



A Fast, Cost-Effective Path to Decarbonization of Heavy-Duty Vehicles

The world is in desperate need of technologies that can quickly and cost-effectively abate the 5-Gt annual CO₂ emissions of heavy-duty sectors, such as on-road freight transportation and off-highway equipment. While electrification is helping to curb tailpipe emissions of light-duty and short-range transportation, large-scale deployment in heavy-duty sectors is still decades away. These industries need solutions today that can bridge the gap to a decarbonized future.

With funding from the National Science Foundation (NSF), ClearFlame Engine Technologies, a startup based in Geneva, IL, is addressing this need. It has pioneered technology that enables lower-carbon and carbon-negative fuels to be easily integrated into diesel engine platforms, offering a more sustainable and cost-effective solution than today's engines. Their technology provides the same performance and efficiency of diesel engines, while eliminating the need for complex aftertreatment. By replacing 100% of the petroleum fuel with lower-carbon fuels such as ethanol or methanol, their solution significantly reduces greenhouse gas emissions, particulate matter, and smog, helping to meet stringent emissions regulations while reducing overall engine cost.

The ClearFlame technology relies on a high-temperature combustion pro-

cess that allows diesel-style (mixing-controlled) combustion of any fuel regardless of ignition characteristics. High temperatures enable short ignition delay times for fuels like ethanol, creating diesel-like behavior from a non-diesel fuel. This is achieved by reduced compressor after-cooling, use of hot (soot-free) exhaust recirculation, and insulation on select combustion chamber surfaces. The fuel injection system is also engineered to accommodate the new fuel.

These innovations, taken together, make it possible to use low-carbon fuels while delivering performance and efficiency. In 2020, the company demonstrated its technology with a 15-L heavy-duty engine that used ethanol in place of diesel fuel. The ethanol-based engine matched the full 500 hp and torque curve of the commercial engine.

While achieving net-zero emissions is a key benefit of the ClearFlame solution, simplifying adoption is a critical factor. In engines with ClearFlame technology installed, 80–90% of the components are the same as a standard heavy-duty engine. Therefore, existing production and supply chains can be used to produce these engines, with an additional opportunity to rebuild/retrofit engines already in use.

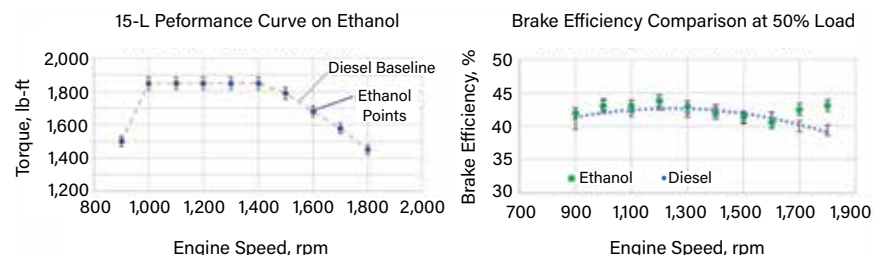
ClearFlame is working to build

an ecosystem around low-carbon and carbon-negative liquid fuels, forming partnerships with producers who can expand fuel availability. The total cost of ownership (TCO) of heavy-duty equipment will decrease due to the low cost of alcohol fuels and the elimination of soot, which otherwise imposes significant maintenance and capital costs on the engine exhaust system. The company will put its first 500-hp demonstration trucks on the road in late 2021 and begin testing with fleets in early 2022. Because of the ubiquity of diesel engines, ClearFlame is also forming partnerships with makers of off-road equipment, stationary generator sets, and other manufacturers in applications that are difficult to electrify.

“Decarbonizing liquid fuels is a critical step in a low-carbon future for commercial transportation. While promising, battery and fuel cell technologies have many hurdles to overcome. Charging/hydrogen infrastructure and limited vehicle range are two significant challenges, particularly in Class 8 long-haul truck markets that consume the most energy,” says Steve Ciatti, Principal Engineer for Advanced Engines at PACCAR. “Leveraging existing infrastructure for liquid fuels with decarbonized sources of those fuels is the most rapid way we can meet future greenhouse gas targets for heavy-duty long-haul trucks.”

Through the environmentally sustainable and cost-saving technology developed by ClearFlame for diesel engines, the company will help reduce the carbon emissions of the heavy-duty sector and bring about a greener future.

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▲ Performance (left) and efficiency (right) data from a 15-L heavy-duty diesel engine operating on 100% fuel-grade (ASTM 4896) ethanol using ClearFlame technology.

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