LCRI LOW-CARBON RESOURCES INITIATIVE

EPRI

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EXECUTIVE SUMMARY

Feasibility Study for Carbon-Free Compressed Air Energy Storage

PRIMARY AUDIENCE

Staff who are involved with energy storage and resource planning, corporate strategy, new resource procurement, and technology assessment, along with those who assess reference sites.

SECONDARY AUDIENCE

Policymakers, researchers, educational institutions, energy and power generators, and other stakeholders who want to understand the development of emerging energy storage technologies.

KEY RESEARCH QUESTION

Energy storage is expected to play a large role in future power systems, especially with higher variable renewable energy deployment and increasing decarbonization targets. The key research question behind this study is whether a combined hydrogen and compressed air energy storage (CAES) system, which produces hydrogen from renewable-generated electricity, stores it alongside compressed air underground, and then utilizes this stored energy for carbon-free dispatchable power generation, is technically and economically feasible. The study aims to assess the economic implications, system performance, and overall feasibility of this innovative concept, including factors such as capital and maintenance costs and efficiency. The findings contribute to the understanding of the potential of hybrid compressed air and hydrogen storage systems to support sustainable energy objectives.

RESEARCH OVERVIEW

This study centers around a comprehensive techno-economic investigation into the feasibility of an innovative energy storage concept – a so-called "carbon-free CAES" system that combines hydrogen and CAES at an actual utility host site. This novel approach integrates electrolytic hydrogen production from renewable power sources and underground storage utilizing salt-mined caverns, along with the compression and storage of air.

The primary objective of the study is to assess the feasibility of this innovative CAES system concept, ultimately laying the groundwork for a more detailed design and a resultant commercial-scale demonstration. The study delves into key technical facets of the research, including system performance, cost implications, and overall project feasibility, while exploring multiple case technology options.

KEY FINDINGS

The findings from this front-end engineering and design study provide critical insights into the feasibility of carbon-free CAES and its potential role in the evolving landscape of sustainable, long-duration energy storage (LDES):

- **Technical feasibility:** This feasibility study confirms the technical viability of a carbon-free CAES system. It showcases higher round-trip efficiency compared to hydrogen fuel cell systems and impressive capabilities for long-duration and large-scale storage, affirming its value as a robust LDES solution.
- **Economic challenges:** The economic analysis performed reveals that the current financial outlook for the carbon-free CAES project is unfavorable. High capital costs of $4,500–$5,000/kW present challenges that need to be addressed to enhance the project's commercial viability. The proposed project's relatively small scale caused significant economies-of-scale impacts, which would be reduced at larger sizes and longer durations. Projected reductions in the cost of producing hydrogen through electrolysis in the future will also improve the overall economics.
- **Environmental benefits:** While the system can be designed for flexible operation to utilize natural gas in addition to hydrogen, for electric power production, the intended carbon-free approach assumes only electrolytic hydrogen would be used. Under these conditions, the project concept contributes positively to sustainability goals. The carbon-free approach significantly reduces greenhouse gas emissions and aligns with the transition to cleaner energy sources.
- **Innovative approach:** The study features the innovative nature of the carbon-free CAES concept. In particular, the integration of hydrogen production and storage with compressed air provides an approach that holds promise for addressing LDES in a renewable energy landscape.

WHY THIS MATTERS

Insights from this study hold importance to industry because of their potential to advance renewable energy integration, reduce greenhouse gas emissions, foster innovation, and inform investment and policy decisions. As the energy industry seeks cleaner and more sustainable solutions, the carbon-free CAES system's technical and economic feasibility could become a critical factor in achieving these objectives, shaping the industry's direction and sustainability goals.

HOW TO APPLY RESULTS

The information presented in this report is a valuable resource for individuals tasked with evaluating the operation and performance of emerging energy storage technologies. It offers comprehensive insights into the design and operation of a carbon-free CAES system, shedding light on both its functionalities and the current challenges it faces. Ultimately, this report serves as a critical tool to provide context and informed guidance for resource planning and collaborative efforts in the advancement of this technology, ensuring that the next steps in its development are well-informed and strategically executed.

LEARNING AND ENGAGEMENT OPPORTUNITIES

- *Energy Storage Technology Database Report: 2022—Annual Year-End Snapshot Report* (3002024003)

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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GTI Energy is a leading research and training organization. Our trusted team works to scale impactful solutions that shape energy transitions by leveraging gases, liquids, infrastructure, and efficiency. We embrace systems thinking, open learning, and collaboration to develop, scale, and deploy the technologies needed for low-carbon, low-cost energy systems. www.gti.energy

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