## EXECUTIVE SUMMARY

# ELECTROLYZER SYSTEM DESIGN FUNDAMENTALS AND DURABILITY CONSIDERATIONS

Hydrogen produced via electrolysis is poised to play an important role in ongoing decarbonization efforts across various sectors. Companies within these sectors are evaluating how incorporating hydrogen produced by electrolysis as a low- or zero-carbon energy carrier or fuel into their operations will impact their respective value chains. Economic implications, as well as operational reliability, flexibility, and safety considerations, are important when integrating electrolysis-based systems into established processes. Ensuring that electrolyzers can withstand the diverse operating modes, variable energy inputs, and potential operational deviations has increased the importance of understanding electrolyzer durability.

Durable electrolyzer systems can provide stable performance over time in various operating conditions. Conversely, durability losses over time not only directly affect key performance indicators such as system efficiency, but can also limit safe operating conditions. In addition, the scalability of hydrogen production using electrolysis depends on the total cost of hydrogen production and system reliability. This report investigates these considerations.

Key findings from the full report include the following:

- Understanding the durability of electrolysis systems aids assessment of electrolysis system reliability and development of realistic feasibility studies for electrolysis plants.
- Electrolyzer manufacturers have significantly improved—and continue to improve—the efficiency and lifetime of their commercial offerings. However, more long-term testing is needed, especially in intermittent operation mode.
- Changes in the stack voltage, temperature, and pressure are known to be the key factors accelerating electrolyzer degradation.
- Durability losses over time affect key performance indicators such as system efficiency and water usage for cooling, and also limit safe operating conditions.
- Electrolysis system durability directly and indirectly affects all three cost categories of capital expenditures, fixed operation and maintenance (O&M) and variable O&M.
- The electrolyzer stack is the heart of the system. However, more durability tests should entail full system testing, as opposed to only testing stacks or cells.
- Although the majority of mitigation strategies for stack degradation rely on optimizing electrolyzer manufacturing and improving materials selection, some plant design and upkeep considerations can help improve stack durability. Following are examples of such considerations:
  - Monitoring and maintaining water quality can decrease the chance of ionomer and membrane poisoning, catalyst deactivation, and system corrosion.
  - Use of polarization rectifiers can reduce the reverse current effect for alkaline electrolyzers.
  - Maintaining stack temperature via proper cooling system design can enhance stack durability.

- Balance-of-plant (BOP) subsystem use in other industries has provided a reasonable understanding of BOP system reliability. However, the industry needs to better understand the effect of BOP performance fluctuation on electrolyzer stacks.
- As the European Union and the European Commission's Joint Research Centre move toward standardizing performance and durability testing, additional effort is needed worldwide to create standards and guidelines for the industry.

The full report reviews electrolyzer technology design, technology fundamentals, and power requirements. It examines electrolyzer stack degradation and BOP durability considerations. The report then reviews operational system impacts, including system considerations for electrolysis system degradation and degradation monitoring. It then summarizes key findings and recommended future durability research.

**The Low-Carbon Resources Initiative**

This report was published under the Low-Carbon Resources Initiative (LCRI), a joint effort of the 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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