Ammonia As Hydrogen Carrier to Unlock the Full Potential of Green Renewables

Dr Camel Makhloufi – ENGIE Lab CRIGEN
Key Expert – P2X R&D program Leader

16th November 2020 – AICHE 2020 –Live from home

camel.makhloufi@engie.com

ENGIE: Leader in Energy Transition

€189 m
spent on research and development (R&D) in 2019

+ 3 GW
installed renewables capacity in 2019

€10.7 bn
revenues in portfolio for customer solutions in 2019

+4,500 km
natural gas transmission network in 2019

52.7GW
natural gas installed capacity at the close of 2019

no. 1 independent power producer (IPP) in the world

no. 1 Natural gas distribution network in Europe

no. 2 Global provider of technical installation services

€60.1 bn revenues

96.8GW installed capacity of which 26.9 GW renewable (28%)

7.4GW

16.3GW

2.6GW

39,400 km natural gas transmission

171,100 employees

ENGIE: Leader in Energy Transition

Industrial-Scale Projects

Project	Sector
HyNetherlands	Chemical feedstock, industrial feul, and transport
HyGreen Provence	Mobility and industry
Zev	Mobility
Yuri	Green ammonia
HyEx	Ammonia nitrate
Multiplhy	Bio refinery
Rhyno	Mining
H2@Rail	Rail
Liquid H2	Maritime and more

Demonstrator Projects

PpP Pau Porte des Pyrénées Ville de Pau
HYNOVAR
SMT Syndicat Mixte des Transports Artois-Gohelle
MÉTHYCENTRE
HY PORT
GRHYD
EffiH2 by ENGIE
Jupiter 1000

Ammonia, a promising and dispatchable energy storage

CO_2 emission and RE production

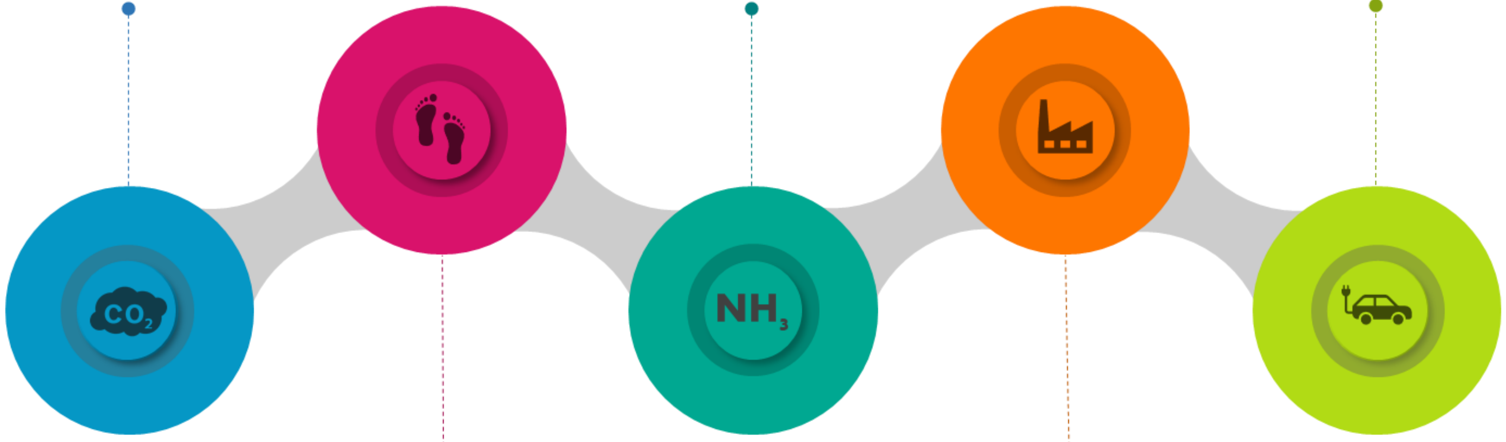
- Power, heat & transport are the main contributors
- Diversification of energy supply through new energy corridors is of utmost importance for Europe

Ammonia as promising solution

- Carbon free e-fuel
- Robust transport & distribution infrastructure
- Existing regulation and safety standards

New technologies for e-NH_3 energy discharge

- Intensified cracker with low CRM impact for decentralized and onboard hydrogen/power generation



E-fuels can unlock hard-to-abate sectors

- EU policies promoting biofuels and e-fuels are implemented
- E-fuels have the least land and water footprints and can be produced at scale

New Technologies for e-NH_3 synthesis

- Flexible NH_3 synthesis loop to cope with intermittent electricity sourcing

Cracking technologies are needed to unleash the full potential of ammonia

Hydrogen refuelling station

- Hydrogen delivered from cracker should have a purity compatible with ISO-14687 with NH_3 max content of 0,1 ppm
- **Cracking system delivering a very pure hydrogen is required at low temperature**
- Fossil fuel Ammonia (and blue ammonia?) comes with various impurities that may be hurt the PEM fuel cell

Fuel cell for decentralized power generation

- Possibly using PEM, SOEC and Alkaline fuel cell with various resistance toward NH3
- **SOFC can possibly profit from high temperature cracking and offer higher efficiency.**
- Impurities in initial fuel should be a concern

On-board generation for Internal combustion engine

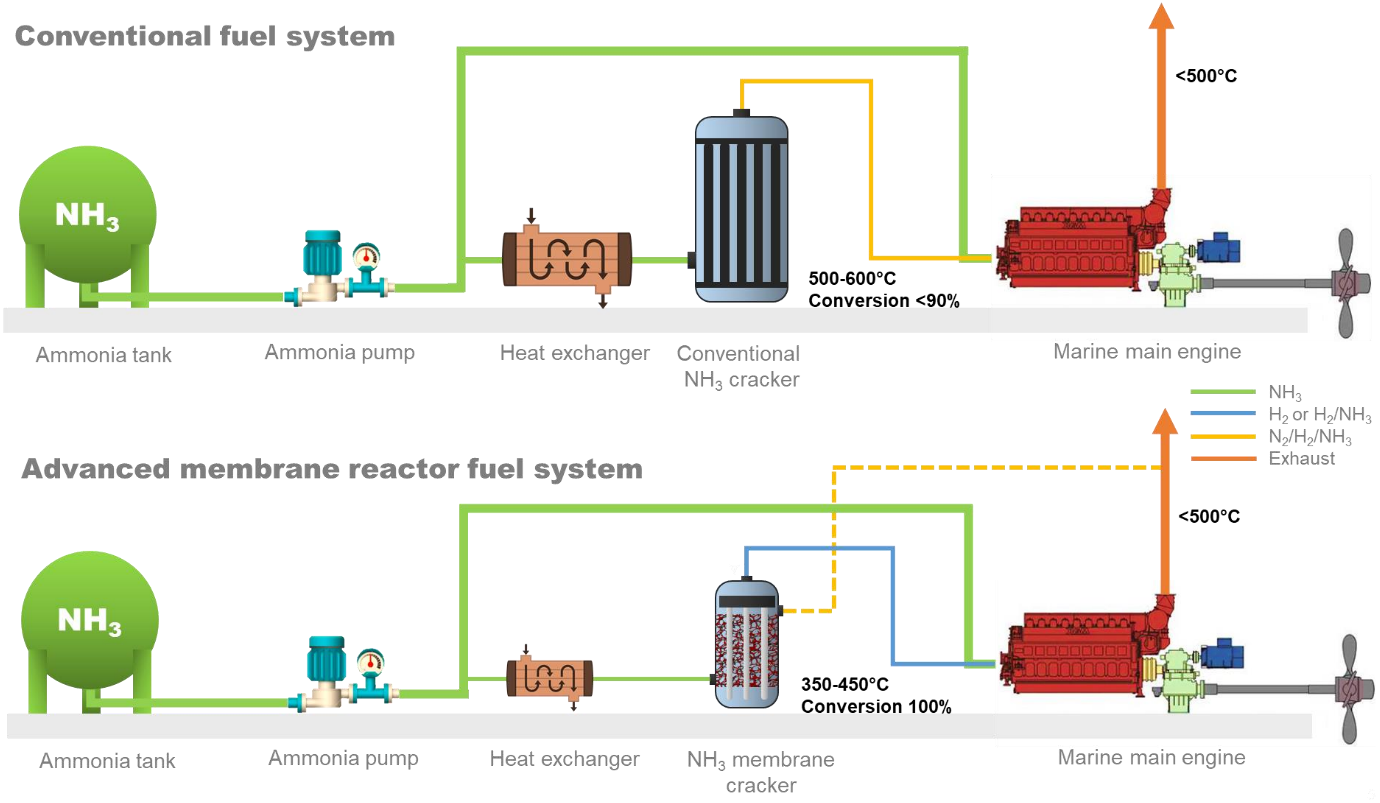
- On-board hydrogen generation may avoid the use of fossil fuel based blend.
- Impact of nitrogen on combustion performance of $NH_3/H_2/N_2$ mixture
- Cracker need to comply with variation of load. Autothermal reformer proposed in some studies

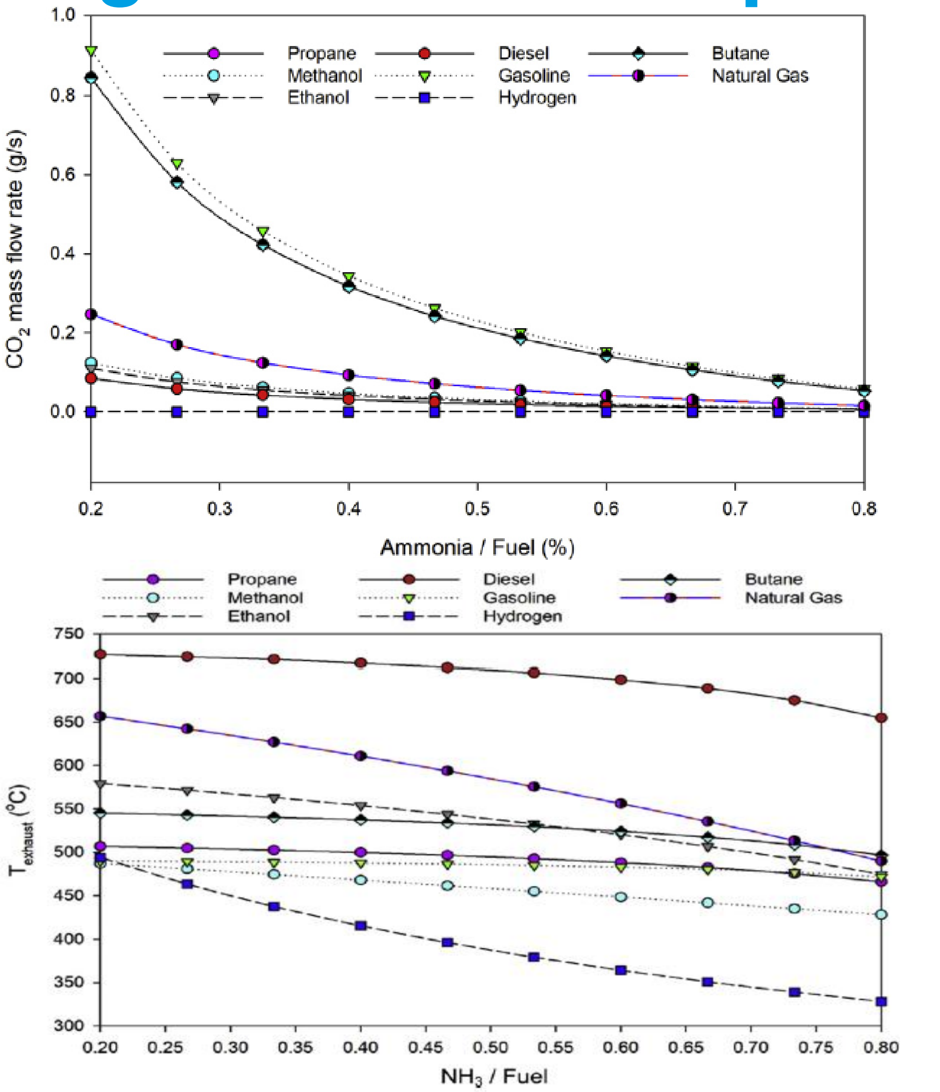
Contaminant	Content	ISO-14687
Carbon Dioxide (CO_2)[1]	≤10 ppm	2 ppm
Chloride (Cl)[1]	≤0.3 ppm	0,05 ppm
Total Sulfur (as SO_4)[1]	≤0.8 ppm	0,004 ppm
Silicon (SiO_2)[2]	≤10 ppm	
Heavy metals	ppb to ppm level	

[1] Microelectronic grade
[2] Technical grade liquor ammonia

An additional upside of green ammonia: a cleaner fuel for further energy discharge in fuel cells.

On-board ammonia cracking for large ammonia ship

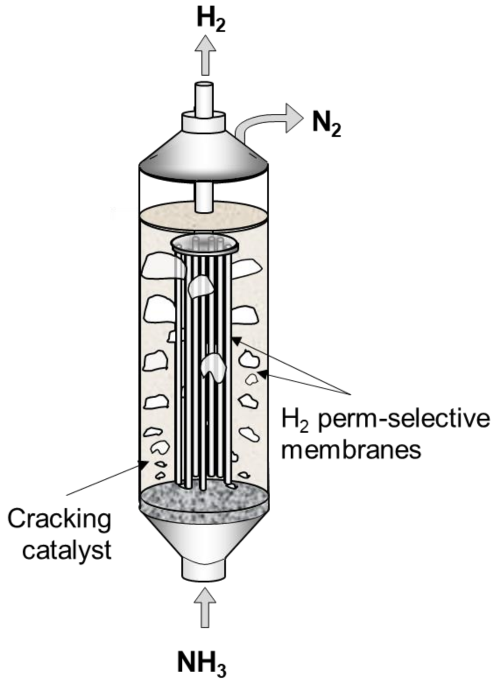


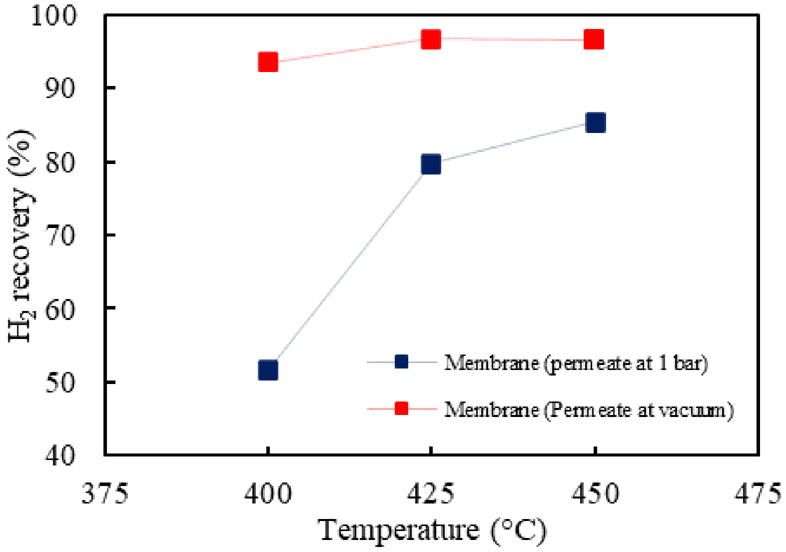


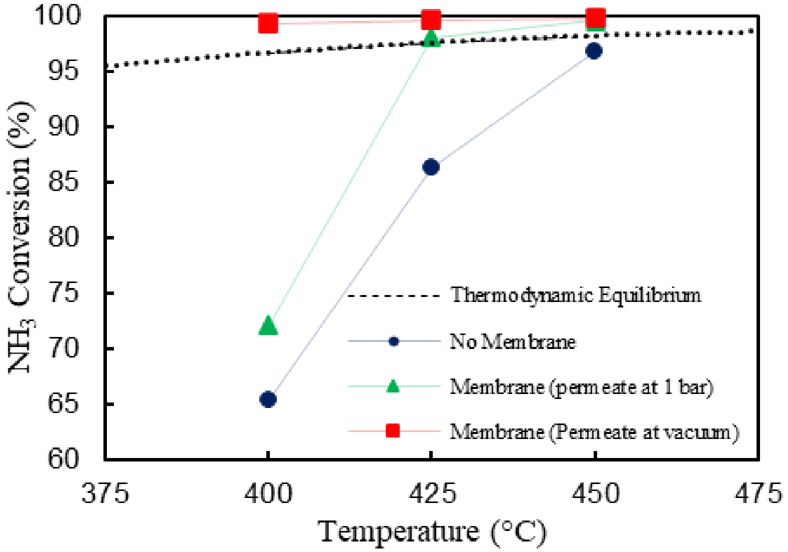
Performance assesment of hydrogen and ammonia combustion with various fuels for power generators; Arda Yapicioglu, Ibrahim Dincer; 2018*

Decentralized Ammonia Reformer : Membrane reactors

Membrane reactor for NH_3 cracking



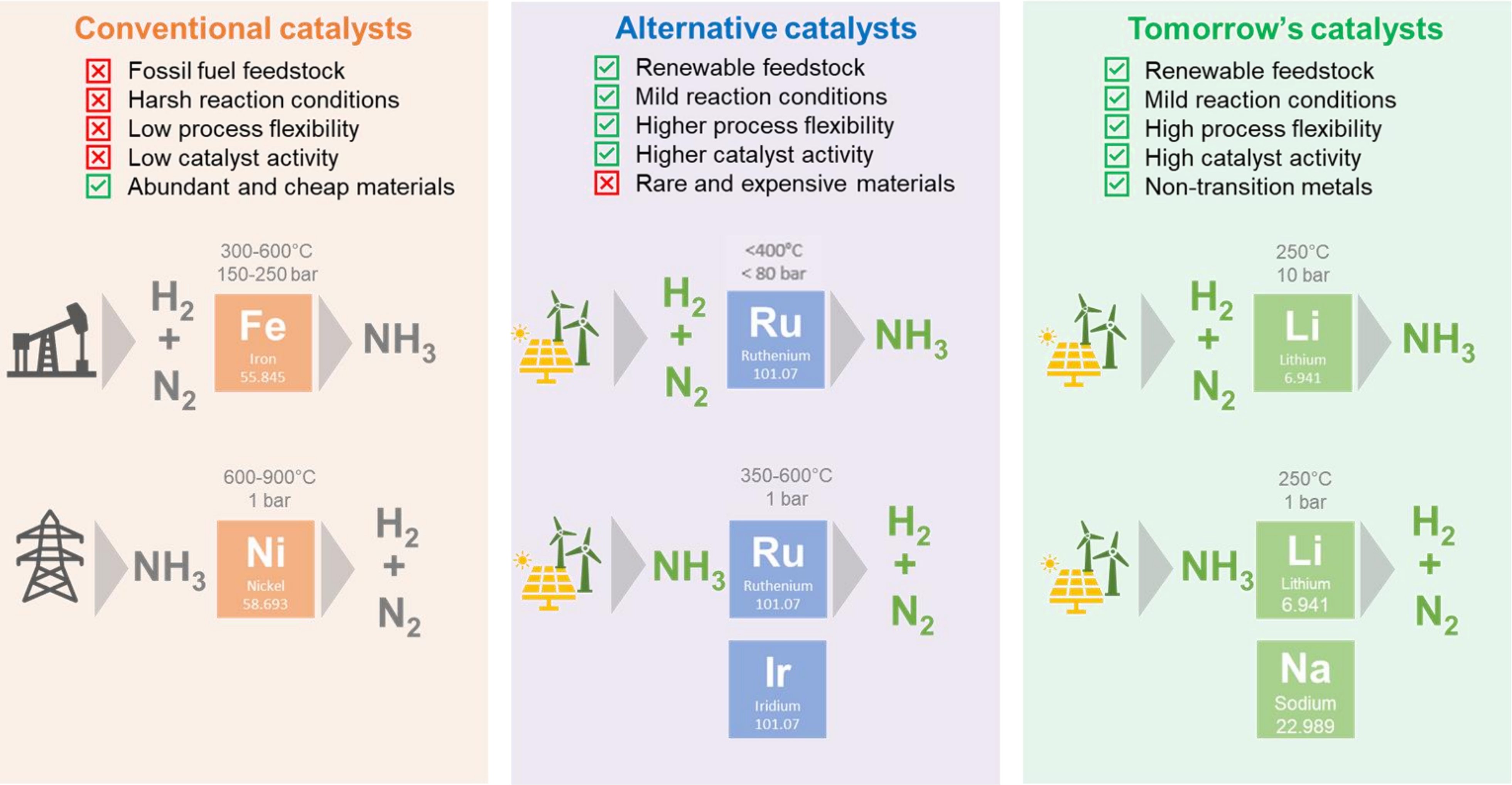




- In a conventional reactor, the NH_3 conversion stays far from the equilibrium at low temperatures.
- In a membrane reactor, the conversion is clearly increased and it can reach equilibrium conditions.
- When vacuum is used in the permeate, virtual full conversion of NH_3 is obtained, even at 400 °C, and in all the cases beyond equilibrium.

H_2 PRODUCTION VIA AMMONIA DECOMPOSITION IN A CATALYTIC MEMBRANE REACTOR; V. Cechetto, L. Di Felice[1], J.Medrano[1,2], C. Makhloufi[1,3], J. Zuniga [1,4], F.Gallucci[1]

Does decentralization imply a high consumption of valuable critical raw materials?




engie