LCRI LOW-CARBON RESOURCES INITIATIVE

EPRI GTI ENERGY

EXECUTIVE SUMMARY

LOW-CARBON FUEL PATHWAYS FOR LARGE-SCALE COMBINED HEAT AND POWER APPLICATIONS

Combined heat and power (CHP) systems utilize a single engine, also known as the prime mover, to convert fuel to both thermal energy and electric power. Due to the high combined thermal and electrical efficiency of existing CHP systems, potential for efficiency improvements to reduce carbon dioxide (CO_2) emissions is limited. Therefore, transitioning these systems to low-carbon fuels such as hydrogen and ammonia could play a key role in decarbonization of CHP. Consequently, it is imperative for prime mover original equipment manufacturers (OEMs) to consider pathways for converting existing and new CHP systems to low-carbon fuels. Depending on the system, this may mean full replacement of the prime mover with a new unit design, or retrofitting key components (e.g., fuel and combustion systems) to accommodate specific low-carbon fuels.

Key findings from the full report include the following:

- Combustion turbines, boilers, and reciprocating internal combustion engines (RICE) represent the majority of the U.S. large-scale industrial and commercial CHP prime mover population and capacity.
- Most of the large-scale CHP capacity in the industrial and commercial sectors was installed in the 1990s and early 2000s. Although more units were installed between 2010-2019, these appear to be small- or medium-sized CHP systems. Given the age of the large-scale fleet, transition to low-carbon fuels will be an important factor as CHP system owners consider prime mover end-of-life retrofits or replacements.
- Renewable natural gas (RNG) may play a role in decarbonizing the CHP fleet, if cost and supply issues can be resolved. RNG is generally considered a "drop-in" fuel for prime movers, and therefore the operational issues are already well understood.
- Prime movers that were originally designed for pure hydrogen or hydrogen-blended fuel have been demonstrated and are developing commercially. However, multiple general challenges with converting existing natural gas-fired units to hydrogen as a fuel impact combustion-based prime mover technologies. Hydrogen has significantly different gas properties than natural gas, diffuses into most materials due to its small molecular size, poses various safety risks, has a higher flame speed than natural gas (which can lead to combustion flashback), and has a higher adiabatic flame temperature than natural gas, potentially leading to higher nitrogen oxides (NO_x) production rates.
- Ammonia poses multiple general challenges as a fuel that cross-cut the combustion-based CHP prime mover technologies. One of the major challenges of ammonia fuel is NO_x emissions. Unlike hydrogen or most hydrocarbons, ammonia contains nitrogen atoms. The fuel-bound nitrogen readily participates in the NO_x formation chemistry. In addition, ammonia is difficult to burn and poses several safety risks.
- General research needs include feasibility studies that evaluate costs, benefits and enhanced resilience when converting CHP systems to (or co-firing CHP systems with) hydrogen or ammonia using various prime movers, and demonstrations to examine the use low-carbon fuels in CHP.
- For combustion turbines, more research is needed to investigate blends of hydrogen and ammonia in combustion, as some flame speed characteristics suggest the possibility of burning certain fuel blends in current natural gas-fueled CTs without significant modifications to the combustion systems.[1]

- For boilers, research needs include demonstrations of on-site hydrogen co-firing with the base fossil fuel to help assess the severity of hydrogen issues, improved understanding of performance degradation in boilers where SCR for NO_x control may not be practical, combustion issues associated with ammonia, and demonstrations for incremental fuel blending of ammonia.[2]
- For RICE, research needs include understanding the prechamber best suited to hydrogen through ignition studies, determining the best method for delivering hydrogen to the chamber, identifying appropriate materials through metallurgical research, and demonstration of on-site hydrogen co-firing with the base fossil fuel as an intermediate strategy that can help assess the severity of hydrogen issues.[3]

This report summarizes information from multiple Low-Carbon Resources Initiative (LCRI) reports and projects covering specific industrial-scale CHP prime mover technologies. It provides an update on the current population, fuel types, and capacities of industrial and commercial CHP systems in the United States. The report summarizes the key combustion and emissions challenges introduced by firing low-carbon fuels, specifically hydrogen and ammonia, in larger industrial CHP prime movers, including combustion turbines, boilers, and RICE. The report concludes with recommended future work for OEMs and researchers to accelerate hydrogen and ammonia fuel pathways for relevant large-scale industrial and commercial CHP prime movers.

1. *Low-Carbon Fuel Pathways for Gas Turbine Applications.* EPRI, Palo Alto, CA: 2022. 3002020539. https://www.epri.com/research/products/000000003002020539.
2. *Low-Carbon Fuel Pathways for Combustion-Based Boiler and Heat Recovery Steam Generator Applications.* EPRI, Palo Alto, CA: 2021. 3002020531. https://www.epri.com/research/products/000000003002020531.
3. *Technology Update: Reciprocating Internal Combustion Engines for Low-Carbon Power Generation.* EPRI, Palo Alto, CA: 2021. 3002020044. https://www.epri.com/research/products/000000003002020044.

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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