LCRI LOW-CARBON RESOURCES INITIATIVE

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EXECUTIVE SUMMARY

BLUE HYDROGEN PRODUCTION

Hydrogen is inherently a low-emission fuel at the point of use, but its life-cycle greenhouse gas emissions can be substantial without a means to reduce CO_2 emissions from its production. Thus, the efficacy of hydrogen as a fuel, chemical feedstock, energy carrier, or energy storage medium in a low-carbon economy is rooted in the ability to produce low-carbon hydrogen economically. The production of hydrogen from natural gas by a chemical reaction in conjunction with capture and sequestration of the CO_2 produced during the process (known as "blue" hydrogen) has become an important part of the global response to limiting greenhouse gas emissions and climate change impacts. This report describes an array of commercial and developmental technologies for producing hydrogen from fossil fuels—chiefly natural gas, but, in some cases, other hydrocarbons—along with approaches to economically incorporate CO_2 capture into the production process. Approaches to CO_2 capture covered in the report span chemical absorption, adsorption, membrane, and cryogenic processes, along with developmental pyrolytic processes for the direct capture of solid carbon from methane.

A focus of the report is to provide readers with information on the status of pilot- and commercial-scale demonstrations, adding CO_2 capture processes to conventional commercial hydrogen production methods, as well as the status of pilot tests of hydrogen production processes with inherent carbon capture. The goal is to create an overall snapshot of the level of activity and commercial readiness (and levelized cost) of blue hydrogen production technology.

Key findings from the full report are summarized as follows:

- CO_2 capture has been demonstrated at commercial scale on key CO_2-laden gas streams in the steam methane reforming production process, yielding carbon capture rates of about 60%, but it has not yet been demonstrated at scale on all of the process CO_2-laden gas streams, which would yield carbon capture rates of 90% or higher.
- The use of regenerable sorbents in conjunction with steam methane reforming can reduce the required reforming reaction temperatures, saving energy, and can increase the purity of the separated CO_2, reducing the need for subsequent processing for commercial use or geologic sequestration. Sorbent-enhanced steam methane reforming processes can also have a smaller plot plan footprint than conventional steam methane reforming with CO_2 capture.
- Gasification processes using solid fuels such as coal and petroleum coke have been applied commercially to make synthetic natural gas and ammonia-based fertilizers. Gasification is also suitable for producing hydrogen, using CO_2 capture processes on pressurized synthesis gas streams, which reduces the energy demand of the capture process.
- Partial oxidation technologies using gaseous feedstocks are akin to gasification technologies using solid fuels. Partial oxidation processes use high-purity oxygen rather than steam in their reforming reactions, and the heat to drive the hydrogen production reactions is generated internally to the reactor rather than externally as in steam methane reforming, thereby reducing the number of CO_2-laden process streams to which CO_2 capture needs to be applied. Like gasification, the synthesis gas streams being treated are at elevated pressure, reducing the energy demand of the capture process. However, the cost and energy demand of an oxygen production plant is incurred in a partial oxidation process.

- Autothermal reforming is a single-reactor process that conceptually combines steam methane reforming and partial oxidation. It is nearly heat neutral and energy efficient, with high hydrogen yields. Its operation at high pressure reduces the energy requirements for subsequent compression of product hydrogen for transportation or high-pressure applications.
- Methane pyrolysis is at an earlier stage of development relative to other low-carbon hydrogen production technologies, but it offers the prospect of lower overall energy consumption and high-value solid carbon byproducts.
- Each of the major processes for producing hydrogen from natural gas—steam methane reforming (and its variants), partial oxidation, and autothermal reforming—appears economically competitive when adapted for CO_2 capture; large, announced projects for low-carbon hydrogen production with CO_2 capture span each of these processes.
- The levelized incremental cost of adding CO_2 capture to large-scale hydrogen production plants using natural gas feedstocks has been estimated at about \$0.50/kg-H_2 when commercial and/or low-cost CO_2 off-take options are available.

The full report surveys the types and development status of initiatives to integrate carbon capture and sequestration into the major technologies for producing hydrogen from fossil fuel feedstocks, especially natural gas. Findings are drawn from research reports, technical papers, and websites summarizing government-funded and private-sector research on hydrogen production with CO_2 capture; technical reports by non-profit research organizations; technology developer websites; and "trade press" news articles.

The Low-Carbon Resources Initiative

This executive summary 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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