Well-to-Wake (LCA) Analysis

Ammonia source comparison

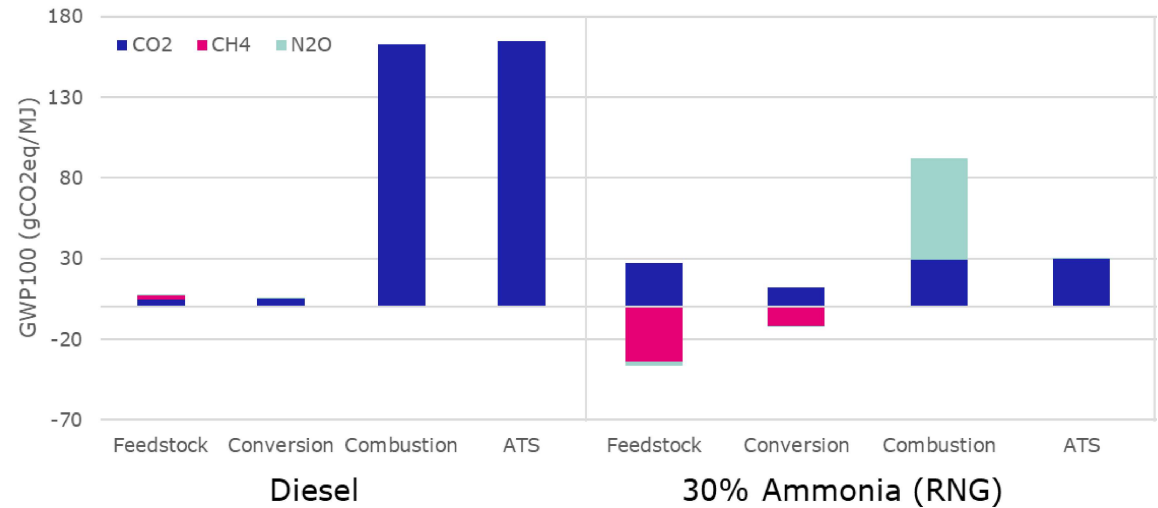
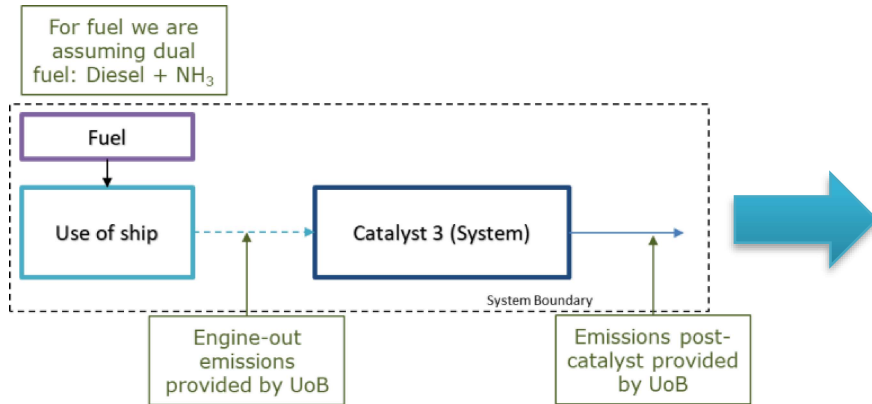


□ Meaningful lifecycle GHG reductions require low-carbon hydrogen sourcing for NH₃.

- Higher NH₃ substitution ratio isn't automatically "lower carbon"
- WTW benefit depends on ammonia's upstream (well-to-tank) GHG intensity.

*GWP100 calculated using R&D GREET Life Cycle Assessment Model

Well-to-Wake (LCA) Analysis



Target: WTW GHG reduction >90%

Project criteria **achieved** throughout the optimal combination of NH₃ feedstock, engine strategy and aftertreatment system (ATS).

% decrease in Total GWP100 using Diesel as baseline	
30% Ammonia (RNG)	45% Ammonia (RNG)
88.1	94.3

Summary

- Develop de-N₂O for N₂O removal below 450 °C.
- Develop and demonstrate an integrated de-N₂O aftertreatment system for simultaneous NH₃, N₂O and NO_x removal.
- Underpinning solutions to inhibit NO_x formation & potential NO_x/NH₃ trade-off from NH₃/H₂ combustion
- WTW GHG reduction >90% **achieved** throughout the optimal combination of NH₃ feedstock, engine strategy and aftertreatment system (ATS).

Acknowledgments



- REGGAE- REducing Greenhouse Gases from Ammonia Engines - 10158976



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Matthey



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