New combustion strategies plus biofuels add up to cleaner, more efficient cars and trucks

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Last year, average fuel economy for light-duty vehicles hit a new high, while the pandemic reduced time on the road, fuel consumption, and emissions. These short-term reductions have spurred efforts to cement

even greater long-term fuel efficiency gains and emissions reductions for gasoline-powered vehicles, which are likely to make up the majority of the U.S. automotive market for years to come. At the same time, to meet delivery demands from surges in online ordering by quarantined Americans, freight trucks have regained activity and diesel consumption levels even higher than those seen prior to the pandemic.

A report released this month highlights the most significant breakthroughs of the last year in the U.S. Department of Energy's (DOE's) Co-Optimization of Fuels & Engines (Co-Optima) initiative, with details on findings that could translate into significant greenhouse gas (GHG) and tailpipe emissions reductions. Researchers from the National Renewable Energy Laboratory (NREL) and eight other national laboratories are collaborating to examine how simultaneous improvements to vehicle fuels and engines can boost energy efficiency and the use of renewable fuels, while cutting emissions.

Much of the Co-Optima research focuses on components known as blendstocks, which can be produced from a wide spectrum of domestic resources, including renewable biomass—such as forestry, agricultural, and food waste—and combined with petroleum-based fuels. Co-Optima researchers have made significant progress in understanding blendstocks' impacts on vehicle efficiency and emissions, with Fiscal Year 2020 (FY20) research concentrating on multimode combustion strategies for light-duty (LD) vehicles and mixing-controlled compression ignition (MCCI) and advanced compression ignition (ACI) strategies for medium-duty (MD) and heavy-duty (HD) vehicles.

"When we combine these new blendstocks with petroleum-based fuels in advanced engines, we're seeing substantial cuts in polluting emissions," said NREL Senior Research Fellow, Advanced Fuels and Combustion Platform Leader, and Co-Optima Leadership Team Member Robert McCormick. "We're talking about blendstocks that reduce greenhouse

gas emissions by more than 60% compared to the petroleum fuel they displace and also reduce tailpipe soot emissions from both cars and commercial trucks—which ultimately means cleaner air and a healthier planet."

Bioblendstocks To Meet Emissions and Cost Targets for Trucks

The diesel-fueled MCCI engines typically found in commercial freight trucks deliver strong power and fuel economy, but require costly and complex control systems to meet emission regulations. FY20 Co-Optima research revealed potential for many candidate MCCI blendstocks to reduce MD and HD criteria pollutant emissions and cut life cycle GHG emissions by more than 60% compared to conventional petroleum-derived diesel, while meeting commercial vehicle production and operational cost requirements.

NREL contributions to this Co-Optima MD and HD research included:

- Using enhanced modeling capabilities to simulate deployment of Class 8 freight trucks using a 10% biofuel blend, revealing potential for a 7.5% decrease in cumulative GHG emissions between 2025 and 2050 (with greater emissions reductions at higher biofuel blend levels)
- Identifying a unique molecular structure, catalyst, and biomass conversion strategy to produce a potentially high-performance, low-carbon, cost-effective bioblendstock for use in diesel engines
- Applying advanced computational methods to discover optimal compression-ignition engine control strategies capable of reducing emissions threefold without a significant dropoff in power

- Quantifying how low-net-carbon biofuel blendstocks can deliver high engine efficiency, with fewer harmful tailpipe emissions and lower life cycle GHG emissions than standard diesel fuel
- Showing how chemical structure affects the sooting tendency of biofuels produced from agricultural and forestry waste to aid the design of cleaner new high-performance blendstocks.

Co-Optima researchers from across the initiative used techno-economic and life cycle analyses to assess and rank potential MCCI blendstocks against 19 metrics for technology readiness, economic viability, and environmental impacts. Renewable diesel produced from wet wastes and used cooking oil using certain methods delivered the most favorable economic potential and emissions reductions. Most candidate blendstocks offered favorable economic metrics, four with target case prices below $4 per gasoline gallon equivalent.

Fuel Properties To Maximize Multimode Engine Efficiency for Cars

Engines that use boosted spark ignition (SI) during acceleration or climbing grades and use ACI/lean-SI modes in more typical driving conditions are known as multimode engines. In FY20, Co-Optima researchers identified 10 bio-based blendstocks that show potential for compatibility with SI, ACI, and other advanced combustion modes, life cycle GHG emissions reductions of at least 60%, high market penetration potential, and better performance when used in LD multimode engines.

NREL's Co-Optima LD research included:

- Identifying techniques to capitalize on blendstocks that provide nonlinear fuel property benefits to deliver greater-than-average

performance, efficiency, and emissions reductions when blended with future fuels and combined with new combustion strategies
- Developing a speedy and accurate online tool to help researchers identify the molecular structure of low-emission, high-efficiency biofuels in seconds rather than days
- Tailoring the composition of biofuels made from woody biomass to provide higher energy density, along with ignition properties and low soot-forming potential vital to boosted SI and multimode engine performance.

ACI and lean-SI combustion modes and engine technologies can boost efficiency and cut emissions for all types of vehicles in typical conditions, while maintaining power density and efficiency gains through turbocharging, direct injection, engine downsizing, and downspeeding. The collaborative Co-Optima team found that all 10 blendstock candidates met the criteria for use in multimode engines, with five demonstrating significantly fewer barriers to adoption, and one (ethanol) already on the market.

New Partners To Accelerate Development and Adoption

Through a competitive process, DOE selected new industry-led projects in FY20 to accelerate the development and adoption of commercial high-performance biofuels by leveraging the unique experimental and computational capabilities of the national laboratories. Shell was chosen to collaborate with NREL on applying metabolic engineering and process optimization to the biological production of the high-performance blendstock isopropanol. The team recently completed its initial computational analysis for the project.

"As industry partners have joined the team, we're that much closer to

completing our handoff," McCormick said. "Eventually, industry will use the scientific underpinnings from Co-Optima to develop the clean, efficient, and affordable new fuels and vehicle engines we need for a sustainable future."

More information: The report is available online: www.energy.gov/sites/default/f … -fy20-yir-report.pdf

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