EXECUTIVE SUMMARY

STATE OF TECHNOLOGY—METHANE PYROLYSIS

Hydrogen (H_2) is a potential clean energy solution when addressing global energy requirements in a deeply decarbonized future. Most current H_2 production processes, such as steam methane reforming (SMR) or coal gasification, dissociate H_2 from hydrocarbons via chemical transformation and co-produce carbon dioxide (CO_2) that must be captured. Other clean H_2 production methods are beginning to be scaled up and commercialized as investment in the broader technology space increases. These methods include water electrolysis and methane pyrolysis (MP). Water electrolysis does not require fossil fuel input, when produced with clean electricity, and has been discussed in prior Low-Carbon Resources Initiative (LCRI) reports (see *Insight Report on Electrolyzer Technologies*: 3002021864). The current report will address production of clean H_2 via methane pyrolysis. This process is unique in clean H_2 production from fossil fuels because no CO_2 is formed as the products are gaseous H_2 and solid carbon. This is potentially advantageous as the transport and storage of solid carbon are likely to be easier and cost less than those of CO_2, with the solid carbon having the potential to be sold in a number of commercial products.

This report will provide a high-level technical overview of MP, a comparative analysis of existing and emerging technologies, including their technology readiness levels (TRL), anticipated techno-economic barriers, and knowledge gaps.

Key insights from the full report include:

- Based on the current body of knowledge, non-oxidative, fossil-based pyrolysis production could serve as a near- to mid-term bridging solution in the production of clean H_2. Several options exist for MP; distinguishing factors include differences in energy supply, reactor design, efficiency, and target products.
- Current H_2 production technologies, such as SMR, are standardized processes designed to maximize process efficiencies, product quality, and performance. SMR operating conditions (temperature, pressure, and reaction times) and energy requirements are optimized for large-scale production. Conversely, most MP processes are in the conceptual design phase. Experiments are underway to identify ideal heat sources and optimal process conditions to reduce cost while improving efficiency and conversion rates.
- Plasma-based and other non-catalytic decomposition processes benefit from the higher methane (CH_4) conversion rates due to higher temperature operation. However, temperatures greater than 1500°C (2732°F) limit the choice of compatible materials, adversely impact equipment life, and exacerbate heat losses. Depending on the temperature of the application, the process must be optimized to counter these effects for long-term operation.
- Despite the availability of abundant catalyst options and ongoing research and development (R&D) studies to reduce catalyst deactivation, challenges exist in separating solid catalysts from the solid carbon product. Molten metal-based catalytic processes have partially addressed some of the issues concerning carbon formation and potential fouling, but the viability of running a molten metal catalytic process continuously at a larger-scale has not yet been demonstrated. In addition, the volume of molten catalyst needed for larger scale production requires further investigation. Future R&D efforts are needed, to identify low-cost, auto-regenerating catalysts that are relatively inert to carbon fouling.

- Innovation to solve fundamental issues associated with solid carbon separation and process challenges associated with product carbon management needs further investigation. Companies are exploring trade-offs that may be required to maximize revenues given the market demand for these products.
- An important, but often overlooked, aspect of prior studies of MP is feedstock gas quality. The difference between feedstock used (natural gas vs. CH_4) can have an impact on the process performance and H_2 product quality. While most studies to date have used CH4 as feedstock, natural gas typically contains many other compounds, such as CO_2, H_2O, higher order hydrocarbons, and sulfur compounds. In some instances, these minor species could complicate catalyst life and increase product cost.
- An abridged summary of published techno-economic analysis findings is included in this report. Most developers state that favorable economics are contingent upon carbon market value, CO_2/greenhouse gas penalty costs, natural gas prices, input energy sources, and other technology-specific constraints.

The full report expands upon the TRL status for MP technologies, provides updates on this rapidly evolving field, and identifies current technical gaps.

The Low-Carbon Resources Initiative

This report was published under the Low-Carbon Resources Initiative (LCRI), a joint effort of EPRI and GTI Energy addressing the need to accelerate development and deployment of low- and zero-carbon energy technologies. The LCRI is targeting advances in the production, distribution, and application of low-carbon energy carriers and the cross-cutting technologies that enable their integration at scale. These energy carriers, which include hydrogen, ammonia, synthetic fuels, and biofuels, are needed to enable affordable pathways to economy-wide decarbonization by mid-century. For more information, visit www.LowCarbonLCRI.com.

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