Request for Information (RFI) DE-FOA-0001460: Co-Optimization of Fuels and Engines

**Category 2**: Input on Barriers to Market Acceptance and Deployment

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## Overview

To resolve the "chicken and egg" dilemma associated with the introduction of new emission control technology and new fuels, EPA has required new fuel formulations to be widely available by a date certain or multi-year phase-in schedule[1]. Auto manufacturers are thereby assured that the technology can be introduced without damage to the engine or emission control system, negative impacts on customer acceptance or unnecessary emission warranty issues. Such was the case with unleaded gasoline in 1975 and low sulfur gasoline in 2004.

Compelling data from auto manufacturer research indicates that a new 98 Research Octane Number (RON) high octane spark ignition engine fuel could enable substantial engine efficiency improvements via higher compression ratios, direct injection, pressurized intake systems and electronic engine controls, producing substantial reductions in greenhouse gas (GHG) emissions to meet new fuel economy and GHG standards. Auto manufacturers have indicated that they could introduce this technology in the next 5 to 10 years provided the fuels are widely available. A mid-level ethanol blend fuel based on current commercial E10 gasoline could offer the most cost-effective alternative without adversely affecting toxic and particulate emissions.

Research at Oak Ridge National Laboratory (described as Optima Thrust I in the EERE 102 Request for Information document) in collaboration with the Coordinating Research Council (CRC) and auto manufacturers has already demonstrated the GHG reduction potential of this combination of engine and fuel technologies. A recent Statement of Work funded by the National Corn Growers Association will demonstrate the GHG reduction potential of 98 RON mid-level ethanol blend fuel on a prototype vehicle equipped with these technologies provided by a major global auto manufacturer. Different from previous research projects with "match blended" fuels intended to isolate the effects of individual fuel properties, the fuel for this program will "splash blend" additional ethanol into current commercial E10 gasoline to approximately 30 percent ethanol to achieve at least 98 RON as commercial E30 would likely be supplied in actual use.

Based on BETO's mission in the EERE 102 Request for Information document, conventional ethanol produced from corn may be the only biofuel in mid-level blends with gasoline that can meet the listed goals: Mid-level ethanol blends (MLEBs) are compatible with today's liquid hydrocarbon fuel storage and distribution infrastructure with well understood minor modifications to address the properties of ethanol. It is widely accepted that corn ethanol reduces GHGs by at least 20 percent relative to gasoline. Perhaps most importantly and following several

[1] See "Statutory and Regulatory Backdrop for Fuel Standards" presentation by Paul Machiele, Fuels Center Director, EPA, January 28, 2013, to Mobile Source Technical Review Subcommittee meeting in regard to EPA statutory authority to regulate fuels.

years of incentives for "advanced" and cellulose derived biofuels, corn ethanol remains the only biofuel that can be produced in sufficient quantities to displace a substantial share of petroleum derived fuels in a near term time frame of 5 to 10 years[2].

In order to successfully introduce a high octane mid-level ethanol blend fuel, the potential of mis-fueling must be addressed. Valuable experience is available in the switch to unleaded gasoline in the mid-1970s where lead additives would permanently disable catalytic converters that were introduced across all news cars in 1975. In the current proposed situation, vehicles would be designed for high octane 98 RON fuel and would not operate satisfactorily with conventional "regular" grade gasoline, and in the conventional vehicle fleet, only 15 million Flexible Fuel Vehicles (FFVs) out of approximately 270 million total vehicles are designed to operate on mid-level ethanol blends. Some have suggested that regular grade gasoline could eventually be replaced entirely with 98 RON E30 given sufficient lead-time for all manufacturers to design for compatibility with MLEBs.

Conventional regular grade gasoline would have to be maintained for some time period to support conventional vehicles. The lower retail price of leaded regular gasoline compared to unleaded regular was a major mis-fueling issue in the 1970s. However, since ethanol used to boost the octane of gasoline provides a positive value to the consumer on an energy equivalent basis without any subsidies, this is not expected to be an issue if a 98 RON MLEB is priced correctly, is widely available around the country and retail stations that do not offer the 98 RON MLEB as an option also do not sell low-cost 87 octane regular gasoline[3]. If these conditions exist, then mis-fueling could likely be successfully addressed with an adequate public education program and proper identification on vehicles and fuel pumps. Otherwise, more robust mis-fueling prevention measures such as electronic communication between vehicles and fuel pumps may need to be considered.

## Responses to Specific Questions

1. *Are there additional barriers or nuances that should be considered? If so, please describe.*

   Nearly all regulations relating to vehicle emissions and fuel economy had their origins at a time when nearly all motor vehicles where powered by gasoline or diesel fuel. These fuels had a number of properties in common, such as the amount of energy contained in each gallon of fuel. Today, as these fuels are being joined by a variety of other renewable fuels, many of the common terms used in regulation become less relevant.

   One such example is the term "miles per gallon," or MPG, as a metric for fuel economy. MPG is really a measure of two factors: 1) how efficiently the vehicle uses the energy contained in the fuel, and 2) how much energy is contained in a given volume of fuel. When virtually all fuel had similar energy density, MPG was used as a metric for the first function, overall efficiency.

[2] For instance, the US Department of Energy, in its 2011 U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry report , stated that "with continued developments in biorefinery capacity and technology, the feedstock resources identified could produce about 85 billion gallons of biofuels." By comparison, Air Improvement Resource has calculated that total fuel sales will fall to the 100 billion gallon range as a result of more stringent fuel economy standards.

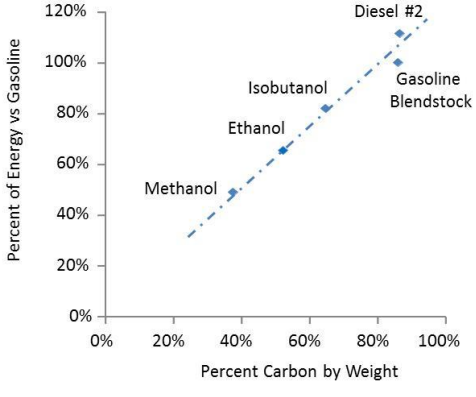
[3] "The Economics of Eco-Performance Fuel", April 22, 2014, Thomas Darlington, AIR, David Aldorfer, D4, Dean Drake, D4, Gary Herwick, TFC and Thomas Walton PhD, D4

With only one fuel type to choose from:

- Consumers used MPG as a surrogate for those characteristics they were really interested in: how much it cost to drive a given distance and how far they could travel without having to refuel, and
- The government uses MPG as a surrogate metric for vehicle efficiency in its Corporate Average Fuel Economy, or CAFE, program.

Many chemical compositions considered as low carbon fuels (LCFs) inherently have less energy per gallon than gasoline. As shown in Figure 1, page 3, the relationship between the percent carbon by weight in a liquid fuel and the energy contained in a gallon of each fuel is essentially linear. While many fuels have less energy than gasoline, that characteristic alone has little relevance to the government's goals of considering new fuel formulations -- lower greenhouse gas emissions and replacement of fossil fuels – and the consumers' desires for low fuel cost per mile and range (which is also a function of fuel tank size).

Figure 1. Energy Density Primarily a Function of Carbon Concentration




Fortunately, the law creating the CAFE standards established fuel economy standards that, while expressed in terms of MPG, specified that the standards were the MPG of a vehicle when tested using the test procedures and fuel used in 1976. In the event that the US Environmental Protection Agency (EPA) changed the test procedures or fuels, its MPG results were to be adjusted using a value called the "R-factor."

Thus, whatever new fuel /engine technology systems emerging from the Optima program would require new, specific R-factors to reflect the lower energy density of lCFs.

2. *Without relying on regulation, how could the Optima effort generate significant market pull? For example, could green marketing generate consumer demand?*

Some use of EPA's regulatory authority may be required to remove market barriers to the release of a new fuel or enable compatibility between new fuels and the vehicles designed to use them. Examples include the above-mentioned R factor regulations, the gradual phase-out of low octane fuel to eliminate the potential of misfueling and regulations to free retailers to use new fuels without violating their contracts with oil companies. In addition, other agencies such as the California Air Resources Board have independent regulatory authority for regulating fuel and their own tools such as the ability to do Multi-Media Modeling that could be a valuable addition to the Optima program. Finding appropriate avenues to engage these agencies throughout the Optima process would significantly enhance the ultimate success of Optima fuel.

3. *What is the value proposition (real or perceived) to consumers that would enable a price differential? How does this alter the strategy for market entry of co-optimized fuels and vehicles?*

   Consumers' fuel purchasing habits are difficult to change. Preliminary results from the D2R studies by Defour Group[4] show that the two most valued properties in a new fuel that motivate consumers to shift fuels are:

   - Lower average cost per mile traveled than gasoline. Stations that participated in the Yellow Hose Program priced E85 at a point that consumers would realize a lower cost per 100 miles travelled. On average, this added value to consumers tripled sales per pump of E85.
   - Consistent value over time compared to regular gasoline. While retailers who get their E85 from oil companies are tied to prices that vary widely over time, Yellow Hose Program prices are pegged to the price of regular gasoline. Thus, consumers are confident that the positive consumer value they were getting from their decision to switch to E85 flex fuel will be available whenever they purchase fuel.

   One key to success of D2R E85 programs is that they are not a part of the oil industry's business model. Unlike oil companies that sell a wide variety of fuels, ethanol producers must ensure the economic success of one product – E85 – in its competition with gasoline.

   Before it can be considered a commercial success, the Optima fuel must:

   - Reach sales volumes per pump equivalent to gasoline and
   - Be widely available throughout the country.

   Otherwise, without a strong regulatory mandate like unleaded gasoline, auto manufacturers would be reluctant to sell vehicles that require Optima fuel until the fuel is widely available. Therefore, the initial consumers of Optima fuel are likely to be the same as those who buy D2R E85 flex fuel– owners of Flex Fueled Vehicles (FFVs). For the Optima fuel to become successful, more FFVs will need to be in the fleet than is now likely with current manufacturer incentives. Incentives for the continued manufacture of FFVs provided by the "F-Factor" in current regulations must be re-examined and perhaps restored in some form rather than being phased out completely in a few years.

4. *Is there a value proposition for fuel providers that would improve the chances of an Optima fuel being brought to market?*

   Fuel providers and retailers attempting to market ethanol blend fuels greater than 10% are encountering a variety of regulatory and non-regulatory barriers. For instance, federal and state fuel property standards put many fuel blends in legal jeopardy. Often, the contracts between retailers and their suppliers make introducing a new fuel more difficult. For an Optima fuel to be a success, these barriers will need to be addressed. These same obstacles will confront the Optima fuel, and may need to be addressed through regulation.

[4] The results of this study will be part of a final report in the Spring of 2016.

5. *Are you aware of any innovative business models for the introduction of new fuels that could be optimized to enable value distribution across the entire supply chain?*

   Ethanol producers that use D2R models for selling E85 have also been creating their own brands and retail outlets. For instance, in California, one producer (Propel) is building its own brand for E85 sales by installing "Propel" brand pumps at retail outlets of other brand fuels and building and operating their own retail stations. This concept could be expanded to not only market Optima fuel, but provide EV recharging stations and CNG refueling facilities as well.

6. *What is the best strategy for transitioning new engine or fuel production technology to the marketplace?*

   The best strategy for transitioning requires coordinated regulatory and non-regulatory incentives. The Optima program can resolve key questions that must be answered to encourage progress, such as:

   - What is the formulation of the new fuel?
   - What are the benefits of the new fuel?
   - How is the new fuel to be produced? (e.g., match blend vs splash blending)

   The Optima strategy should be shared with other agencies and branches of government to influence their actions as well. For instance:

   - EPA and NHTSA need to know what changes to regulations need to be made at the mid-term review of 2017 – 2025 fuel economy standards as well as what may need to be done at the 2026 and later fuel economy rulemaking.
   - If the Optima fuel is to use ethanol, then Congress needs to know what actions are necessary after the current Renewable Fuel Standard expires in 2022.

   Finally, automakers need to have a roadmap for fuel introduction and vehicle regulatory enablers enacted.

   - What is the likelihood that low cost high octane fuel will be widely available, and when can that be expected to happen?
   - Does the R factor for the new fuel fully correct for the energy density issues with low carbon fuels?
   - Will there be any incentive for automakers to ramp up the production of flex fueled vehicles in advance of the Optima fuel rollout to ensure there are sufficient vehicles in the fleet to provide sufficient demand for the fuel in its early years?
   - What provisions are being made to prevent the possibility of low octane fuel being introduced into a vehicle that requires the Optima fuel (misfueling)?