

# Meeting the Challenge of Efficient Hydrogen Production with Higher Efficiency Catalyst Solutions

Ken Chlapik, Johnson Matthey.

Reprint from Hydrocarbon Engineering June 2025

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As hydrogen emerges as a key vector in the global energy transition, its efficient and cost-effective production has become increasingly critical. Steam methane reforming (SMR) remains the predominant method for producing hydrogen, supplying major industries such as refining, chemicals, and fertilisers. However, growing hydrogen demand places pressure on SMR facilities to boost production without increasing environmental impact or operational costs. Solutions like Johnson Matthey's **CATACEL SSR™** (Stackable Structured Reactor) technology has been developed to address these challenges.

## The Rising Demand for Hydrogen Production

The growing role of hydrogen in decarbonisation efforts is clear. It is a versatile energy carrier, supporting applications ranging from fuel cells to synthetic fuels and heavy industry. Global hydrogen demand has more than tripled since 1975, driven largely by industrial processes, and is expected to continue rising as governments and companies set ambitious net-zero targets.

Existing SMR facilities often operate at or near capacity, making it difficult to meet this rising demand, and operators face multiple technical and operational constraints. For instance, increasing throughput can exacerbate thermal stress, pushing tube wall temperatures close to material limits, which risks reducing their lifespan. Similarly, conventional ceramic pellet catalysts, while effective, can result in high pressure drops and inefficient heat transfer. The combined effect is a ceiling on production capacity and an increase in the carbon intensity of hydrogen.

In response, operators are seeking cost-effective and sustainable methods to enhance SMR performance without requiring significant capital expenditure or additional energy inputs. This is where structured catalysts can help.

## The Role of Structured Catalysts

Structured catalyst technology offers a practical solution to many of the challenges faced by SMR operators. Unlike conventional ceramic pellets, which rely on bulk material design, they employ engineered geometries that optimise flow, heat transfer, and catalytic activity. One prominent example is the **CATACEL SSR** technology, a Johnson Matthey innovation that has been implemented in over seventeen SMR facilities globally.

The **CATACEL SSR** technology breaks away from many of the limitations imposed in using ceramic pellets by adopting a foil-based structure. Through this design,

it exhibits a higher activity, improved heat transfer, lower pressure drop, and improved resistance to carbon formation. These types of catalysts offer a path to increased efficiency and sustainability in hydrogen production.

It uses a special high temperature alloy as a substrate material. The alloy strip is formed into engineered foil structures called fans, which are coated with a nickel-based steam reforming catalyst using a proprietary process that ensures the catalyst remains attached to the surface of the foil during the catalyst lifetime. The fans are stacked one upon another in the reforming tube, separated by thin metal washers. The outer edges of the fans are located close to, but not touching, the internal surface of the tube. (see Figure 1)



Figure 1: **CATACEL SSR** fan structure

The stacked fans deliver superior heat transfer by impinging gas on the internal surface of the reforming tube rather than relying on convective heat transfer mechanisms. During operation, gas flows down the tube and encounters the first fan structure. It cannot move through the fan and therefore it is forced out of the triangular ducts. The process gas thus jets directly onto the internal surface of the reformer tube, where it gathers heat. Having nowhere else to go, the gas flows around the edges of the fan and back into the triangular duct on the underside of the fan and the targeted flow of process gas ensures contact with the increased catalysts surface across the stacks compared to randomly packed pellets. The washers that separate the fans from one another facilitate this flow back into the fan. Once inside the fan, the gas is free to move to the next fan in the stack and repeat the process.

By designing the catalyst in this way, heat transfer is increased through a mechanism known as impingement.

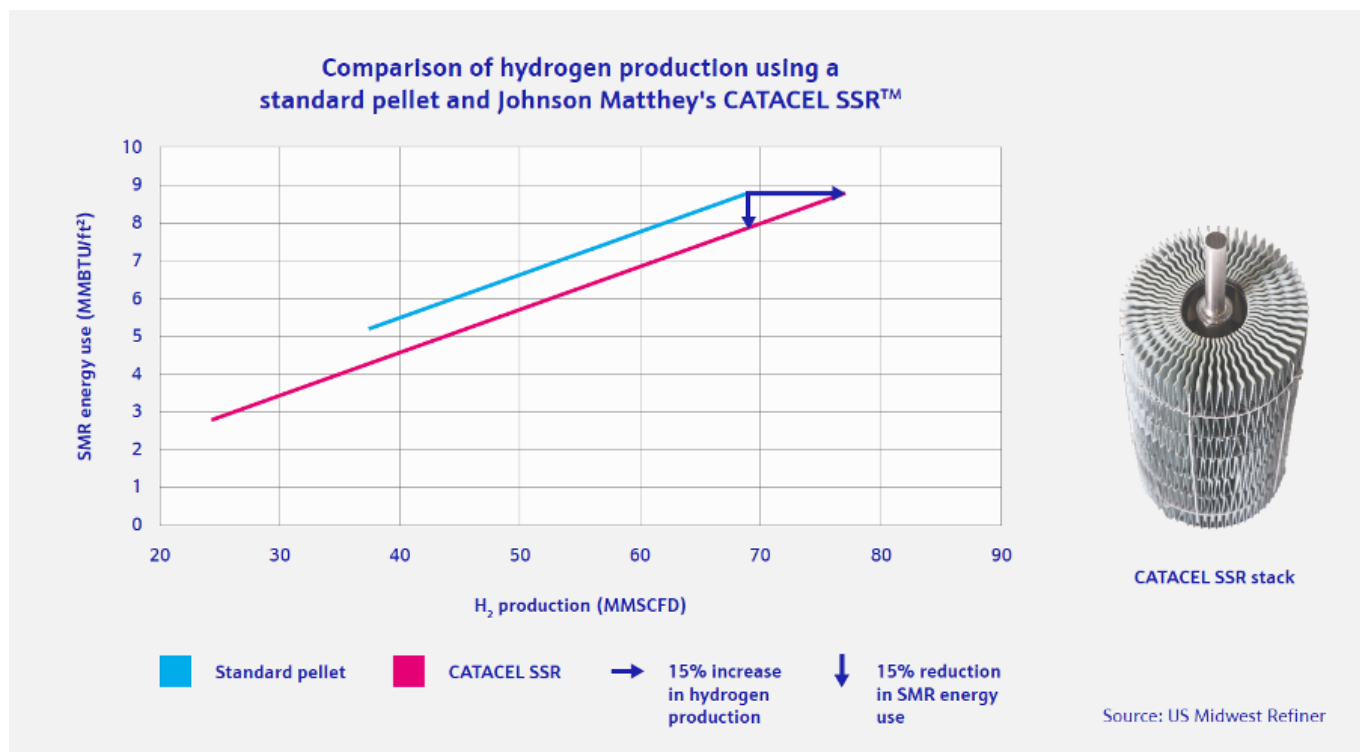


Figure 2: Comparison of hydrogen production using a standard pellet and **CATACEL SSR** technology.

Process gases are forced directly against the internal tube walls, which disrupts the insulating gas layer typically found in conventional systems. This direct interaction enhances the efficiency of heat exchange, improving heat transfer by 20–30% compared to traditional pellet systems.

### The benefits to production

These structural advantages translate directly into measurable production benefits, including increased hydrogen output and reduced energy consumption. For instance, at a major US Midwest refinery, the enhanced energy management, superior methane conversion rates and optimized heat transfer within the reformer provided by the **CATACEL SSR** reactor has delivered a 15% increase in hydrogen production without additional natural gas consumption. Such improvements are particularly valuable for plants operating near their design limits, where conventional upgrades would require substantial investment.

In addition, structured catalysts can reduce pressure drop due to their high voidage design. Lower resistance to gas flow enables operators to maintain or increase throughput without requiring additional energy to overcome flow constraints. The increased geometric surface area of structured catalysts, which is up to twice that of pellets, ensures more effective contact between

the gas and catalytic material, promoting better methane conversion and reducing methane slip. Figure 2 shows how **CATACEL SSR** has provided increased hydrogen production at the same SMR firing duty or a reduction in firing duty for the same level of hydrogen production.

The effectiveness of the **CATACEL SSR** reactor is supported by a decade of commercial data. Unlike newer technologies, which may lack field validation, this catalyst has demonstrated consistent performance across a range of SMR applications. This long-term reliability is critical for operators seeking proven technologies to enhance their operations.

The environmental benefits of advanced catalysts align closely with global sustainability objectives. By improving the efficiency of heat transfer and methane conversion, these systems reduce the amount of natural gas required to produce hydrogen. This translates to lower CO<sub>2</sub> emissions, directly contributing to decarbonisation efforts.

At the Slovnaft refinery in Slovakia, the adoption of the **CATACEL SSR** technology facilitated a significant increase in throughput while maintaining lower tube wall temperatures. Data from this installation suggests that the **CATACEL SSR** reactor has enabled natural gas savings of over 8,000 tonnes over the lifecycle. These savings are accompanied by a 15% reduction in SMR furnace CO<sub>2</sub> emissions, providing a dual benefit of cost reduction and environmental impact mitigation. This example highlights

the ability of structured catalysts to increase production efficiency. Their use balances energy consumption during significant uprates, thereby reducing the energy required per unit of hydrogen.

### Addressing Sustainability Goals

As the demand for lower-carbon fuels grows, many refineries and biofuel producers are incorporating biogenic feedstocks into their processes. These feedstocks, which often have a lower hydrogen content than fossil-derived alternatives, require additional hydrogen during upgrading. By utilizing hydrogen lean biogenic feeds, producers can significantly reduce the overall carbon intensity of fuels, contributing to lower Scope 3 emissions across the value chain. Many of these projects are designed in phases, allowing existing hydrogen production facilities to establish an uprate at existing plants and supply the incremental hydrogen needed, minimising capital investment and operational disruptions. This approach supports a more sustainable and cost-effective transition to low-carbon fuel production while optimizing existing assets.

Moreover, the design of the structured catalyst minimises the risk of carbon formation, a common issue in conventional SMR systems. Lower steam-to-carbon ratios can be maintained without compromising performance, further enhancing the sustainability of hydrogen production.

### Evidenced Lifecycle Performance and Reliability

Durability and consistency are critical for any catalyst technology, and structured systems excel in these areas. The **CATACEL SSR** technology has been deployed in commercial settings for over a decade, providing a wealth of data to support its claims. It has demonstrated excellent lifecycle performance, with some installations maintaining their efficacy for more than nine years. This robustness ensures operators benefit from long-term reliability and minimises the frequency of catalyst replacement, reducing both costs and disruptions.

The structured design also offers practical advantages during installation and maintenance. Preamsembled stacks of catalyst-coated foils can be easily deployed using standardized installation tools, simplifying the process and minimising downtime. Installation and extraction of the catalyst is executed in the same time period as a typical pelleted catalyst changeout. This ease of use, combined with the proven operational benefits, makes structured catalysts an attractive option for both new installations and retrofits.

The financial advantages of structured catalysts further

enhance their appeal. By enabling significant capacity gains without requiring costly plant modifications, these systems provide a cost-effective alternative to mechanical upgrades. For medium-to-large hydrogen plants, the net present value (NPV) of adopting structured catalysts can reach \$25–50 million over a ten-year period, driven by natural gas savings, increased hydrogen output, and avoided capital expenditure.

The combination of lower operating costs, enhanced efficiency, and reduced environmental impact positions structured catalysts as a valuable investment for SMR operators.

The success of solutions such as the **CATACEL SSR** technology is rooted in the extensive experience and expertise of their developers. Johnson Matthey has been at the forefront of catalyst technology for over 70 years, with deep experience in reforming processes and industrial-scale catalyst coating. This unparalleled knowledge has informed the design and implementation of structured catalysts, ensuring they meet the complex needs of SMR facilities.

Johnson Matthey's track record of delivering reliable, high-performance solutions provides operators with the confidence that structured catalysts are a proven and dependable choice for enhancing hydrogen production.

### Conclusion

As hydrogen demand continues to grow, technologies that enable efficient and sustainable production are essential. Structured catalyst systems, exemplified by the **CATACEL SSR** reactor, offer a practical and effective means of addressing the challenges faced by SMR operators. By increasing hydrogen output without additional energy input or capital expenditure, lowering CO<sub>2</sub> emissions and carbon intensity of the hydrogen while also improving furnace efficiency with a lower steam-to-carbon ratio, these systems support both economic and environmental objectives.

With a decade of proven performance, extensive field validation, and the backing of Johnson Matthey's expertise, the **CATACEL SSR** technology is a critical innovation in the pursuit of efficient, low-carbon hydrogen production. The technology combines technical, operational, and sustainability benefits, proven by real-world performance data, positioning this solution as an indispensable tool for the evolving hydrogen economy.

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