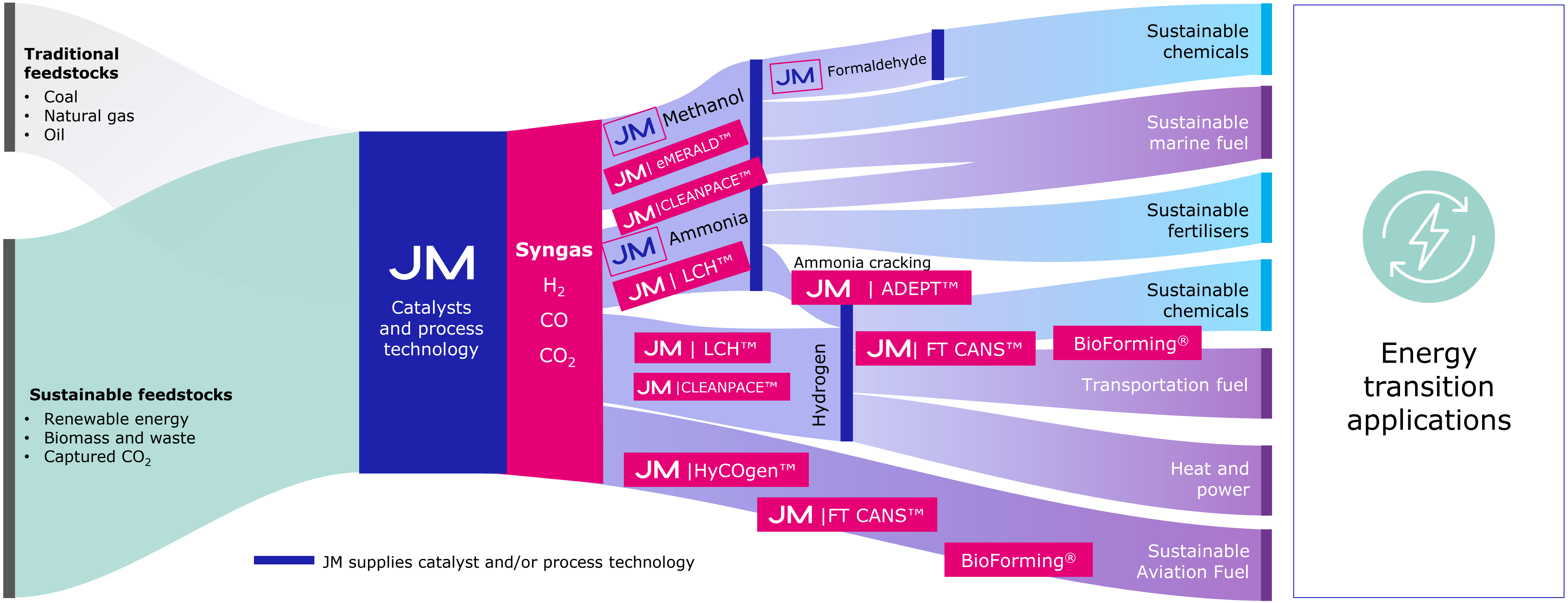
Johnson Matthey

JM Davy Technologies Limited - Sustainable solutions in the ammonia sector

Workshop on Green ammonia energy - intensified production, conversion and separation

Marie Genelot - 01/04/2026

JM is uniquely positioned across the value chain to **decarbonise through syngas**



Note: H_2 – hydrogen; CO – carbon monoxide; CO_2 – carbon dioxide
LCS – Low carbon solutions; FT CANS™ – Fischer-Tropsch CANS
HyCOgen™ – Reverse water gas shift technology
FT CANS™ in collaboration with bp. BioForming® in collaboration with Virent

Ammonia synthesis - challenges

Demand for ammonia expected to grow but currently ammonia production represents:

- 2% global energy production
- 3% global CO_2 emissions

Decarbonisation needed:

- Blue ammonia (carbon capture)
- Green ammonia

Partnership with Thyssenkrupp Uhde

- Thyssenkrupp Uhde provides process (blue ammonia)
- JM provides catalyst

Main challenge for green decentralised ammonia: pressure

- High cost for H_2 compression (CAPEX, OPEX, safety)
- Impact on ammonia separation

Ammonia synthesis - catalysts

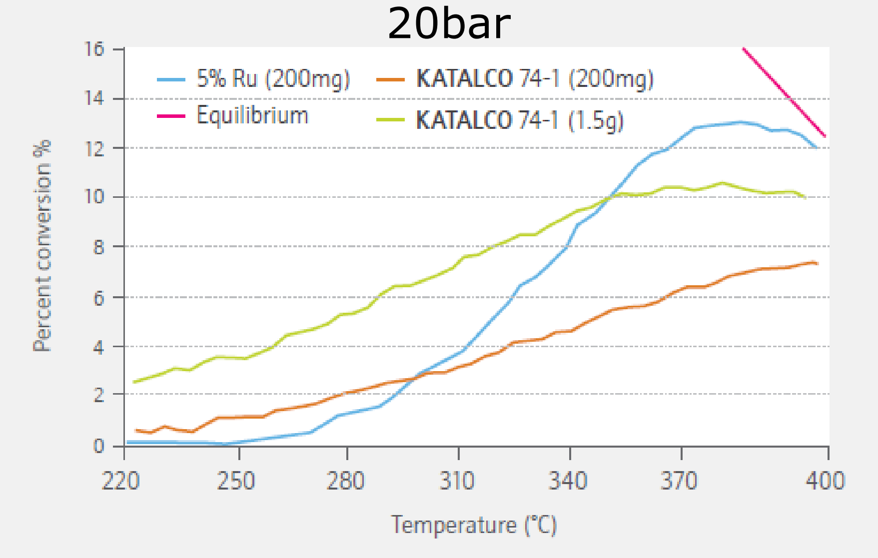
Catalyst for low pressure duty:

- **KATALCO**™ 74-1 is Fe catalyst with Co promoter
- Low activity of the Ru catalyst at T <300°C (in line with literature for other Ru-based catalysts)
- 5% Ru is high loading: Ru about 500 000 times more expensive than Fe ore*
- On a volume basis (1.5g Fe versus 200mg Ru-based): Fe performs much better

Ru also suffers "hydrogen poisoning"

- Strong hydrogen sorption on Ru leading to catalyst inhibition
- Ru catalyst operated under non-stoichiometric conditions
- Impact on downstream ammonia separation

⇨ No benefit from Ru catalyst over Fe



1. Smith, C., & Torrente-Murciano, L. "Low temperature and pressure single-vessel integrated ammonia synthesis and separation using commercial KATALCO catalysts". *Johnson Matthey Technol. Rev.*, 2022, **66**, (4), 435–442

* Based on Ru (https://matthey.com/products-and-markets/pgms-and-circularity/pgm-management) and Fe prices (https://tradingeconomics.com/commodities)

Ammonia synthesis - external funded projects

AMBHER: Ammonia synthesis in membrane reactor with structured catalysts

- Low temperature and pressure ammonia synthesis
- Low temperature due to presence of membrane for ammonia separation

What JM wants to learn:

- Benefit of membrane on ammonia production and separation?
- Benefit of Periodic Open Cell Structures as catalyst support?
- TEA?

Ammonia synthesis - external funded projects

HYSTRAM: Sorption enhanced ammonia synthesis

- Low temperature and pressure ammonia synthesis
- Low temperature due to sorbent for ammonia separation

What JM wants to learn:

- Benefit of sorbent on ammonia production and separation?
- TEA?

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Ammonia synthesis - external funded projects

ASPIRE: Flexible reactor design with high turn-down capability

- High temperature and pressure ammonia synthesis
- Off-grid operation for decentralised green ammonia production

ASPIRE
AMMONIA SYNTHESIS PLANT USING INTERMITTENT RENEWABLE ENERGY

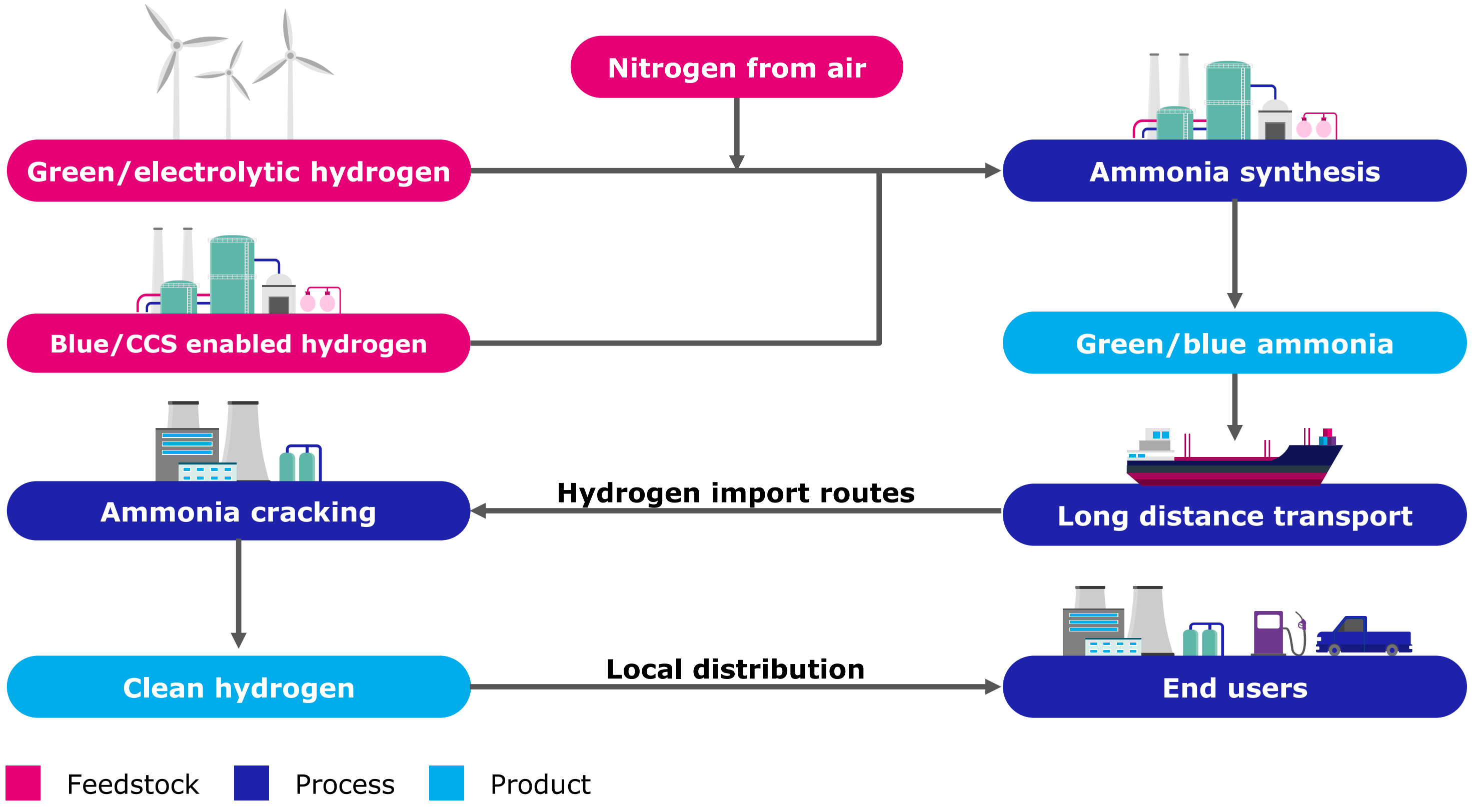
What JM wants to learn:

- Effect of intermittency on catalyst activity and ageing?
- TEA?

JM

NH_3 cracking is central to open up the broader value chain for H_2

Ammonia cracking value chain unlocks a global trade of clean hydrogen



Global clean hydrogen trade creates a **new import market**

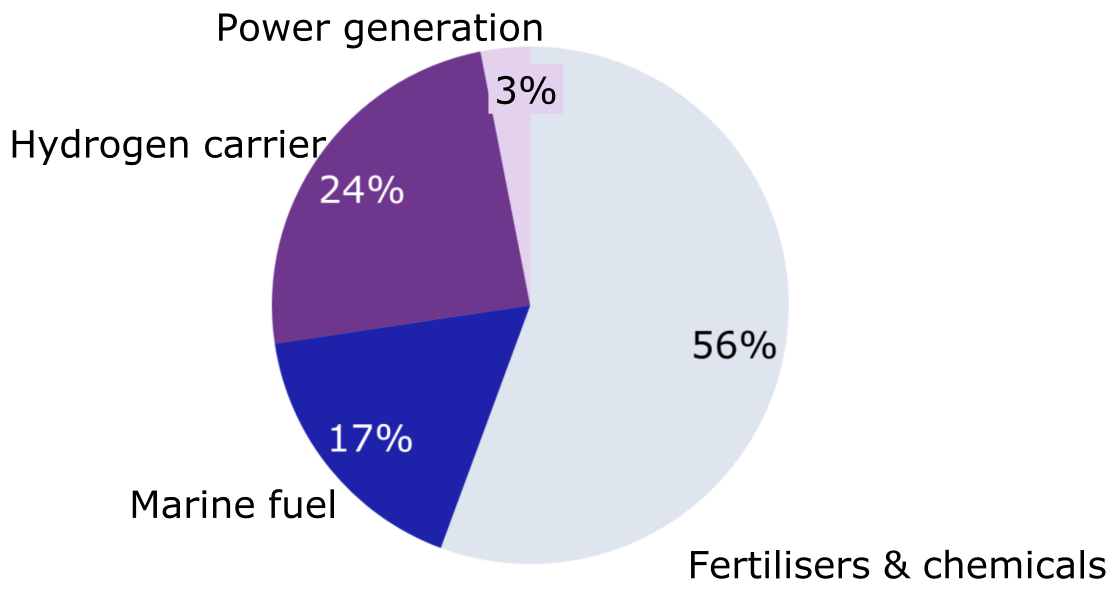
Ammonia cracking is key to **enabling clean hydrogen imports**

JM plays a leading role as a **catalyst and technology provider**

Hydrogen transport

Approximately a quarter of ammonia produced in 2050 will be used as a vector for storing and transporting clean hydrogen

Total ammonia demand by sector in 2050
IRENA projections

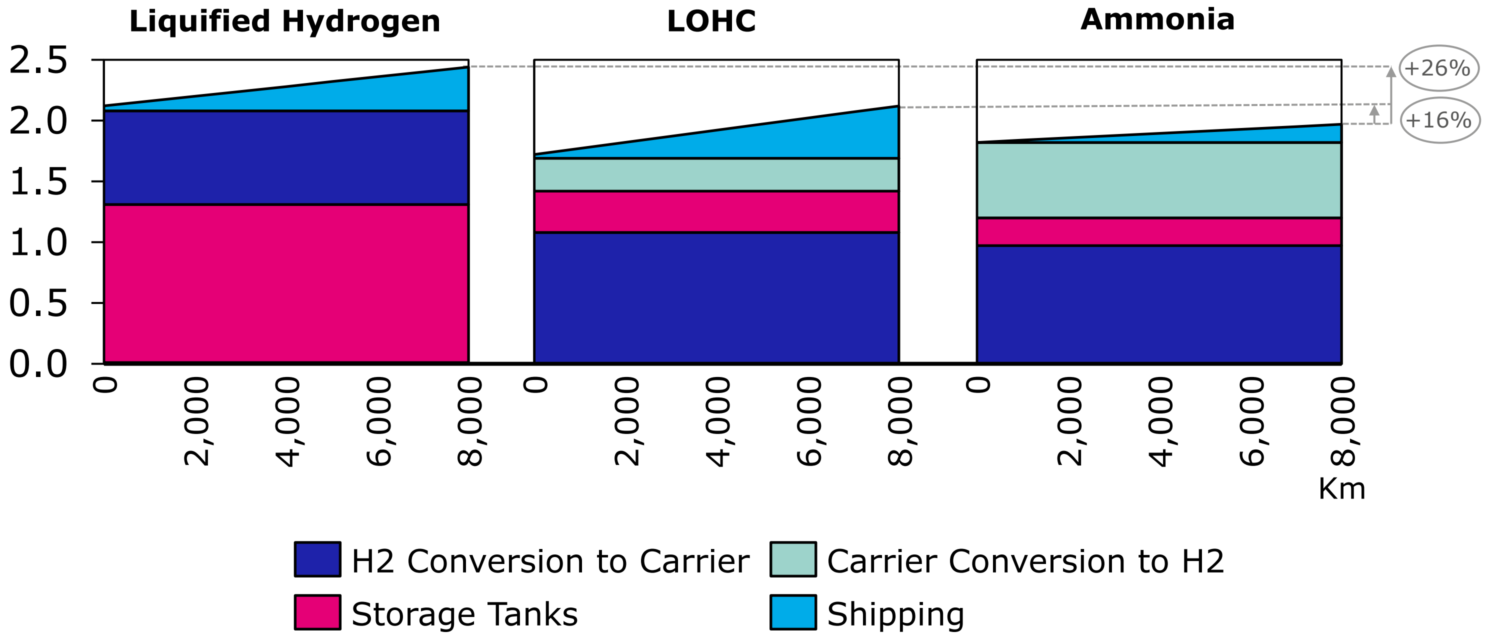


Power generation	Ammonia as direct co-fuel with fossil fuels and possibly displacing them in power plants to decarbonise electricity
H_2 carrier	Around a quarter of ammonia produced in 2050 will be used as a chemical vector for storing and transporting clean H_2
Marine fuel	Ammonia as sustainable fuel for maritime transport
Fertilisers & chemicals *(traditional uses)*	80% of current ammonia production is dedicated to fertilisers and 20% to chemicals, with modest growth to 2050 expected

Hydrogen transport

Ammonia is the most mature and cost-effective vector for H_2 transport over long distances

H_2 transport cost by vector
$\$/kg_{H2}$ contribution to LCOH



There are different routes to transport hydrogen like; LOHC, LH_2 and NH_3 cracking.

NH_3 is a **globally traded** commodity, **~20Mt** traded today, and benefits from **existing infrastructure**, scale and know-how.

NH_3 has additional benefits:

- NH_3 is the most **cost-effective** hydrogen vector, about **26% cheaper than liquified hydrogen.**
- 1 m^3 of **NH_3 carries 70% more H_2** than the same volume of liquid H_2
- NH_3 can be transport at **-33°C,** nearly **8 times warmer** than the temperature necessary for H_2.
- Loss of NH_3 through **boil-off** is essentially **zero**, unlike liquid H_2.

H_2 – hydrogen; LOHC – liquid organic hydrogen carrier; NH_3 – ammonia; LCOH – levelized cost of hydrogen
IEA, "Energy Technology Perspectives", 2023

JM Ammonia cracking

JM has nearly 100 years of ammonia cracking heritage

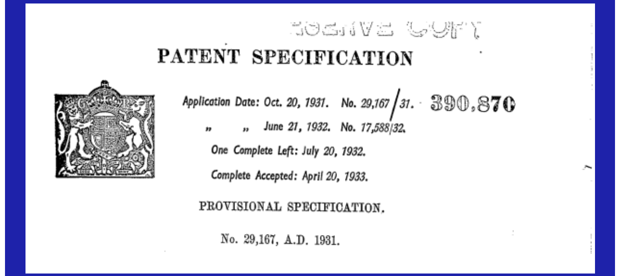
Early patent position

Early patent applications

1931
Nitrogen generator, hydrogen superfluous to requirements

1954
For metallurgical purposes, nickel on alpha alumina, improvement over iron based catalysts

1962
Nickel on gamma alumina



PATENT SPECIFICATION

Application Date: Oct. 20, 1931. No. 29,167/31. 390,870

„ „ June 21, 1932. No. 17,588/32.

One Complete Left: July 20, 1932.

Complete Accepted: April 20, 1933.

PROVISIONAL SPECIFICATION.

No. 29,167, A.D. 1931.

Historical experience

JM's predecessor company helped develop small ammonia crackers, some of which are still on the market today

Operational experience of fired-heater style crackers used to generate N_2 and/or H_2 for start-up and shutdown

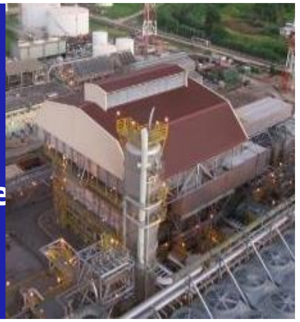
Ammonia cracker from ICI Agricultural Division/Hogg

Recent developments

JM's High activity PGM catalysts (used in CSIRO's ammonia to hydrogen fuelling system)

Developed large scale ammonia cracking flowsheets with suitable catalyst offering

World scale ammonia cracke based on world scale SMRs



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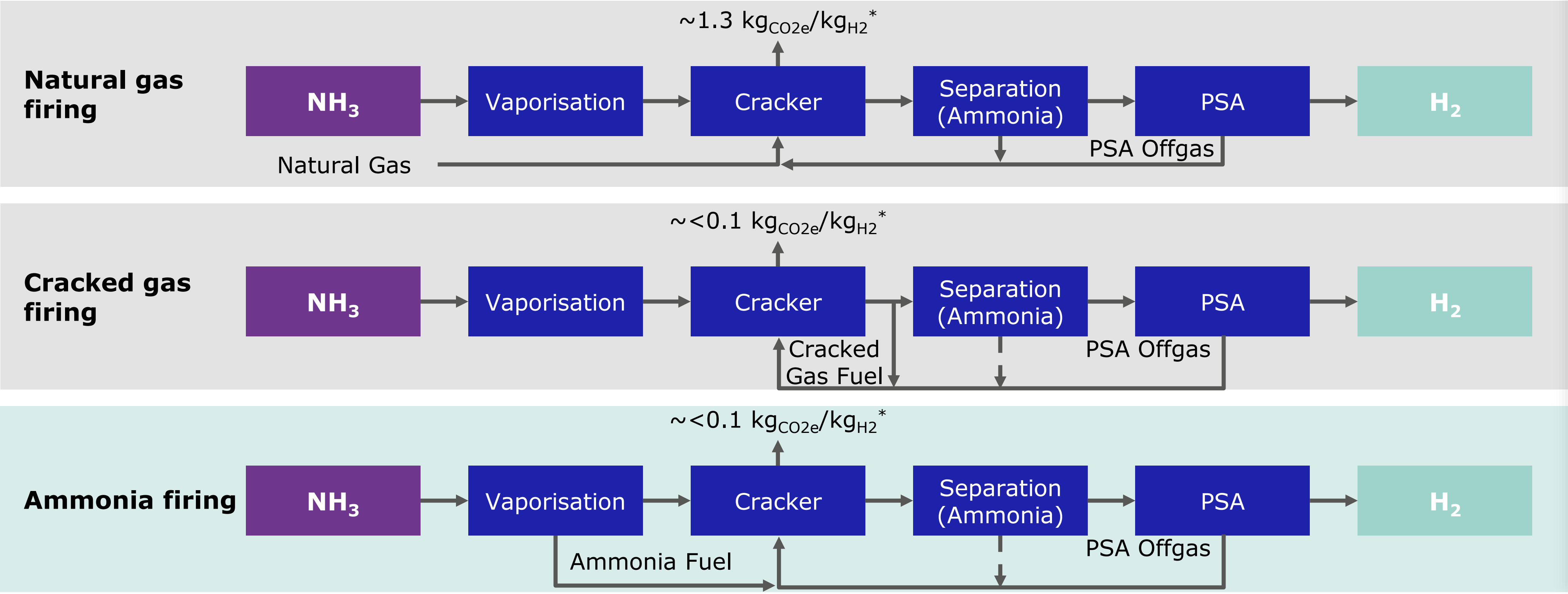
JM ADEPT technology

ADEPT™ ammonia cracking can operate in 3 different modes for the cracker firing



Trade Offs

Natural gas firing:
- ✓ NH_3 consumption
- ✗ Carbon intensity
- ✓ Plot space

Cracked gas firing:
- ✗ NH_3 consumption
- ✓ Carbon intensity
- ✗ Plot space

Ammonia firing:
- ✓ NH_3 consumption
- ✓ Carbon intensity
- ✓ Plot space

We believe ammonia firing achieves the greatest balance between decarbonisation and process economics

* Process (Scope 1) emissions only

JM ADEPT technology

Johnson Matthey's award-winning ADEPT technology delivers:

Competitive ammonia consumption guarantees built on:

- **Established ammonia cracking catalyst** based on >50 years of supply
- **Decades of experience in designing** steam-methane reforming technologies for syngas production

- Capability to seamlessly switch between natural gas and ammonia trim fuels, giving futureproofed plants
  - **Process carbon intensity <0.1 kg_{CO2e}/kg_{H2}** (ammonia/cracked gas firing)
  - **Expertise in NOx, NH_3 and N_2O abatement,** minimising environmental impact of the technology
- ADEPT can be integrated with gas turbine technology, with solutions for rapid ramping, hot standby and low turndown

JM-Doosan collaboration agreement signing ceremony

IChemE Awards 2024

ADEPT wins at ICIS Innovation Awards in "best Process Innovation by a large company"

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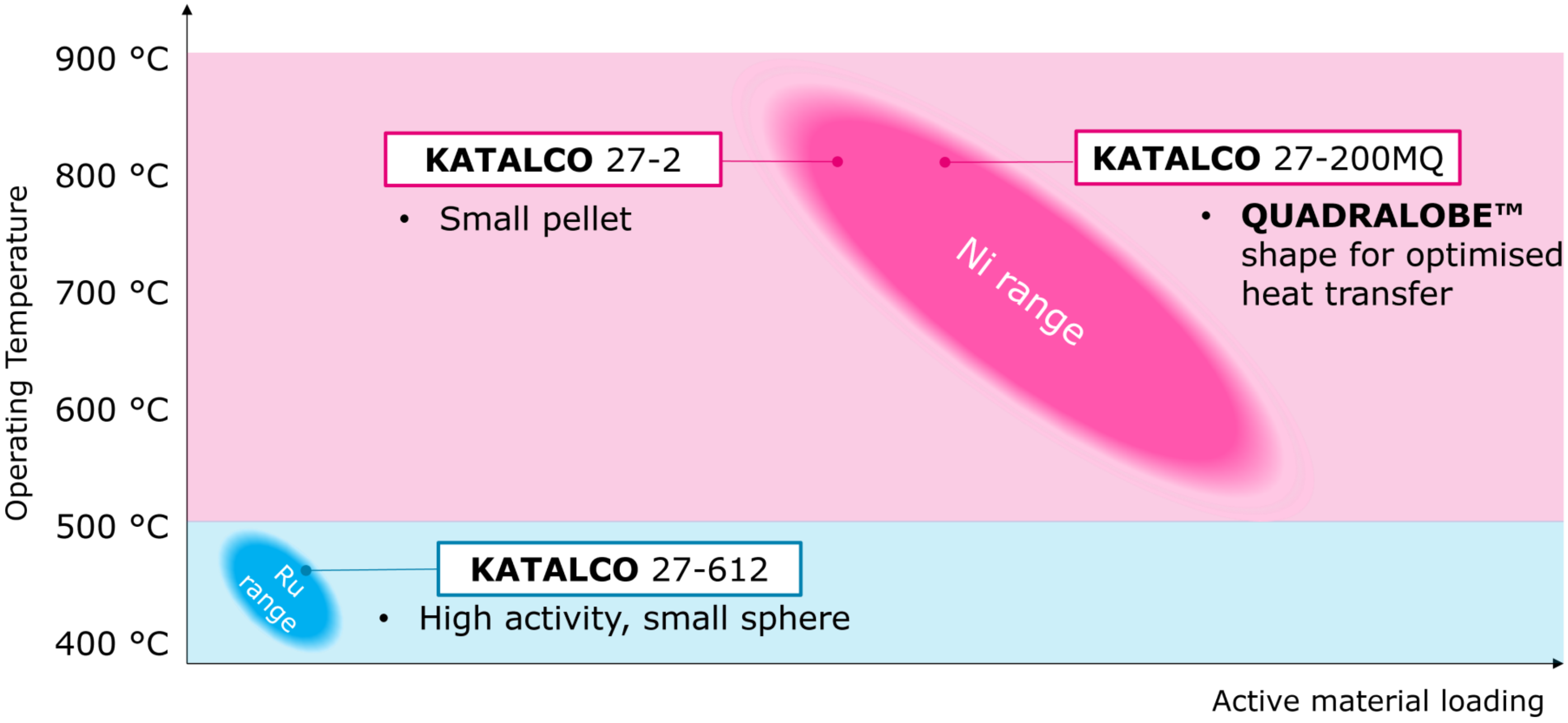
JM KATALCO commercial catalysts for ammonia cracking

KATALCO 27-Series of catalysts and their target operating range



Ammonia cracking - external funded projects

APOLO: Ammonia cracking in membrane reactor

- Low temperature ammonia cracking

What JM wants to learn:

- Benefit of membrane on ammonia conversion?
- TEA?

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