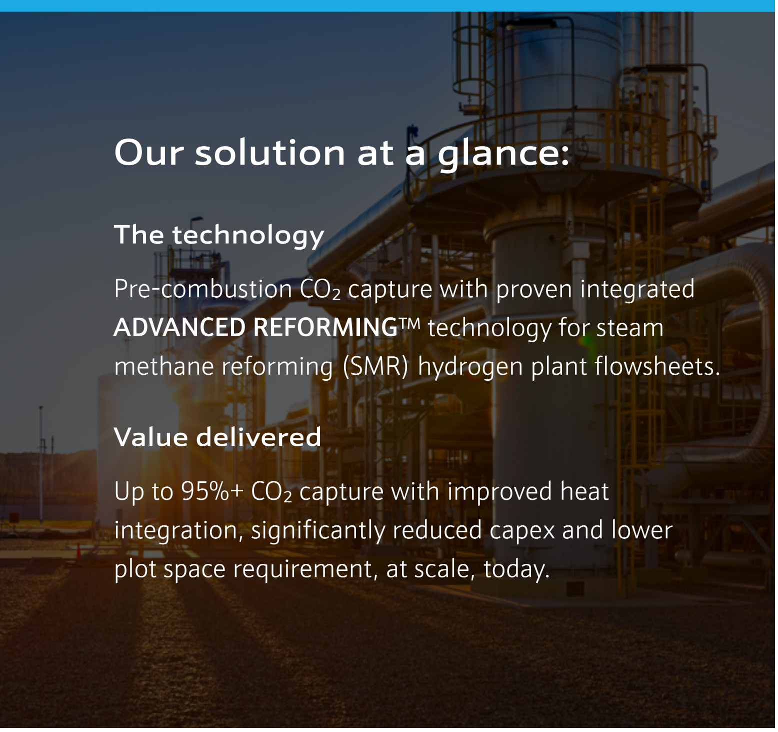
CLEANPACE hydrogen solutions

Decarbonise your existing SMR based hydrogen plant today

Johnson Matthey
Inspiring science, enhancing life

Our Low Carbon Solutions business helps our customers navigate and overcome the challenges they face in meeting emissions reduction targets. We provide tailored solutions that help you achieve significant and sustained reductions in carbon emissions; at scale, today, with existing technology.



Our solution at a glance:

The technology

Pre-combustion CO_2 capture with proven integrated **ADVANCED REFORMING**™ technology for steam methane reforming (SMR) hydrogen plant flowsheets.

Value delivered

Up to 95%+ CO_2 capture with improved heat integration, significantly reduced capex and lower plot space requirement, at scale, today.

To address climate change, we must continue to find the solutions that will help substantially reduce CO_2 and other greenhouse gas emissions. The refining and chemical industry is the third largest emitting industry behind the iron/steel and cement industries; so to meet net zero targets, the adoption of low carbon solutions in the chemicals space will be key.

Tackling carbon intensive processes such as the production of fossil fuel derived syngas, a significant source of CO_2 emissions, is one of the many areas where we can help. Johnson Matthey (JM) has a rich history providing catalysts and technology to the petrochemical industry and has played a major role in the development of syngas production. Our experience in this industry, coupled with our expertise in deploying technology at scale allows us to provide our customers with innovative solutions that accelerate their progress to net zero.

JM believes the syngas industry can reduce its carbon dioxide (CO_2) emissions using innovative solutions for the energy efficient production of hydrogen, ammonia and methanol that are demonstrated at scale and available today. "Conventional syngas production uses a steam methane reformer (SMR) to convert natural gas and other hydrocarbon-based feedstocks into a mixture of hydrogen and carbon monoxide. The hydrogen produced via this process is used for petroleum-based clean fuel, ammonia fertiliser, and methanol production. The syngas carbon monoxide (CO) can be used to produce chemicals, fuel and energy, or additional hydrogen (H_2) via the water-gas shift (WGS) reaction.

While syngas production through the decades has focused on reducing production cost, attention is now on reducing greenhouse gas (GHG) emissions to meet 2050 Net Zero CO_2 emissions targets. Broadening the use of proven technologies, as well as CO_2 capture, utilisation, or storage technologies (CCUS), can significantly reduce the carbon intensity of syngas production. These CCUS technologies use existing technology and materials, manufacturing, and supply chain infrastructure, enabling these solutions to be utilised at scale today.

On site refinery hydrogen plants are valued assets to the Refinery

50 years ago, most of the hydrogen available on a refinery site was a by-product stream from the catalytic reformer. As Clean Fuel legislation progressed around the globe, SMR-based hydrogen plants have been the means to produce the additional hydrogen needed to manufacture these Clean Fuels, providing ultra-low sulphur fuels that improve the environment in our cities and regions. There are more than 700 refinery hydrogen plants around the world; nearly 90% of these plants are SMR based. Over 40% of these plants are less than 20 years old with many still being depreciated. These more modern plants have been designed to improve the efficiency and cost of the hydrogen produced, as well as manage the capital cost of the hydrogen plant. For the last 30 years, most of these plants have been designed with pressure swing adsorption (PSA) based hydrogen purification systems that reduce the additional fossil fuel demand for the SMR through off-gas recycling. In these plants this recycled stream, or PSA purge gas, is the predominant portion of the fuel to the SMR. While there might be long-term refinery site or regional plans to introduce low carbon hydrogen fueled energy through new clean or even electrolytic hydrogen assets to meet 2050 net zero CO_2 emissions targets, many of the existing hydrogen plants will be revamped to address the largest single source of CO_2 emissions within the refinery.

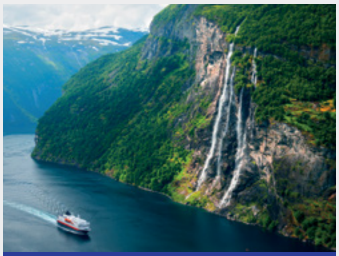
CLEANPACE technology suite

Hydrogen

Decarbonising existing SMR based refinery hydrogen plants

Offgas to methanol

Converting captured CO_2 and/or low value process off gases at any scale



Methanol

Decarbonising existing methanol plants

Rapid development

Delivering new, innovative, solutions based on existing technology

Underpinned by proven **ADVANCED REFORMING** technologies

CLEANPACE hydrogen solutions enable existing SMR hydrogen plants to 95%+ CO_2 capture

The good news is that there is a proven way to generate syngas at scale in which all the CO_2 comes out in a single stream at high pressure within the process, making it easy and economical to capture it with very high efficiency – 95% and above.

Our **CLEANPACE**™ technology suite provides innovative, tailored, solutions for the decarbonisation of existing syngas plants and processes.

Existing SMR refinery hydrogen plants are the single largest source of CO_2 emissions in the downstream refinery. To future-proof existing SMR refinery hydrogen plants to align with 2050 net zero targets, 90+% capture of the CO_2 emitted from the SMR hydrogen plant needs to be achieved. Process CO_2 capture in existing SMR based flow sheets doesn't get to this required level.

While post-combustion CO_2 capture can achieve this level of CO_2 capture, it requires a high level of capital at a time when refinery capital is being compressed in response to the pandemic and capital utilisation is of greater importance. As well as cost, post-combustion capture requires a substantial plot plan to install. As refineries continue to increase their complexity to make higher-value products, plot space continues to be scarce and become more valuable, particularly for those refinery sites that are near metropolitan areas.

However, the 90+% capture target can be exceeded by integrating **ADVANCED REFORMING** technology into existing SMR hydrogen plant flowsheets and producing hydrogen at a very low carbon intensity with improved heat integration. This integration moves the CO_2 emissions predominately into the process side of the flowsheet enabling low-cost CO_2 capture with minimal energy and plot space requirement (enhanced carbon capture).

	Process carbon capture	Flue gas carbon capture	CLEANPACE hydrogen solutions
Maximum possible direct CO_2 reductions	60%	90%+	95%
Relative capital cost	45%	100%	70%
Relative plot space requirement	40%	100%	60%

Table 1: Comparison of Carbon Capture options for an existing Steam Methane Reformer. Based on the results of a recent decarbonisation study for a European customer

ADVANCED REFORMING technology generates CO_2 which can be captured with >95% efficiency

ADVANCED REFORMING technology, utilising a combination of endothermic and autothermal processing steps such as JM's gas heated reforming (GHR) and other non-fossil fuel fired technologies, has been used at industrial scale for decades, and removes the need for a separate stream of methane fuel to be used to generate the temperature to drive the reactions. This in turn eliminates the dilute, low pressure outlet stream containing CO_2 (post-combustion CO_2) that results from the fossil fuel-based firing. Some technologies generate heat with process-side combustion using oxygen or enriched air to then drive the reforming reactions that generate the by-product CO_2. This requires a source of oxygen, which is typically produced through air separation. A GHR can be combined with an SMR or other **ADVANCED REFORMING** technologies to achieve even greater heat integration, lower by-product CO_2 and lower carbon intensity than an SMR alone. A GHR achieves this lower carbon intensity by using the hot outlet process gas of an SMR or other **ADVANCED REFORMING** technology to heat the inlet feed gas to the GHR, which enables the efficient use of natural gas within syngas production.

Progressing projects with sustainability and longevity in mind

When considering decarbonisation solutions like those mentioned, consideration must also be given to the lifecycle emissions associated with implementing a new solution or technology. To utilise hydrogen in the future, energy infrastructure and electric grids need to be renewable based. However, waiting for renewable energy to achieve a clean electrical grid might be too late in some cases. Therefore, using solutions that decarbonise outside the grid allow the end-user to avoid competition for renewable energy with hard-to-abate sectors and allow significant carbon reductions to be achieved today. Applying integrated **ADVANCED REFORMING** technologies and enhanced carbon capture to existing refinery hydrogen plants provides a cost-effective means to achieve low carbon intensity refinery hydrogen production today that is sustained and aligned with renewable based hydrogen production decades from now.

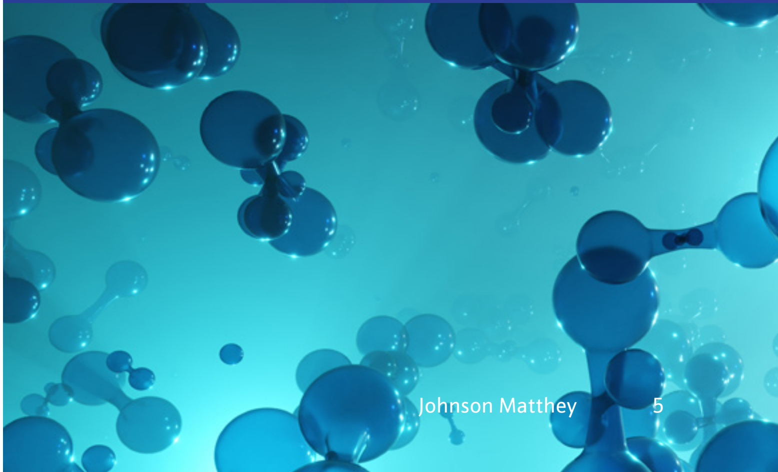
Accelerate your journey to net-zero

We offer a techno/economic feasibility study into decarbonising your hydrogen plant with JM's solution:

- Process simulation before/after
- Comparison of key process performance parameters before/after
- CO_2 capture rate
- Plant layout study
- TIC estimate
- OPEX sensitivity analysis

Key advantages of JM's solution

- Low capital expenditure v post-combustion capture
- Highly efficient process – so low operational expenditure
- CO_2 emission reduction up to 95% possible
- Limited space requirement to ease implementation in an existing plant site
- Using only well proven technologies at scale
- Can be implemented in phases to spread investment over time



How to decarbonize existing SMR based hydrogen plants

Post-combustion capture

- CO_2 capture rates up to 95% possible
- Relatively high capex and lots of space required

Pre combustion capture

- More efficient than post-combustion capture (lower opex, capex, space)
- CO_2 capture rate limited to around 60%

Electrical SMRs

- Early-stage technology, not commercially demonstrated
- Requires high amounts of renewable power

CLEANPACE hydrogen solutions

- Benefits from using precombustion capture
- CO_2 capture rate up to 95%
- Can provide additional tailored benefits to the hydrogen plant

CO_2 in SMR based hydrogen production

Conventional SMR technology comprises a fired heater with catalyst-filled tubes in which reforming reactions take place. Usually, gasified coal, natural gas, or other hydrocarbon-based fuels, such as refinery off-gas and PSA purge gas, are burned with air in the fired heater to generate thermal energy required for the reforming reactions. The CO_2 generated in the fuel side of the SMR is emitted in the flue gas stream and is referred to as post-combustion CO_2. In general, the post-combustion flue gas is produced at low-pressure and contains water, excess-oxygen, and significant quantities of combustion related impurities from the fuel and air. Although technically complex, established solvent-based technologies can be used to capture the post-combustion CO_2.

The other source of CO_2 originates from process-side syngas production where natural gas is converted into a mixture of predominately hydrogen and CO_2 and CO. This syngas is processed in a WGS reactor to convert the bulk of the CO process stream, which contains >70% hydrogen, goes into a PSA process to reach high level (99+%) purity hydrogen for use in refinery downstream hydroprocessing and isomerisation unit technologies to produce cleaner fuels. The CO_2 generated is at high pressure and the process stream composition is simpler with minimal impurities making it easier to work with. Consequently, the capture of this process-side by-product CO_2 is less complex and costly, and established solvent and absorbent-based technologies can provide cost-effective solutions.

Capturing post-combustion CO_2

In a post-combustion scheme, CO_2 is removed from the flue gas stream. New technologies, including amine based but also cryogenic and other novel forms of post-combustion are focusing on minimising cost and improving reliability. Using carbon capture at this location can achieve CO_2 reductions of greater than 90%.

However, since the SMR furnace operates at a negative pressure, the flue gas pressure is quite low and will complicate the design of the solvent-based system. Lower pressure requires larger equipment, which requires more space; in an existing facility, plot space is likely at a premium. The amine solutions used for carbon capture are prone to oxidative and sulphur degradation. Fresh amine will have to be added more often on a post-combustion system, increasing operating cost.

Capturing pre-combustion CO_2

In this scheme the CO_2 is removed from the process stream after the WGS reactor and upstream of the PSA. The process stream will contain known components (H_2O, CH_4, CO, CO_2 and N_2), so impurities such as oxygen and sulphur are not present and will not contribute to degradation of the amine solution. Pressure control exists at the PSA inlet, meaning this stream will be available at a high, defined pressure; all of this simplifies the design and reduces the size of the removal system. In addition, operating cost of the liquid amine-based contact system will be lower for pre-combustion carbon capture.

While these systems benefit from smaller plot space and solvent stability, pre-combustion capture means only the process side CO_2 is removed. Looking at the total CO_2 generated in a hydrogen plant, this can typically represent up to 60% of the total carbon emissions but will vary depending on plant conditions.

CLEANPACE hydrogen solutions

Our unique solutions combine the benefits of pre-combustion carbon capture with the high carbon reduction rates typically only achievable with a post-combustion capture system. By utilising ADVANCED REFORMING technologies, these solutions remove the need for post-combustion capture and enable a more efficient route to remove up to 95% of the CO2 generated in the hydrogen production process. CLEANPACE hydrogen solutions can be tailored to suit the existing and future needs of your hydrogen plant, meaning that you can decarbonise and benefit from efficiency and/or production capacity improvements at the same time.

Contact us to find out how your hydrogen plant can be transformed.

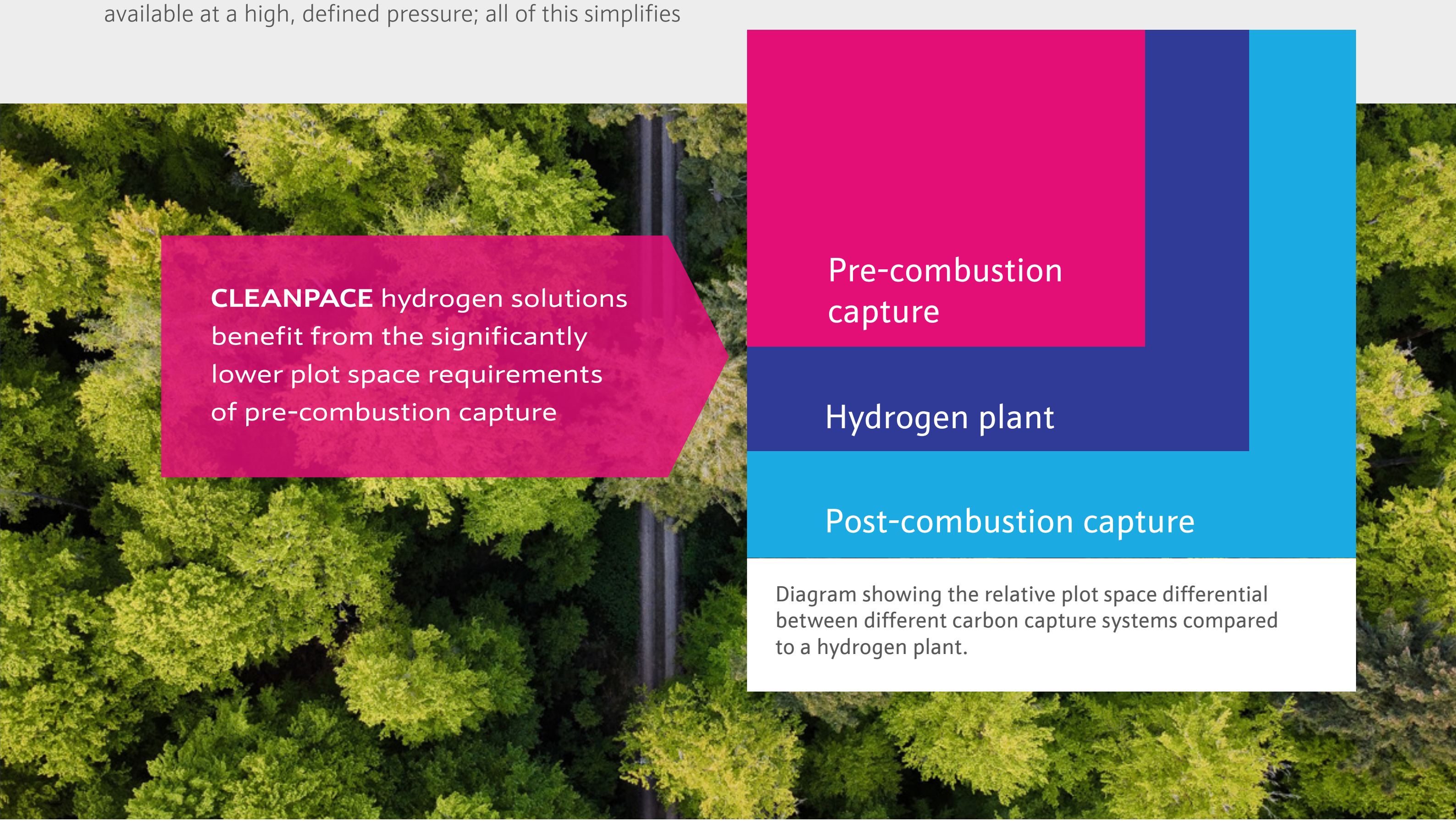


Diagram showing the relative plot space differential between different carbon capture systems compared to a hydrogen plant.

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