Purification and Upgrading of Raw Synthesis Gas

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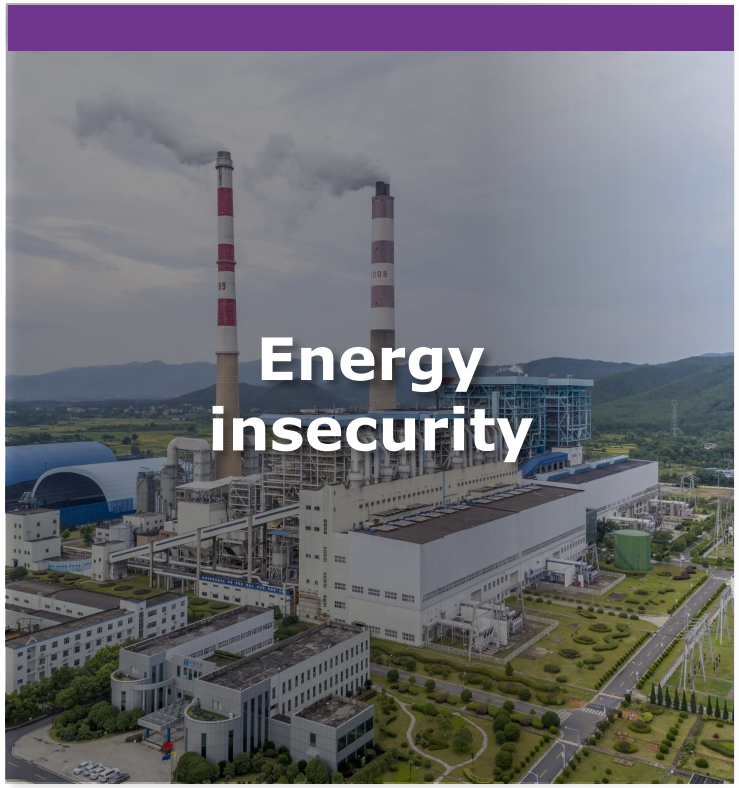
Our vision is for a world that's cleaner and healthier; today and for future generations.

The world is facing some of its biggest challenges yet



We need to transition to net zero.

JM

Aspiring to lead across our four core businesses

Catalysing the net zero transition

Clean Air

Leading in autocatalyst markets

Catalyst Technologies

#1 in syngas-based chemicals and fuels technology

Hydrogen Technologies

Market leader in components for fuel cells and electrolysers

PGM Services
(Platinum Group Metals Services)

#1 recycler of PGMs[1]

1. Iridium, palladium, platinum, rhodium and ruthenium.

JM’s leading process technologies and catalysts enable customers to operate efficiently, profitably and sustainably

Process technologies

Licensing and engineering services to enable more efficient chemical processes

- Design and flowsheets of world-class plants and retrofits
- Optimised footprints enable minimum capex
- Technical services

The combination maximises value to customers and supports long-term relationships

High performance catalysts

Catalysts that enable chemical processes

- Increase plant efficiency and production, using less feedstock
- Small cost for customers, significantly lowering their OPEX

Key Takeaways

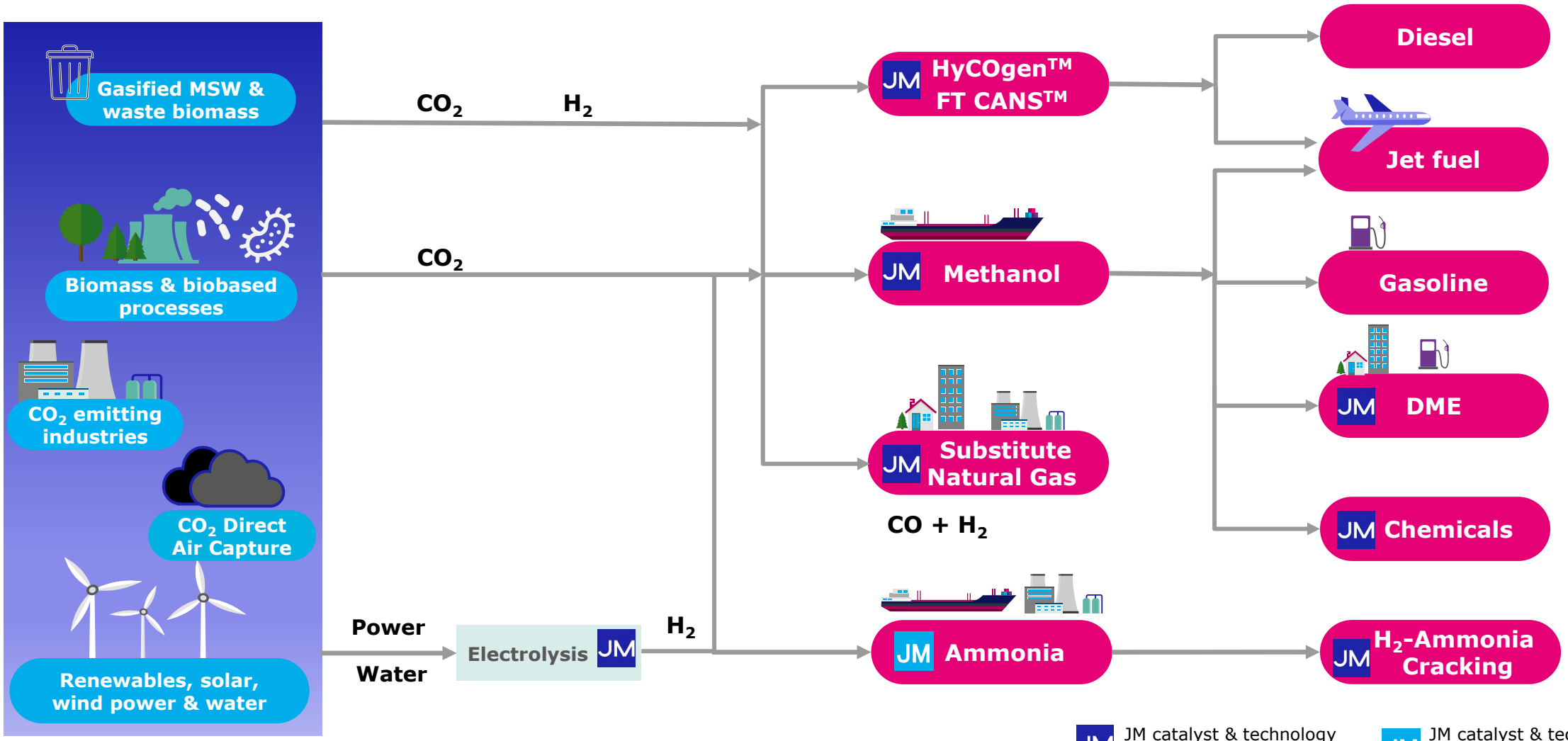
Understand the crucial need for feed purification and its complexity

Be able to identify JM’s world class upgrading technologies for synthesis gas

Be motivated to with Johnson Matthey to leverage to bring value to your process!

JM

JM Catalyst Technologies for the Upgrading of Raw Synthesis Gas



JM catalyst & technology areas

JM catalyst & technology partner areas

Feed Purification – Ensures a Safe and Resilient Technology

Catalyst Performance

- Retains catalyst activity
- Removal of poisons
- Maintains catalytic design

Plant Reliability

- Safety consideration
- Material of construction compatibility

Product Purity

- Removal of contaminants that can accumulate with recycle and scale-up

- Feed purification is crucial for any process
- Purification is not trivial and unique to each process
- Ensuring feed is on spec. helps ensure a drop-in technology

- One of JM's services includes the appropriate purification, customized to an application

JM

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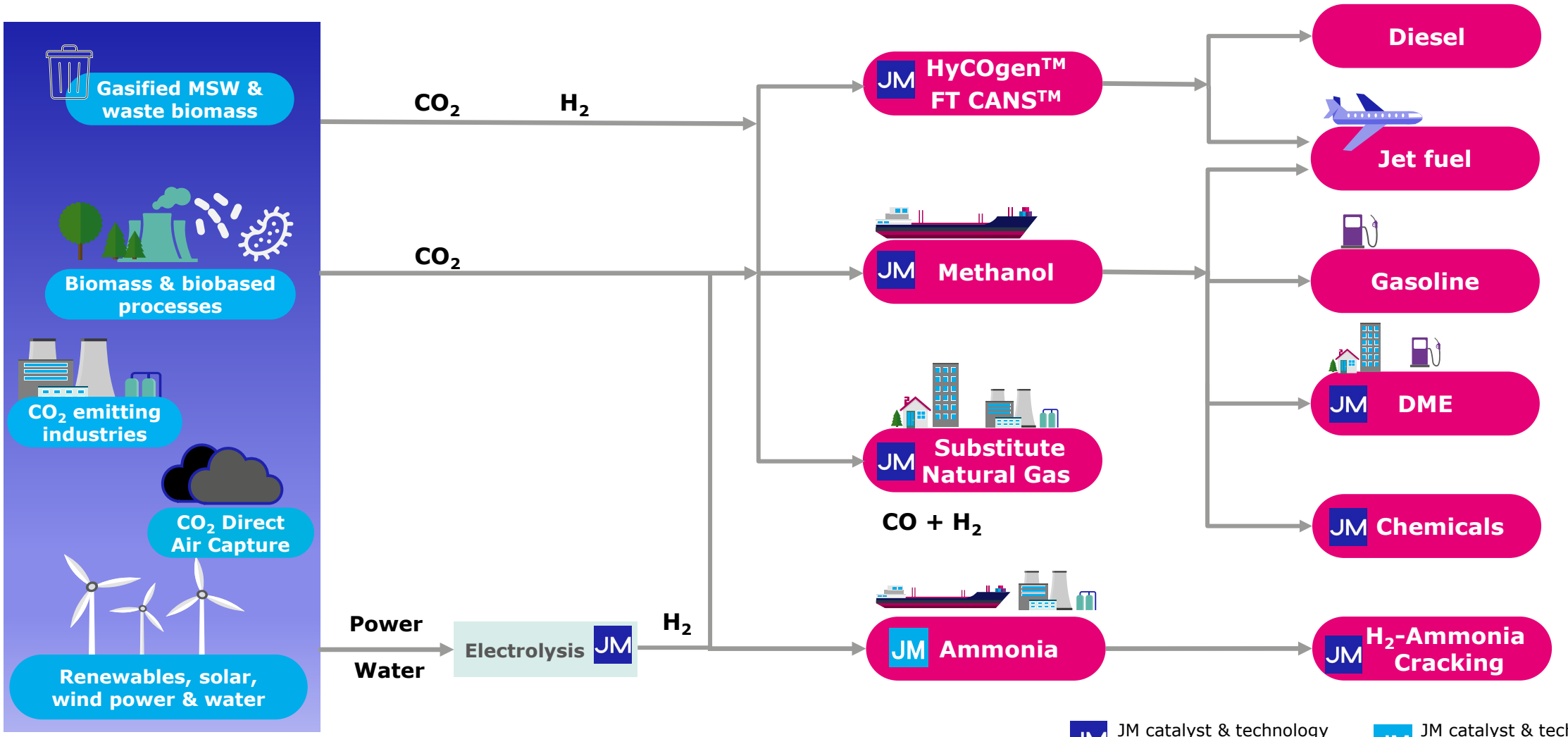

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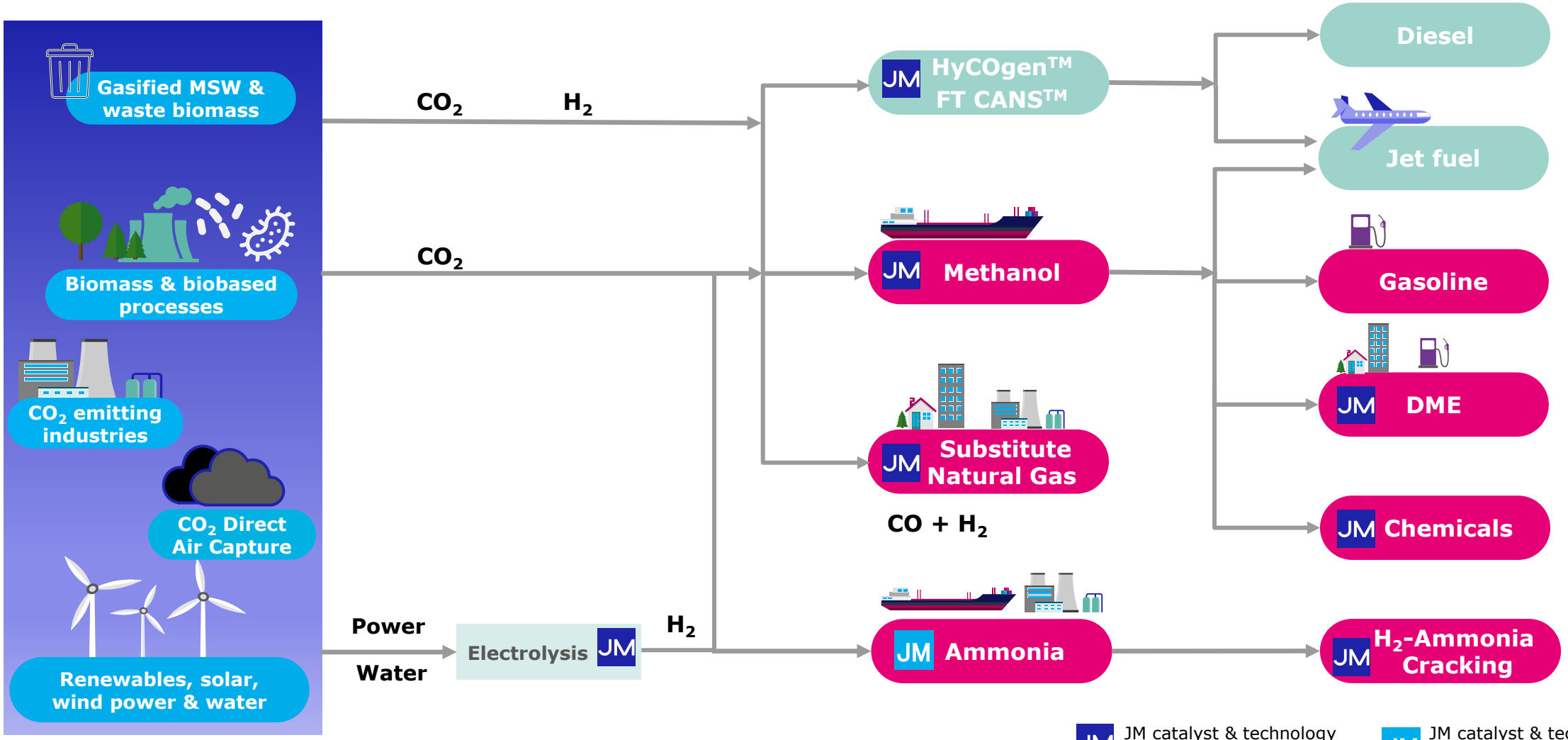

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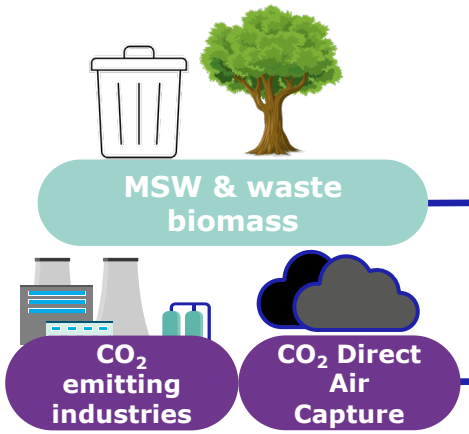
Multiple Routes to Sustainable Fuels via FT Synthesis



MSW & waste biomass

CO_2 emitting industries

CO_2 Direct Air Capture

syngas generation (gasification)

Syngas clean-up and conditioning

syngas generation (HyCOgen)

conditioned syngas

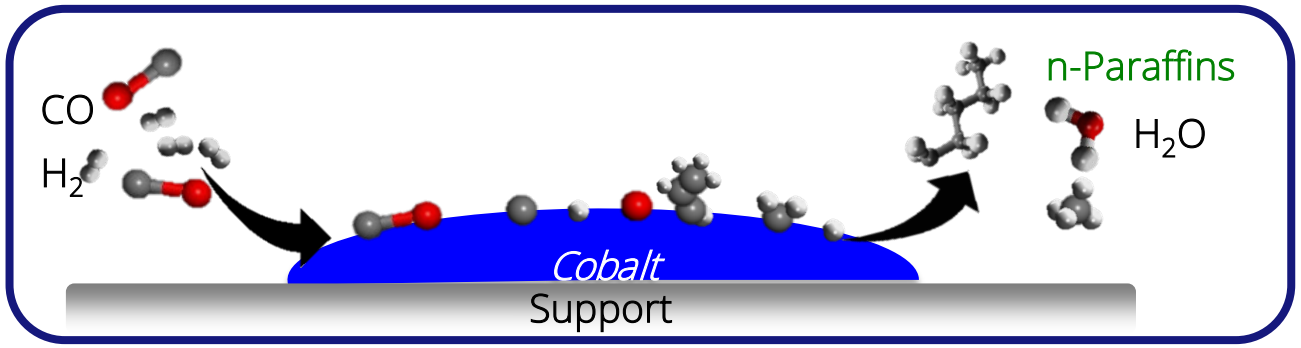
$CO + 2H_2 \rightarrow -CH_2- + H_2O$

Fischer-Tropsch synthesis (FT CANS)

crude FT products

product upgrading (hydro-processing/ fractionation)

naphtha
diesel
kerosene



offsites and utilities (potentially including oxygen and hydrogen supply)

Key

JM technology (licence, catalyst and proprietary equipment)

bp/JM technology (licence and filled FT CANS)

Third party technology

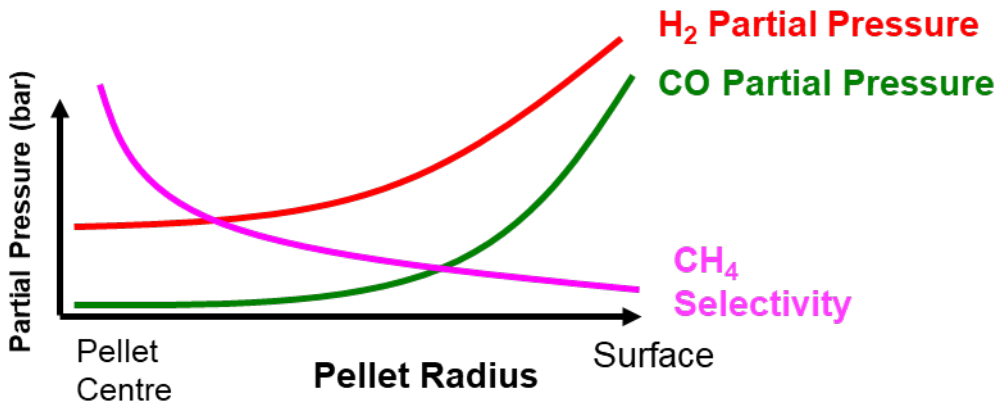
JM

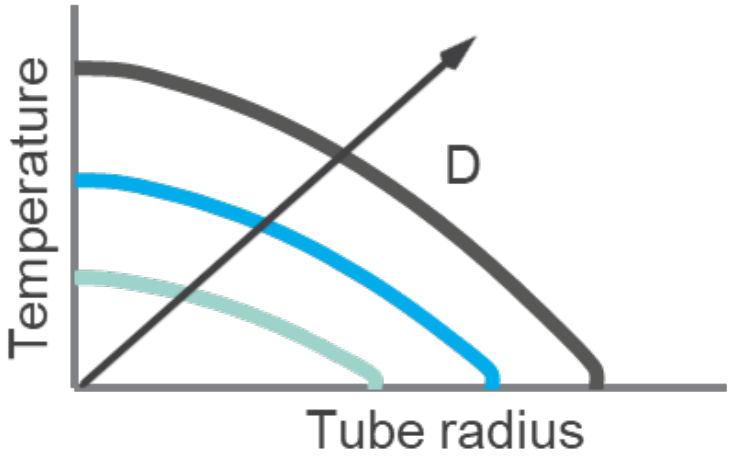
The Challenge for FT Chemistry

Distribution of Products	Heat Transfer	Mass Transfer

JM Solution

Catalyst Design	Process Engineering

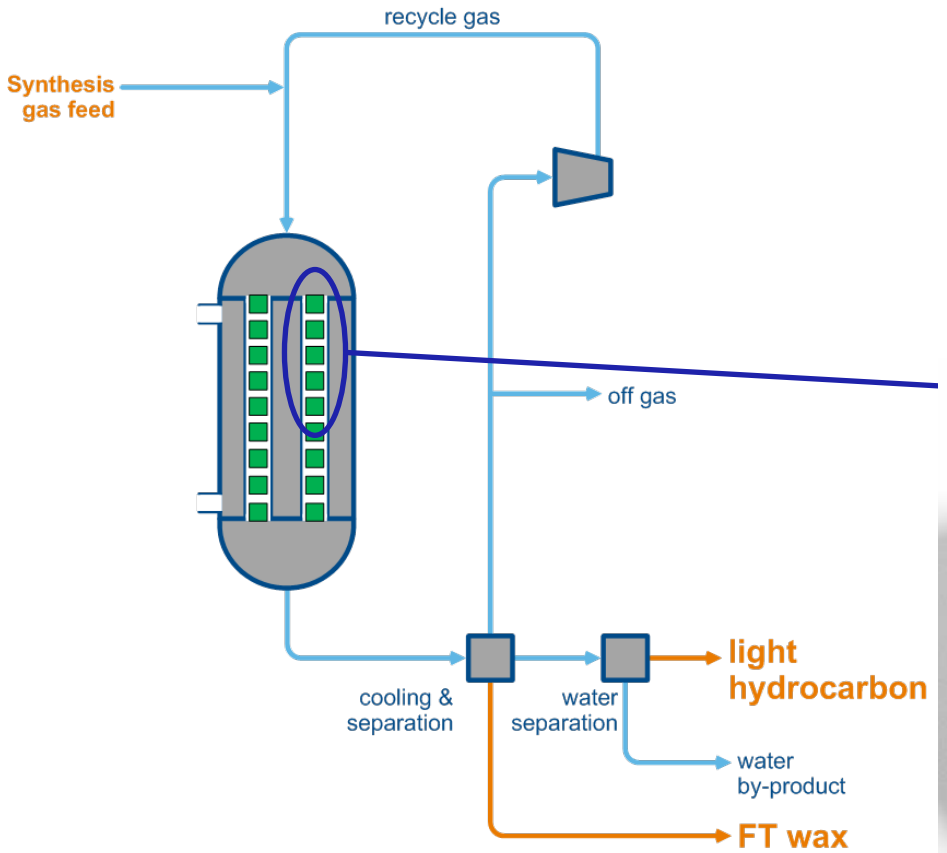


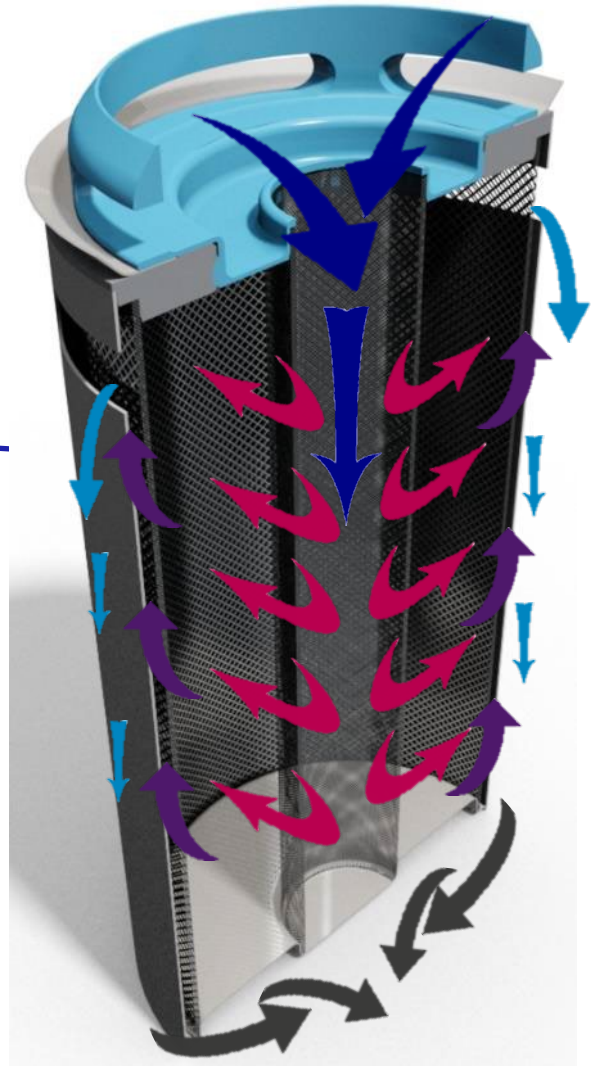


JM FT CANS technology brings an easy to operate and selective process for by unifying catalyst design and reactor engineering

FT **CANS** is the Remedy to FT's Challenge's

A modular solution for all scales





Gas flows from **CANS** catalyst carrier above passing down a porous central channel. Provision is made to ensure liquid flows down the tube

Radial flow through catalyst bed where reaction occurs and gas heats up

Gas exits via porous outer wall and flows to the top of the inner side of the carrier body

Gas flows down a narrow annulus between the carrier body and the inside wall of the tube where it cools by transferring heat to the boiling water on the shellside

A seal prevents the gas bypassing the next **CANS** carrier and the gas enters the carrier below to repeat the process.

JM

JM's **FT CANS** technology enables **efficient SAF production**

Fischer-Tropsch (FT) converts carbon and hydrogen into fuels.

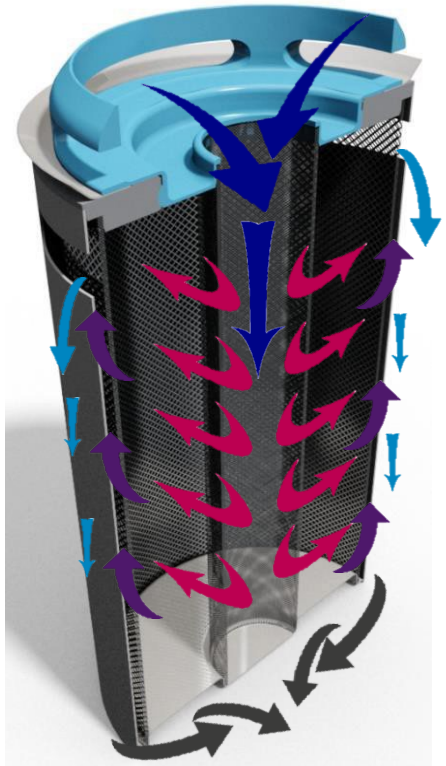
$$CO + 2H_2 \rightarrow -CH_2- + H_2O$$

Step-change improvement over fixed-bed FT technology

Being deployed in plants **today**

Simple to operate

Highly **scalable** technology



- FT unit cost reduced by ~50% versus conventional tubular reactors
- **Three-fold increase** in production for same size reactor
- Improved catalyst performance
- **No catalyst lost** in the product due to no movement

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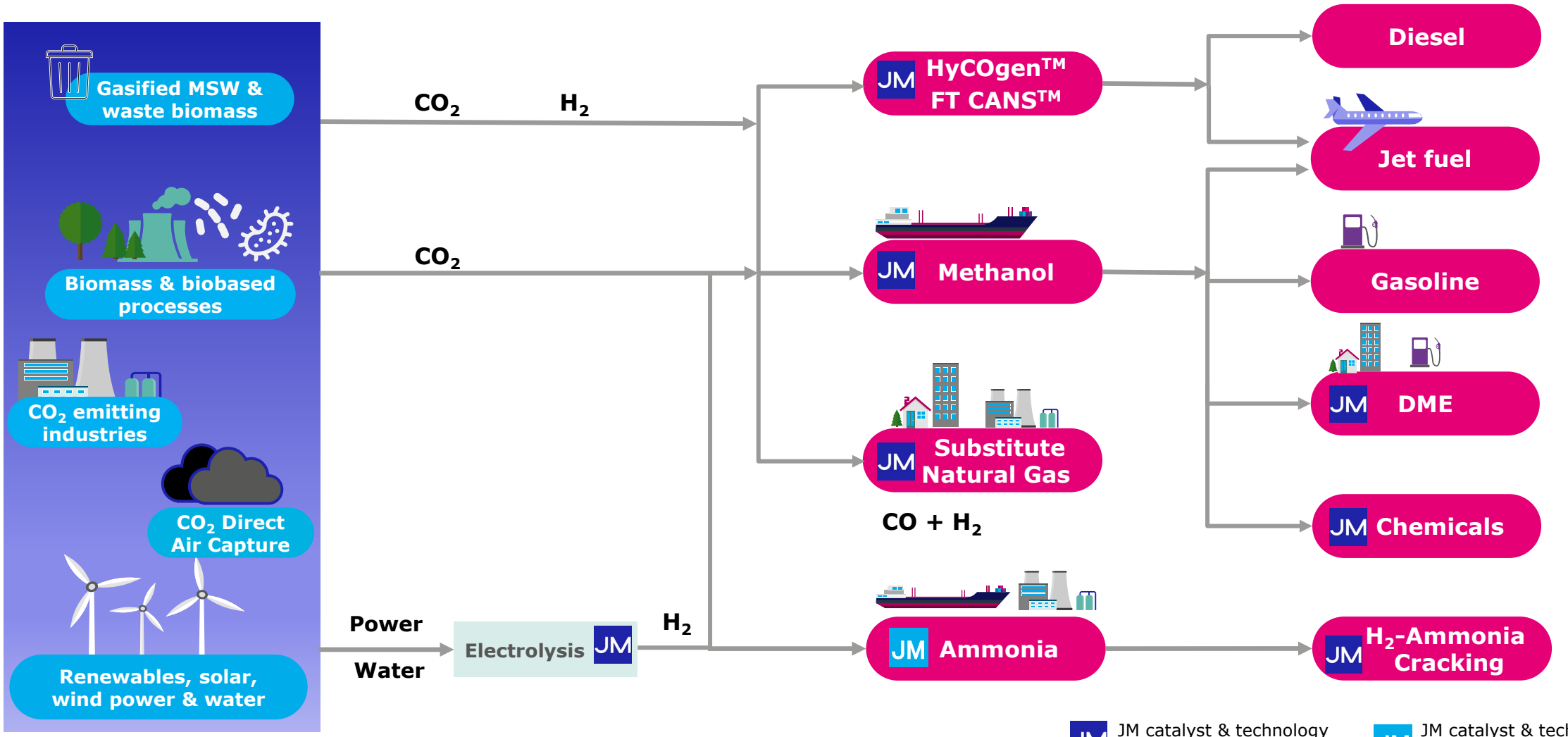
JM Catalyst Technologies for the Upgrading of Raw Synthesis Gas



JM catalyst & technology areas

JM catalyst & technology partner areas

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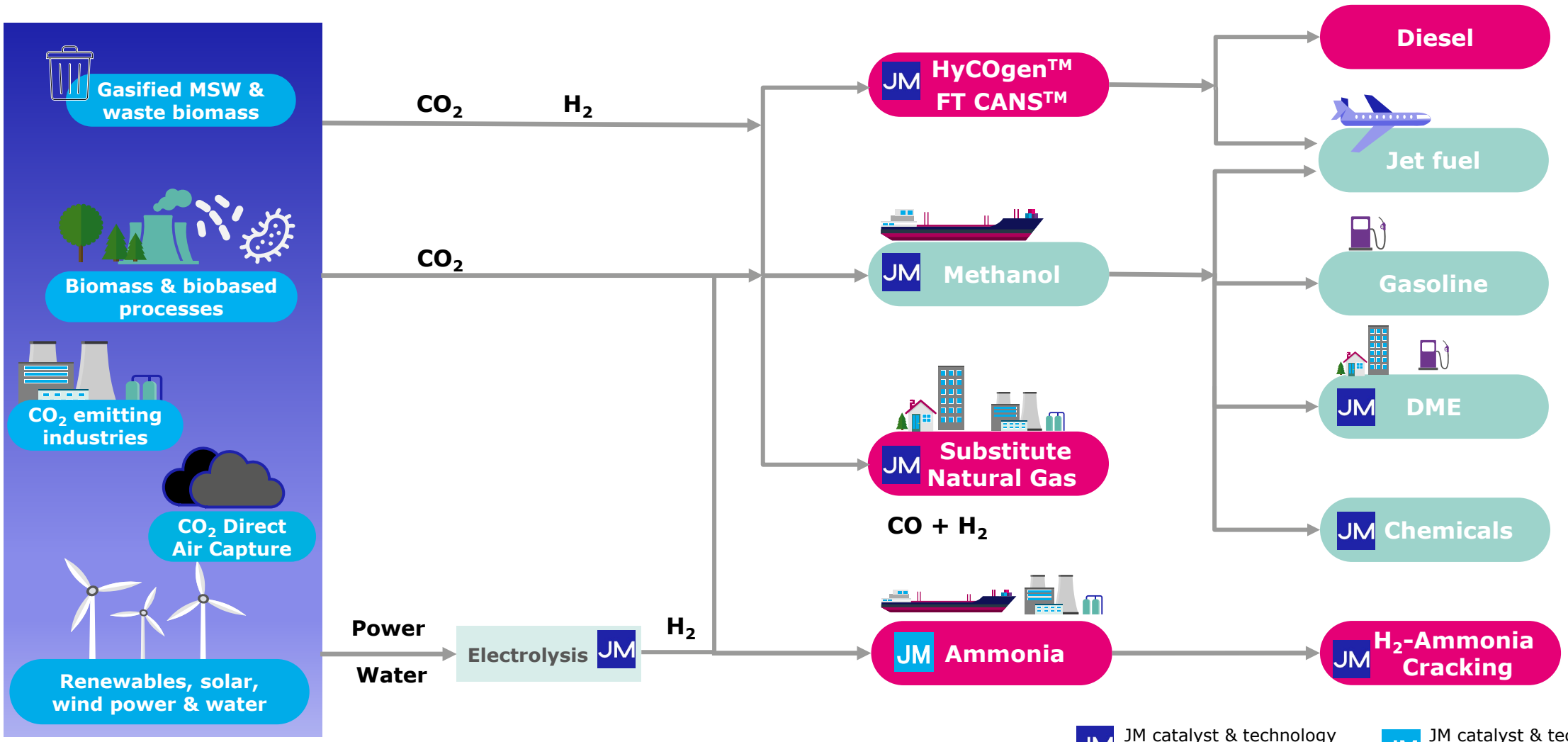

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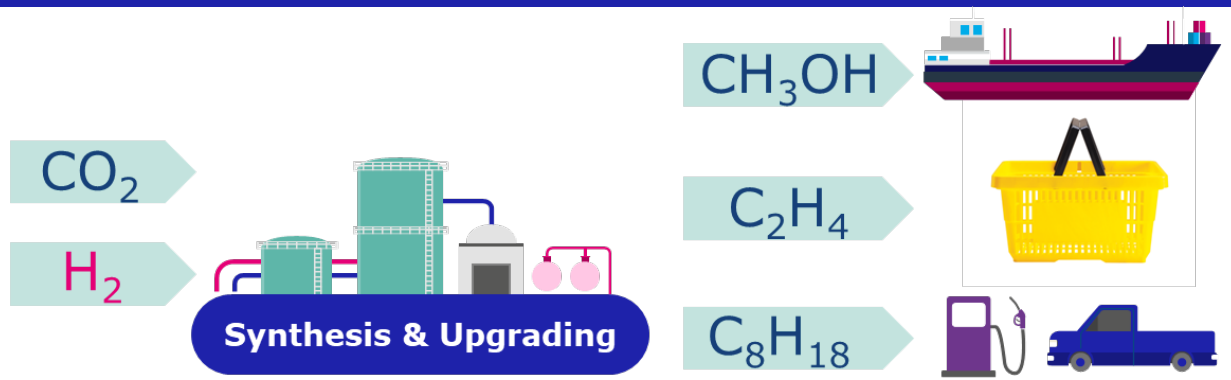
Why Methanol?



Biodegradable and low toxicity

1

Easy to store and transport

2

Fuel or fuel/chemical precursor

3

Ideal net zero synthesis route with > 50% electricity-to-LHV efficiency

4

Methanol: Efficient production from all feeds and at the largest scales

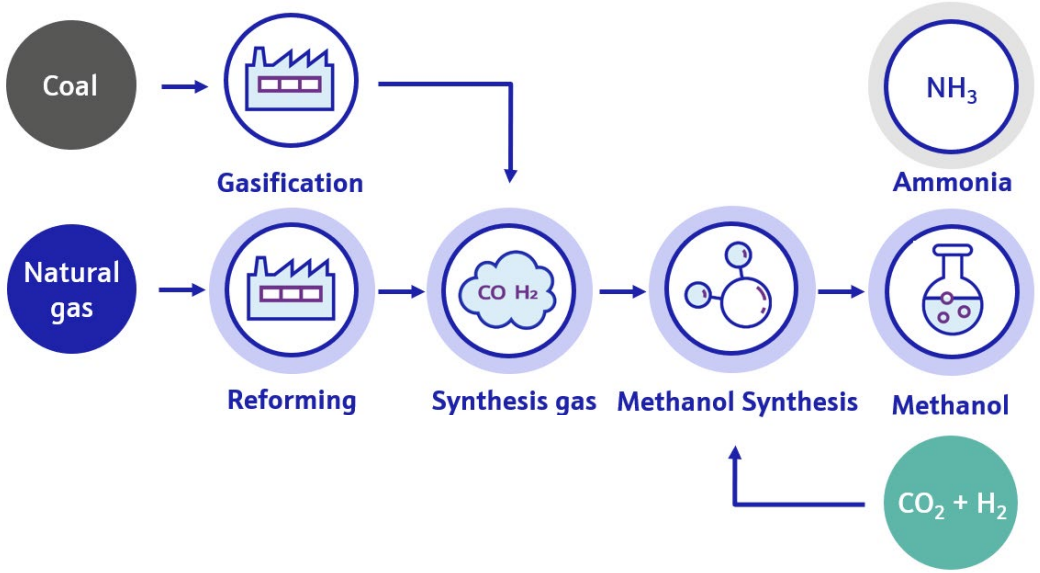
We are the world's leading methanol synthesis technology and catalyst supplier

#1	100+	70M	60	8,400
licensed capacity and installed synthesis catalyst	licenses	t/y licensed methanol production	years of experience	t/d max capacity in a single train

Global experience enabling **efficient**, **reliable** and **profitable** methanol production to many producers

Source: S&P Global Inc

Through our **expertise** and **strategic partnerships**, we help our clients make methanol from any feedstock.



By JM By technology partner

JM

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Gasification of waste and biomass offers a drop-in sustainable solution

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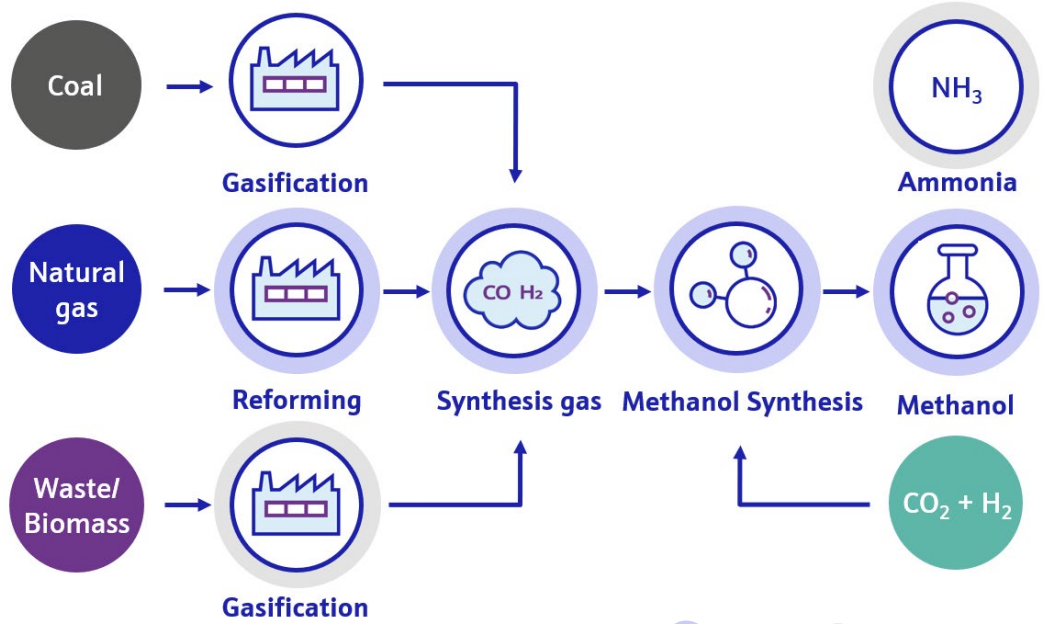
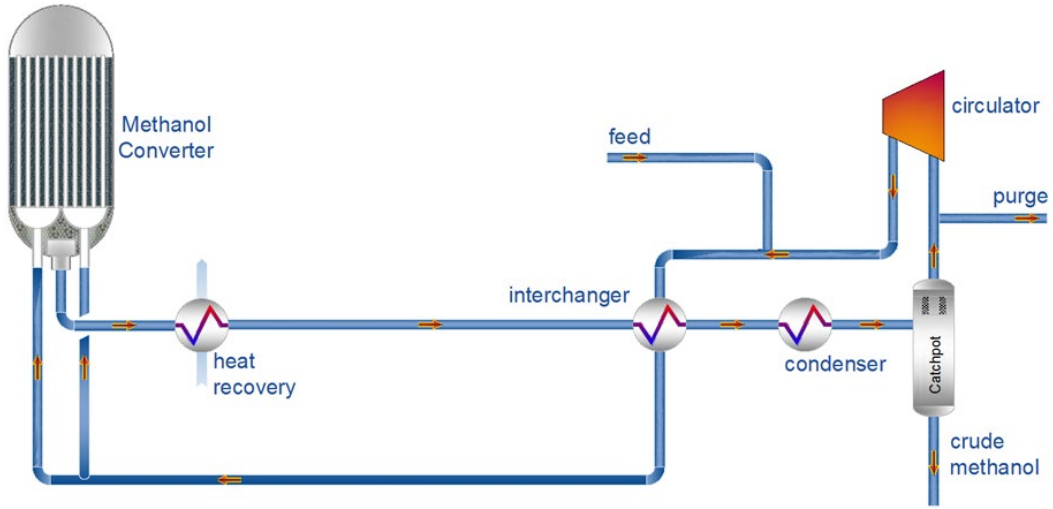


Source: S&P Global Inc

JM's CO_2 to methanol: **commercially proven**, **low risk** and **offering 99% H_2 efficiency** to support a strong business case

METHANOL SYNTHESIS LOOP

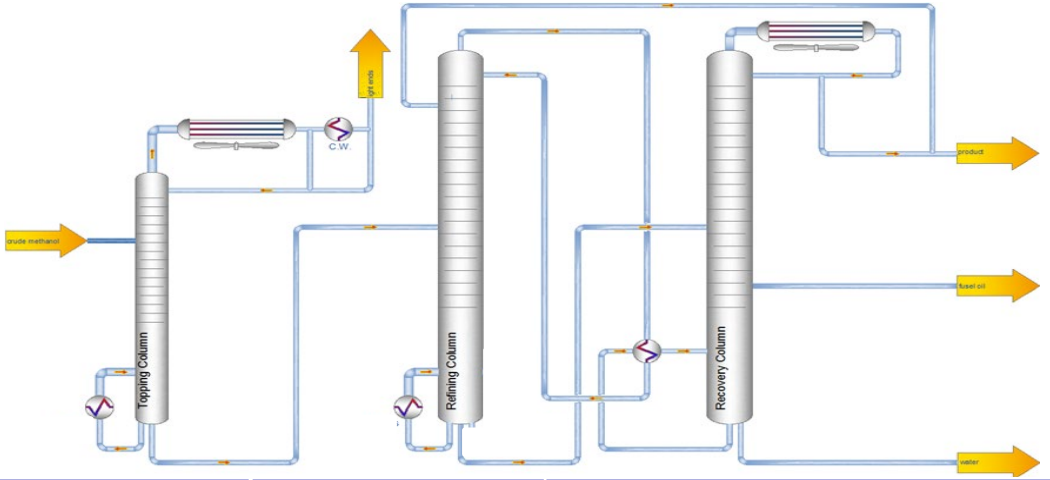
- **Converter and loop design tailored for CO_2 to methanol plants, ensuring high feedstock efficiency**



INDICATIVE PERFORMANCE[1]	Value
Hydrogen loop efficiency	**~99%**
Carbon loop efficiency	**~99%**
Electric Power	~450 kWh/te
Cooling water	~140 te/te

METHANOL DISTILLATION

- Adapted to suit end-product and customer requirements
- Optimising capex and opex of the process



	US Federal AA	"fuel-grade"	
	3 Columns	1 Column	3 Columns
Heat import	1	1.4	0.02
Equipment Cost	1	0.4	0.9

[1]Based on specific convertor type & partially compressed feed

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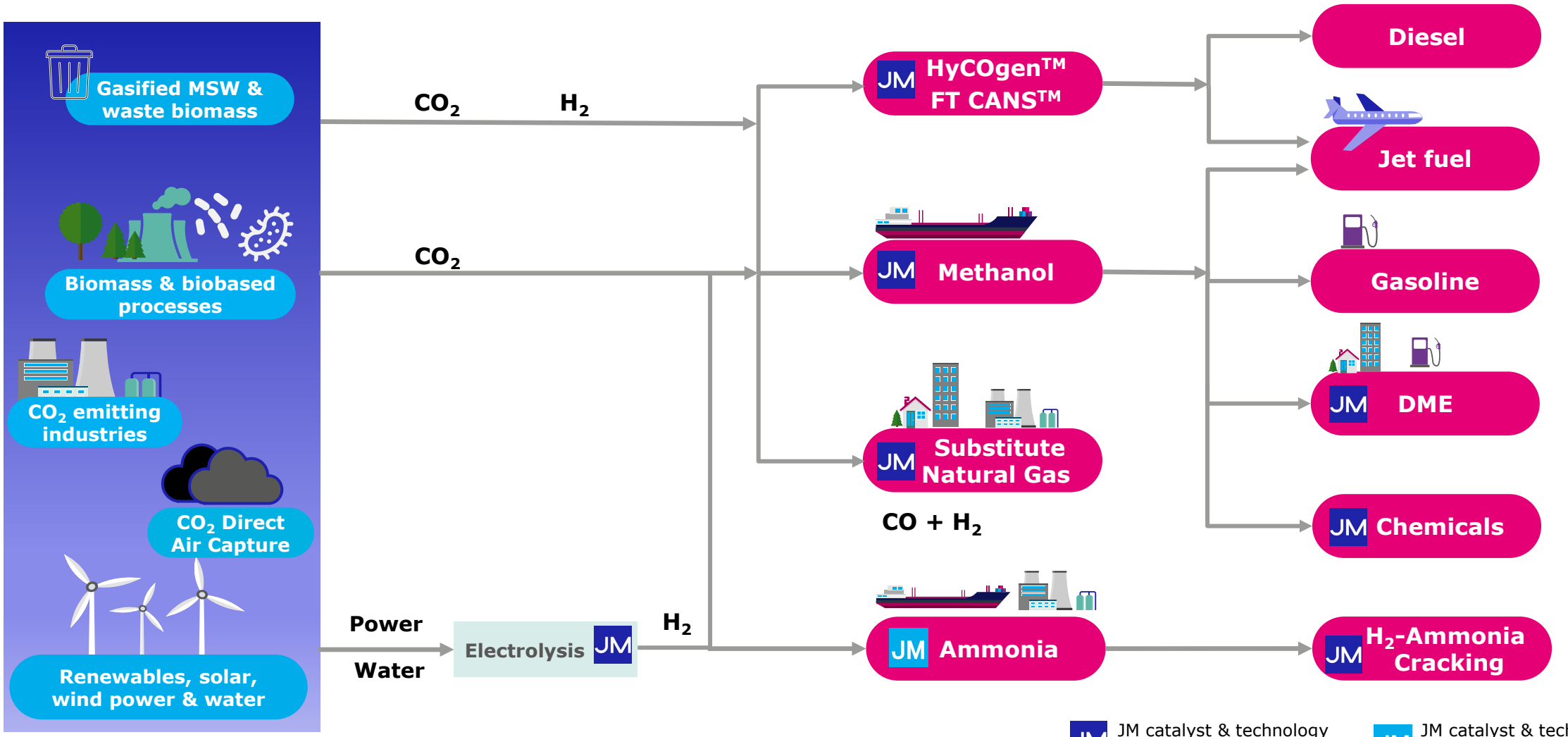

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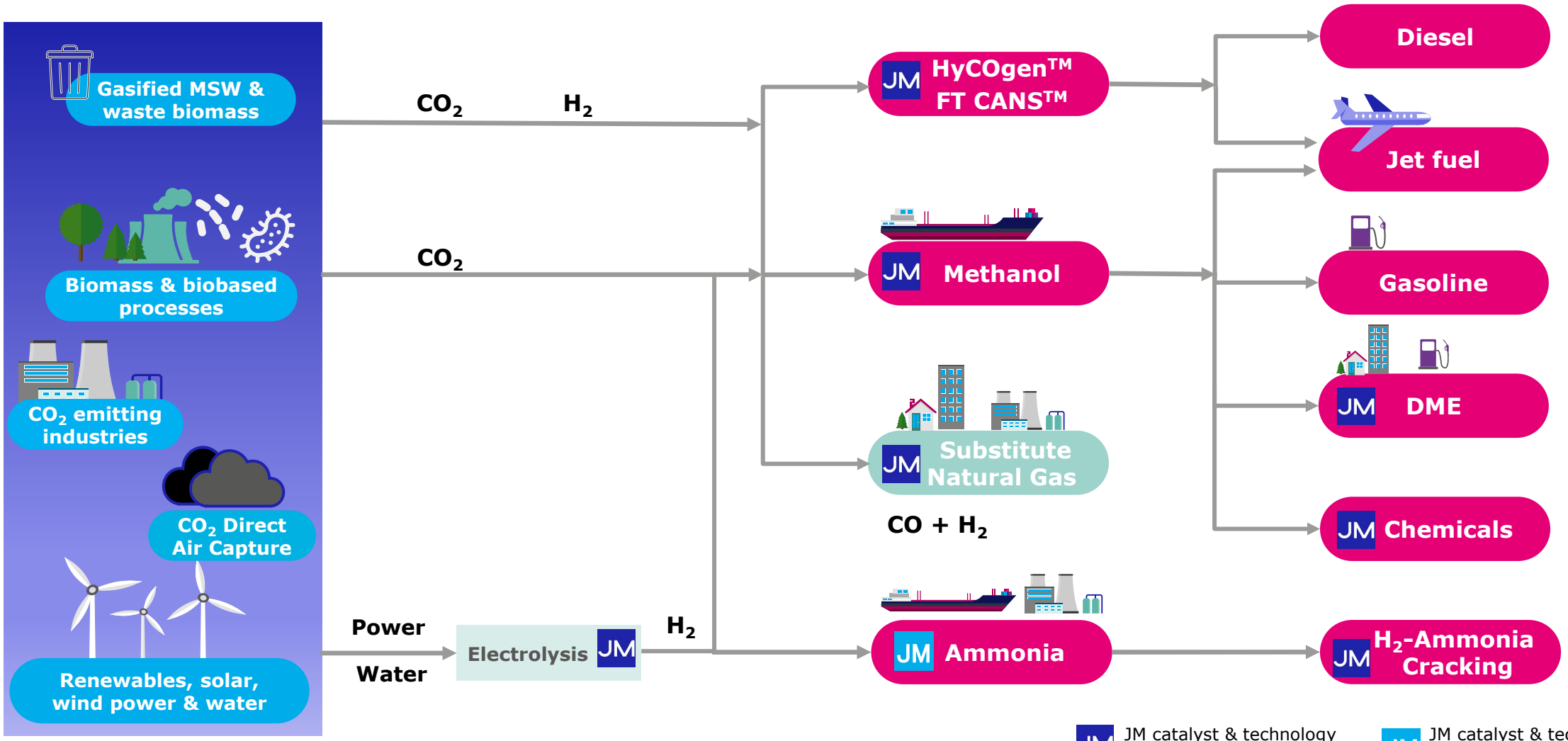

JM catalyst & technology areas

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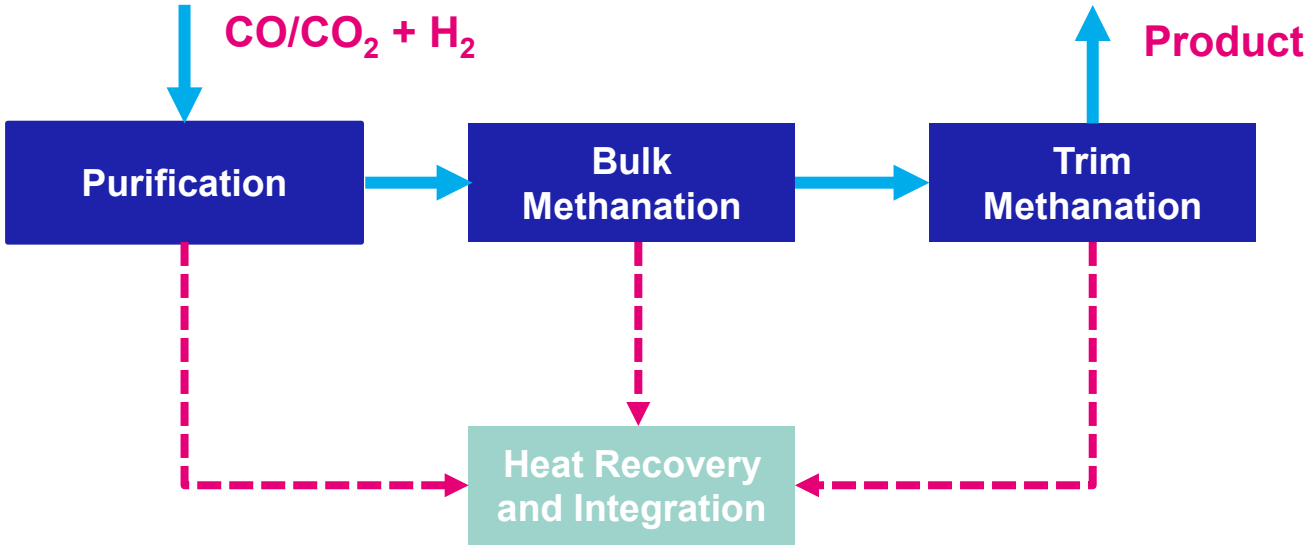
JM technology offers catalyst and flowsheet which is optimised to reduce cost of production. We are preparing to deploy this into the eNG market.

JM Davy Methanation Flowsheet



JM CRG catalyst

Flexible flowsheet to accept different feeds (CO, CO_2, Syngas) and proper control to increase catalyst life and heat recovery **optimising OPEX**.

Proven technology with **optimised process** therefore **reduced CAPEX and complexity**.

Stable, high activity catalyst reduces reactor volume and has a low pressure drop that contributes to further operating cost benefits.

JM Methanation technology meets the new demands of eNG production. We are taking the steps to **optimize our technology** for this market.

JM's core capabilities in process engineering and catalysis are poised to address the broader challenges of eNG/rNG production

Challenges overcome by JM methanation technology to maximise value for customers

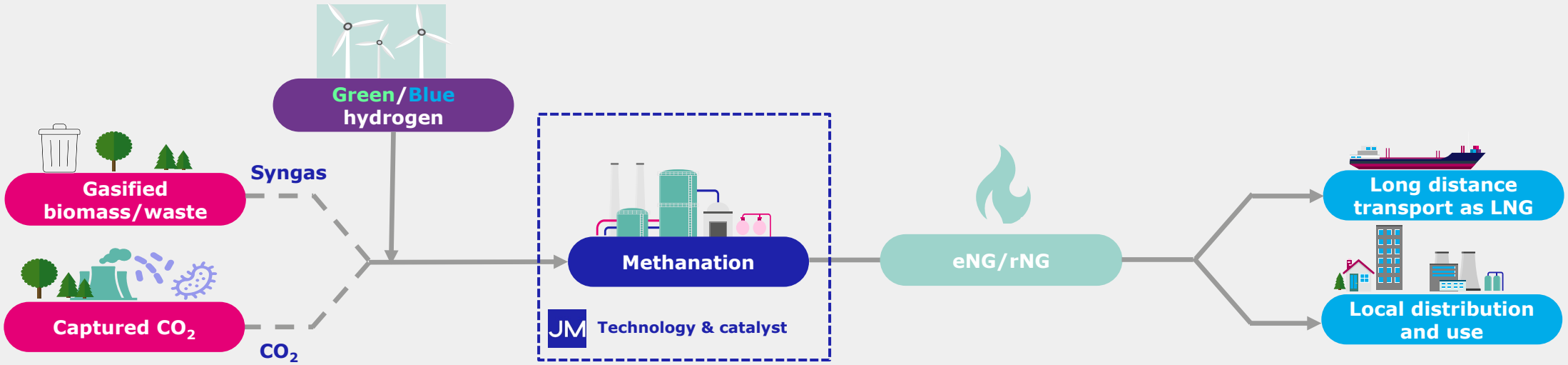
CO_2 feedstock
Catalysts and flowsheet which can convert both CO and CO_2.

Intermittent operation
Wide operating range based on client requirements.

Cost, scale and safety
Simple adiabatic reactors reduces costs; wide range of plant scales are possible; JM designed plants feature industry-leading safety.

Heat recovery
Optimisation of waste heat recovered for steam generation according to client needs.

Product specification
Adaptability of flowsheet to end-use needs for LNG production.



eNG = electrolytic natural gas SNG = substitute natural gas
rNG = renewable natural gas LNG = liquefied natural gas
CRG™ is a Trademark used under licence from GLIS.

Key Takeaways

Understand the crucial need for feed purification and its complexity

Be able to identify JM’s world class upgrading technologies for synthesis gas

Be motivated to with Johnson Matthey to leverage to bring value to your process!

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Key Takeaways

Process longevity and increased performance are benefits that can have monumental cost savings. Solutions are not trivial and custom services are provided by JM

Visit Process Licensing

JM's Syngas Based Solutions for Energy Transition

FT – higher hydrocarbons / SAF enabler

Methanol – maritime fuel and chemical / fuel precursor

SNG – a sustainable drop in technology

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Thank You

Andrew Palermo