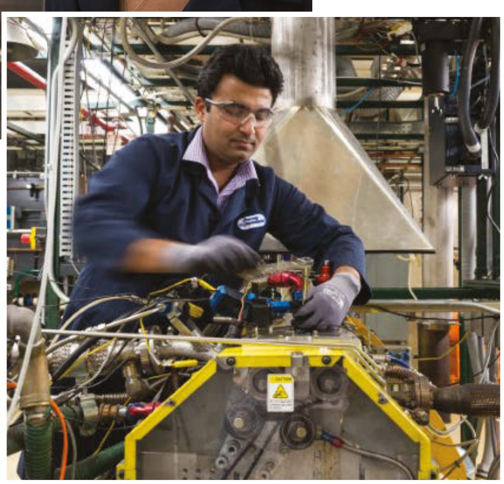
Co-Optimization of Fuels & Engines

SCIENTIFIC INNOVATION FOR EFFICIENT, CLEAN, AND AFFORDABLE TRANSPORTATION

FUELS AND ENGINES AS DYNAMIC DESIGN VARIABLES

While vehicles are becoming more efficient, the properties of conventional fuels continue to limit the performance of internal combustion engines in most cars and trucks currently on U.S. roads. The U.S. Department of Energy (DOE) Co-Optimization of Fuels & Engines (Co-Optima) initiative is bringing together top scientists, engineers, and analysts from nine national laboratories with more than 20 university and industry partners across the country to investigate fuels and engines as dynamic design variables that can work together to boost efficiency and performance, while minimizing emissions. Applications include the entire on-road fleet, from light-duty (LD) passenger cars to heavy-duty (HD) freight trucks.



Co-Optima brings together top researchers from national laboratories and universities to explore simultaneous improvements to fuels and engines.

Photos:
Top – National Renewable Energy Laboratory (NREL),
Bottom – Argonne National Laboratory (ANL)

The objective scientific outcomes of this initiative will provide American industry and policymakers with the knowledge, data, and tools needed to decide which changes could prove most viable and beneficial for drivers, businesses, and the environment.

Potential benefits include dramatic improvements in vehicle fuel economy and increases in the use of domestically sourced fuel for transportation. This, in turn, has the potential to create new U.S. jobs and keep energy dollars in the United States, while reducing emissions and costs for consumers and commercial operators at the pump.

RIGOROUS SCREENING TO IDENTIFY BLENDSTOCK POTENTIAL

A major portion of Co-Optima research is focused on identifying blendstocks that can be added to conventional liquid fuels to tailor the fuel properties. Researchers are considering blendstocks that can be produced from a wide variety of domestic resources, including nonfood domestic biomass such as forestry and agricultural waste. Research is exploring options that pair these blendstocks with combustion solutions including:

- Turbocharged (or “boosted’) spark-ignition (SI) and multimode approaches for LD vehicles targeting a 10% improvement in fuel economy. This is beyond an already expected 25% improvement in fuel economy for engine-only advances anticipated through 2025 (reference case is a 2015 baseline).
- Mixing-controlled compression ignition (MCCI) for medium-duty (MD) and HD trucks targeting a 50% reduction in engine-out criteria pollutant emissions (compared to a 2009 baseline).
- Advanced compression ignition (ACI) for the full range of vehicle classes targeting 60% brake thermal efficiency with a 50% reduction in engine-out criteria pollutant emissions (compared to a 2009 baseline).

WIDE-REACHING COLLABORATION

Co-Optima leverages synergies across DOE’s Office of Energy Efficiency and Renewable Energy (EERE). Led by EERE’s Vehicle Technologies Office and Bioenergy Technologies Office, partners include Argonne, Idaho, Lawrence Berkeley, Lawrence Livermore, Los Alamos, Oak Ridge, Pacific Northwest, and Sandia national laboratories; the National Renewable Energy Laboratory; and numerous university and industry partners.

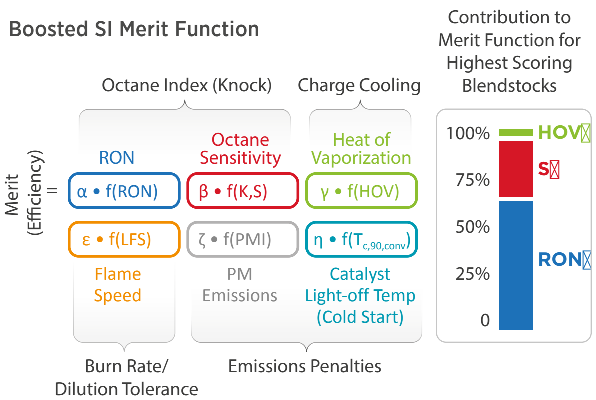
PINPOINTING PROPERTIES TO OPTIMIZE LIGHT-DUTY PERFORMANCE

Breakthroughs in Boosted SI Research

In fiscal year 2018, the Co-Optima team completed research focused on full-time operation of boosted SI engines and fuels for LD vehicles. Researchers determined:

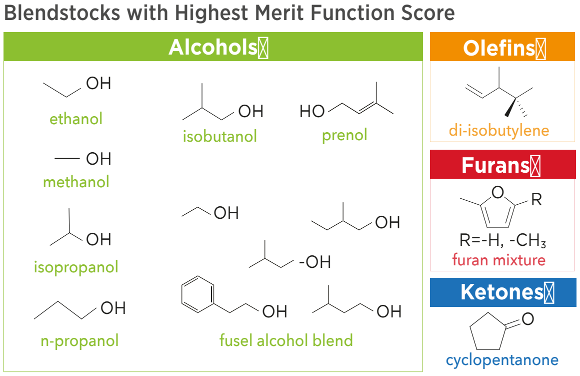
- How fuel properties impact boosted SI engine performance
- Which blendstocks offer desired fuel properties and life-cycle energy benefits
- Projected barriers to commercial introduction for representative blendstocks.

Through development of a quantitative merit function to evaluate the potential thermal efficiency benefits of multiple fuel properties, Co-Optima researchers revealed how engine parameters (compression ratio, downsizing) and optimization of fuel properties can improve fuel efficiency. Research octane number (RON), octane sensitivity (S), and heat of vaporization (HOV) proved to be the fuel properties with the greatest impact on boosted SI engine efficiency.



This made it possible to identify 10 blendstocks from four chemical families—alcohols, olefins, furans, and ketones—with the greatest potential to increase boosted SI efficiency. Collectively the Co-Optima research and analysis has led to a much-improved understanding of the trade-offs of fuel costs, engine technologies, and fuel economy.

Blendstocks with Highest Merit Function Score



Ongoing Multimode Research

Ongoing Co-Optima LD research and development is focusing on multimode solutions that make use of boosted SI and ACI combustion modes to enable additional engine efficiency improvements across a broader range of the vehicle drive cycle, along with potential for greater cost savings and fuel economy. ACI combustion has well-documented potential to improve efficiency and emissions under typical operation, but poses challenges in certain conditions.

Multimode SI/ACI combustion is projected to deliver substantial engine efficiency improvements across the speed-load range while maintaining power density and efficiency gains achieved through downsizing and downspeeding. Research is currently underway to expand the understanding of fuel properties on ACI combustion through a focus on fuel-dependent kinetics of autoignition, flame initiation and propagation, spray development, mixture formation, combustion development, and soot formation.

MEETING CHALLENGES UNIQUE TO MEDIUM- AND HEAVY-DUTY VEHICLES

MD and HD vehicles present challenges that are distinct from those of LD vehicles. Co-Optima MD/HD research is investigating options that range from near-term MCCI solutions to longer-term kinetically controlled ACI concepts. MCCI diesel engines are very efficient but require complex and expensive emissions control systems. Co-Optima researchers are exploring opportunities to reduce MCCI engine-out emissions and the corresponding expense of emissions controls systems.

This includes screening potential blendstocks from 18 chemical families to assess properties vital to MCCI combustion. Kinetically controlled combustion has the potential for higher engine efficiency with lower engine-out emissions. Early-stage research in this area is examining fuel properties and engine technologies that offer improved efficiency, reduced emissions, and a wider range of operability.

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