EXECUTIVE SUMMARY

REVERSIBLE FUEL CELL REVIEW

Reversible fuel cells are systems that can act as low-carbon hydrogen producers and in reverse as power generators, potentially reducing cost and space requirements by combining the two functions in one device. They can also serve as mid- and long-duration energy storage systems with minimal standby losses. Multiple fuel cell and electrolyzer companies are working to advance the technology readiness level of reversible fuel cell technologies, typically with support from government research organizations. Reversible fuel cells have the potential to provide the benefits of fuel cell power generation (high efficiency, low emissions, and quiet operation) and electrolytic ("green") hydrogen production combined in one device. These benefits can currently be achieved using optimized electrochemical stacks in separate fuel cells and electrolyzers. Thus, a fundamental question for unitized reversible fuel cells is whether design trade-offs can be balanced in such a manner that their levelized cost is lower than the levelized cost of a paired system of similar capacity, but independent, electrolyzer and fuel cell. In the broader context of energy storage, hydrogen energy storage using an electrolyzer and fuel cell must develop to be competitive with other energy storage technologies capable of durations ranging from diurnal to seasonal with minimal standby losses. Further, technical questions remain about the potential readiness of reversible fuel cells, including their ability to be durable and flexible over long periods of operation with daily cycling; their ability to meet capital cost and efficiency targets, including for some technologies the ability to function effectively with low-cost alternatives to platinum-group metal catalysts; their ability to manage and store thermal energy between power generation and electrolysis cycles; and their timeline for becoming commercially competitive.

This report summarizes a literature review of reversible fuel cell technologies and current research funded by the U.S. Department of Energy and others. EPRI findings from previous fuel cell reports also served as a source of information.

Key insights from the full report include:

- Of the five primary electrolyte chemistries used for fuel cells, three underpin development efforts for reversible fuel cells: proton exchange membrane, solid oxide, and alkaline. No reversible fuel cell technology is currently commercial.
- A unitized, reversible fuel cell stack typically entails design compromises relative to independently optimized electrolyzer and fuel cell stacks.
- Among the design aspects posing challenges in a reversible fuel cell are flow management of feedstocks and products, water purity control, thermal management, electrode architecture, catalysts (where used), operating pressure, and durability.
- Polymer electrolyte membrane reversible fuel cells have the greatest operating flexibility in terms of start time and ramp rate.
- Solid oxide reversible fuel cells have the highest efficiency, but they also operate at the highest temperature and therefore have the longest start time.
- One developer of both polymer electrolyte membrane and aqueous alkaline membrane technologies has observed that alkaline technology has a lower cost for the stack of electrochemical cells but has higher costs for balance-of-plant equipment (at large scale) and higher maintenance costs.

- Benefits of successful reversible fuel cell development include lower capital costs and smaller unit footprints (i.e., higher energy density) for hydrogen utilization, expanded options for grid-connected and off-grid long-duration energy storage systems with minimal standby losses, fast-start/fast-ramp resources that contribute to grid reliability and resiliency, renewables-balancing resources that boost their utilization, and quiet, compact, and emission-free capacity for power generation and low/zero-carbon hydrogen production.

This report can help LCRI members understand and plan for the commercial availability of reversible fuel cells, and how they may be incorporated into distributed power plant/energy storage and low-carbon hydrogen production portfolios as new assets.

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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