LCRI LOW-CARBON RESOURCES INITIATIVE

EPRI GTI ENERGY

EXECUTIVE SUMMARY

ASSESSMENT OF LOW-CARBON FUEL PATHWAYS FOR RAIL TRANSPORT

Rail transport plays an essential role in the modern global economy, accounting for 8% of passenger traffic and 7% of freight, but only about 1.9% of final energy demand in the transportation sector.[1] With electricity accounting for 39% of the sector's final energy demand,[2] rail is also the most electrified transport segment.

Despite rail's inherent efficiencies, the scale and interconnectedness of the industry warrants decarbonization action. Taking into account emissions from electricity generation and emissions from mining, transport, and storage of fossil fuels, rail contributes about 4.2% of the transportation sector's greenhouse gas (GHG) emissions,[2] with diesel-fueled freight transport the most significant contributor.[1] As decarbonization in electricity production progresses, the focus for deep decarbonization efforts in the sector shifts to addressing the most emissions-intensive, difficult-to-electrify segment: long-distance freight rail. Line-haul freight locomotives are primarily diesel-fueled and so present the greatest opportunities for reducing carbon emissions in this industry.

Key findings from the full report include:

- Because rail is already highly efficient, shifting passenger and freight transport from on-road transport modes and aviation to rail offers significant emissions reduction potential.
- Passenger rail and some short-haul freight segments are already widely electrified via overhead (catenary) wires or third rails supplying electricity to power the locomotive. Electrified locomotives are commercially available and may offer the highest overall per-ton energy efficiency, where practical.
- Increased uptake of efficiency measures, such as anti-idling technologies, energy management systems, and regenerative braking offer some potential for nearer-term emissions reduction. However, deep decarbonization of the sector requires a large-scale transition of freight rail to lower-carbon, alternative energy sources, such as battery electric power and low-carbon fuels.
- Freight rail is less suited to line electrification due to the cost of installing overhead wires for these long-distance, lower utilization routes. Battery electric locomotives are at a high technology readiness level but are primarily in use for short-haul operations.
- Blending conventional diesel with lower-carbon, near-drop-in fuels can reduce emissions with lower up-front costs, and the industry is already using 5% biodiesel fuels and beginning to introduce 20% blends. However, fuel demand competition with other end-use sectors, adverse impacts to engine life, and maintenance impacts pose challenges to increased biofuels adoption in rail. While work continues on retrofits or engine redesigns for higher-proportion blends, biodiesel is generally viewed as a near-term, transitional solution in this industry.

1. The Future of Rail. International Energy Agency, Paris: 2019. https://www.iea.org/reports/the-future-of-rail
2. Railway Handbook 2017: Energy Consumption and CO2 Emissions. International Energy Agency and International Union of Railways: November 2017. https://www.iea.org/reports/railway-handbook-2017

- Dual-fueled natural gas locomotive engines are also under development. Renewable and synthetic natural gas could reduce the GHG footprint of these systems. However, the use of natural gas has been limited to date.
- Although some research and development (R&D) on ammonia has been done, industry stakeholders are beginning to focus on hydrogen as a longer-term deep decarbonization solution for applications that are not feasible to electrify. Most work in hydrogen-fueled rail centers on hydrogen fuel cells (HFCs) with battery energy storage and regenerative braking. This technology is in early-stage, small-scale commercial use for passenger transport, while development of line-haul HFC locomotives remains at the R&D stage.
- At present, all low-carbon energy carriers under consideration are significantly more expensive than diesel fuel, and future costs are not yet well understood. These pathways rely heavily on fuel production, transport, and storage infrastructure development, each with significant uncertainty in required investment and potential operating costs. Hydrogen-based alternatives, in particular, require substantial capital investment.

This report reviews decarbonization solutions for rail transportation, especially freight, because long-distance trains produce the greatest proportion of GHG emissions in this industry. The discussion addresses direct electric pathways as well as the key alternative energy carriers: ammonia, hydrogen, natural gas (and related fuels), and biodiesel. The report discusses research gaps and development status, highlighting noteworthy demonstration and early-commercial projects.

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.

Technical Contact: Rick Ranhotra, Senior Technnical Leader, 404.884.4324, rranhotra@epri.com

3002025337 August 2022

EPRI
3420 Hillview Avenue, Palo Alto, California 94304-1338
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com