EXECUTIVE SUMMARY

RECIPROCATING INTERNAL COMBUSTION ENGINES FOR LOW-CARBON POWER GENERATION

Reciprocating internal combustion engines (RICE) have been a stable and reliable provider of power for a variety of applications for decades, including automotive and marine transportation. Stationary engines have also provided emergency/backup power needs as well as baseload generation in regions with limited fuel access. Typically, these engines were diesel, compression-ignition types that operated off liquid fuels. More recently, medium-speed, spark-ignited engines, in sizes ranging up to 25 MWe, have been applied, operating off natural gas (NG) or on a dual-fuel basis, to support the ancillary services market in locations with a higher degree of variable renewable energy.

As efforts intensify to decarbonize the power sector, and generating assets capable of flexible operation take on a greater role in grid balancing, it is increasingly important to understand what options are available to contribute to low-carbon electricity in the future. Engines are a candidate for low-carbon fuel use and have a potential role as part of the low-carbon power market because of their significant fuel and operational flexibility, relatively high efficiency, and low cost.

Key findings include:

- Application of post-combustion CO_2 capture to RICE plants is likely uneconomic in most cases because of their small unit size and largely intermittent operational profiles, so decarbonization of power produced by RICE is expected to be driven by decarbonization of the engines' fuel supply.
- Nearly all of the major engine manufacturers are exploring engine operation on low-carbon fuels. Among the low-carbon fuels of interest for RICE plants are hydrogen, ammonia, biofuels, and synfuels. In some cases, RICE are already using low-carbon fuels (for example, biogas) and, in others, the estimated timeline to commercial readiness is within the next 3–5 years (for example, ammonia and hydrogen) with some variance depending on the manufacturer and market developments.
- In the near term, many initiatives for RICE plants are targeting intermediate reductions in greenhouse gas emissions by blending hydrogen with NG. Manufacturers report that engines designed for NG can accommodate hydrogen blends of up to 20–25% (volume) without requiring hardware modifications.
- Manufacturers are exploring engine operation on 100% hydrogen, too, but don't see the market developing in the short term. Optimizing an engine for operation on pure hydrogen also reduces its flexibility to use other fuels for backup. Challenges related to the use of pure hydrogen include optimizing the fuel injection approach, mitigating NO_X emissions, and materials selection. The necessary engine design modifications to run on 100% hydrogen are more substantial, whereas the modifications needed to run a <25% (volume) hydrogen/NG blend are likely minor.

- Biofuels are already being used commercially in engines. Biodiesel can generally be used as a direct substitute for conventional diesel with only minor accommodations (for example, fuel filter changeout), and an extensive commercial history exists for the operation of RICE units on biogases from landfills, livestock operations, and wastewater treatment plants.
- Methanol and ammonia initiatives appear focused, at present, on marine applications. Engine modifications being explored for the use of these fuels involve fuel handling, fuel injection, and cylinder heads, and should largely be transferrable to stationary power generation applications for these fuels.

The full report provides a summary of the current status of engines, an overview of low-carbon fuels, challenges for RICE when using these fuels, research ongoing in this space, and potential next steps that could be undertaken as part of the Low-Carbon Resources Initiative to advance RICE using low-carbon fuels. The report summarizes a literature review and interviews with engineers at RICE manufacturers, national laboratory and university researchers, and consulting firms that provided insights into RICE operations and efforts to adapt the technology to low-carbon fuels. The report also provides recent findings from the Electric Power Research Institute's RICE Interest Group and Technical Assessment Guide activities.

The Low-Carbon Resources Initiative

This executive summary was published under the Low-Carbon Resources Initiative (LCRI), a joint effort of the Electric Power Research Institute (EPRI) and Gas Technology Institute (GTI) 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.

Technical Contact: Dr. Andrew Maxson, *Program Manager,* 650.862.7640, amaxson@epri.com

3002021871 July 2021

Electric Power Research Institute
3420 Hillview Avenue, Palo Alto, California 94304-1338 • PO Box 10412, Palo Alto, California 94303-0813 USA • 800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com

© 2021 Electric Power Research Institute (EPRI), Inc. All rights reserved. Electric Power Research Institute, EPRI, and TOGETHER . . . SHAPING THE FUTURE OF ELECTRICITY are registered service marks of the Electric Power Research Institute, Inc.