Understanding the Emissions Benefits of Higher Ethanol Blends:

EPA Modeling Fails to Tell the Whole Story

CFDC CLEAN FUELS DEVELOPMENT COALITION

A White Paper from the Clean Fuels Development Coalition

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As Chair of the Technical Committee for the Urban Air Initiative (UAI), Steve's strong mechanical background, collection of technical data, and engineering relationships have offered beneficial insight into America's energy and environmental needs. He has been involved over the past several years in numerous projects surrounding the use of higher blends of ethanol. Recent testing encouraged by Steve has helped to publish several Society of Automotive Engineers (SAE) papers on ethanol performance. Steve has also been instrumental in other projects related to emissions testing. His desire to develop new ideas then expanded his work into engine and fuel properties. Some of these findings led to the need to inform and educate the public through the formation of UAI.

Adding ethanol to gasoline improves it in every way. It lowers carbon, reduces common air pollutants for smog formation, lessens CO2 emissions, reduces sulfur content, and provides clean octane as a replacement for toxic aromatics. In short it makes gasoline significantly better than what would otherwise go into your tank. EPA's modeling does not show that to be the case, but it should.

Perhaps there is no better illustration of the jumbled and joint jurisdiction of the US Congress than energy policy, and specifically the Renewable Fuel Standard (RFS). On the surface it appears to be clearly in the domain of energy but a complex path that actually began with the Clean Air Act Amendments (CAA) of 1990 has landed renewable fuels under the watchful eye of the Environmental Protection Agency (EPA). Because EPA regulates fuels and emissions they control the RFS destiny despite the fact that the RFS originated in the Energy Policy Act of 2005 – which itself amended the CAA. Although biofuels have implications for energy, agriculture, and a range of economic issues, its future is in the hands of EPA. This is due in part to Congress recognizing when they created the RFS that modified the federal reformulated gasoline (RFG) program, there might be unforeseen emissions impacts. Therefore they included in the RFS legislation directives to the EPA to monitor fuels and emissions and specifically direct them to construct a model to look at various combinations of fuels and fuel properties. These models then serve as the technical basis for required reports to Congress, sometimes referred to as anti-backsliding reports, to ensure air quality is not threatened by these new fuels.

Modeling is the lifeblood of EPA in that it is the tool that allows the agency to look into the future. It is a type of balloon flattening exercise to see what happens over here when you flatten something out over there. Modeling, however, is far from an exact science and variable inputs will affect the outcome. For example, EPA's model underestimated the effectiveness of the original RFG formula that included oxygenates like ethanol to reduce ozone exceedances and, on the other hand, seriously overestimated the effectiveness of simply lowering gasoline vapor pressure. The California Air Resources Board (CARB) model used by many regulators was at odds with EPA's model on issues ranging from vapor pressure to NOx. Both models failed to grasp the realities of how consumer fuels are blended at the refineries.

Recently, EPA has "re-designed" a model that has as its basis little real world applicability. In fact a recent EPA presentation to explain the model (available on the EPA/OTAQ website) admitted as much, with a note on one of the slides stating "CAUTION: Does not work this way for real fuels". This model was designed for EPA's ongoing analysis of fuels and emissions, including the anti-backsliding reports required under the Energy Bill of 2005. Unfortunately, the methodology of this so-called EPAct model is seriously flawed. Consequently the results of what is termed as the EPAct E-89 study are skewed and need to be understood.

Where the EPA Got It Wrong

As we look at this EPAct study, it is important to assess the parameters and results. Key to that is recognizing it is not just a study focused on ethanol performance and emissions but includes the blending practices that make the ethanol-gasoline fuel blend. And therein lies the problem.

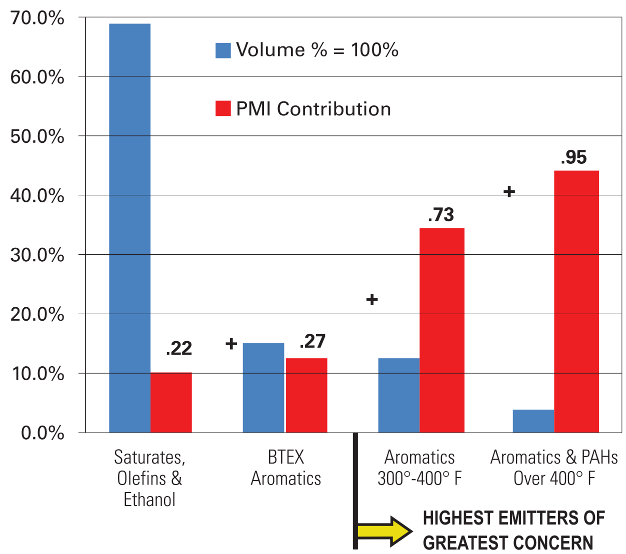
How could the EPAct report conclude that increasing the percentage of ethanol also increases harmful pollutants? The answer is in the formulation of gasoline that will later be blended with ethanol. RBOB (*Reformulated Blendstock for Oxygenate Blending*) is a good example. Refineries make a sub-octane RBOB knowing that 10% ethanol will be added later. The addition of 10% ethanol increases the fuel's octane above the required minimum. This helps explain how and what the gasoline refiners can do, knowing high octane via clean burning ethanol will be added later.

All gasoline contains hydrocarbons which contribute to air pollution. Inherently some hydrocarbons are more polluting than others. Aromatic hydrocarbons are the major source for the pollutants that are the most harmful to human health. The subject of aromatic hydrocarbons is important due to environmental concerns and long term health effects.

Continued

Oil is refined into various groups of hydrocarbons including polluting aromatics, which are then formulated to provide fuels such as RBOB. Aromatic hydrocarbons, which are a source of octane for refiners, are toxic and often carcinogenic. Figure 1 is typical of fuel composition across America and illustrates that a small portion of consumer fuel is responsible for the majority of the particulate emissions. The last 15% of gasoline emits 75% of the particulate emissions. Lowering the final boiling point of gasoline will have a dramatic effect on emissions. EPA does not limit end point allowing refineries to blend these high emitters.

Figure 1 – Average of 46 Fuel Samples



When blending E10, or E20, the physical properties of ethanol change the blended fuel's properties in terms of combustion and pollution. Adding 10% to 20% clean octane ethanol makes a big difference. This fact is known by the auto industry, and by automotive engineers who want a clean burning, high octane fuel supply.

Match or Splash?

One key reason for concern that was recognized early on by Urban Air Initiative (UAI) research is the potential variation of test results depending on whether fuels are either *splash or match blended.*

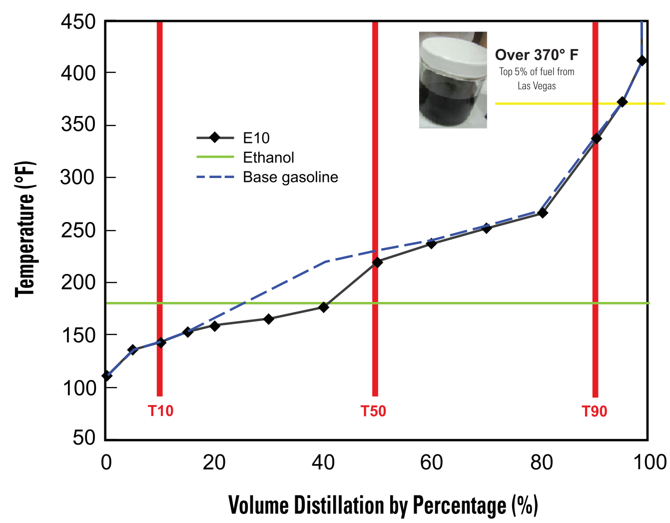
Splash blending is best described as simply adding ethanol to gasoline. Today, ethanol is added to gasoline meeting most gasoline emission and fuel quality requirements. The addition of ethanol to create E10 provides a nearly three octane point increase in order to meet the minimum 87 octane requirements. Simply adding *more* ethanol to create E15 or E20 (over the base E10) would also be considered splash blending and the original gasoline stock is not changed (for the worse) because more ethanol was added.

Match Blending, as done in the EPAct study, is when the base fuel prior to splash blending ethanol, is altered to achieve desired outcomes. For example, the match blending at the refinery is a blend of different hydrocarbons for maximum production from a barrel of oil.

What's in your tank?

Many of the molecules in gasoline are known carcinogens; especially toxic are the higher boiling point hydrocarbons also known as T90. Refineries formulate fuels around 3 main points: T10 (when 10% of this fuel vaporizes), T50 (when 50% vaporizes), and T90 (90% vaporizes).

Figure 2 – Volume Distillation by Percentage (%)



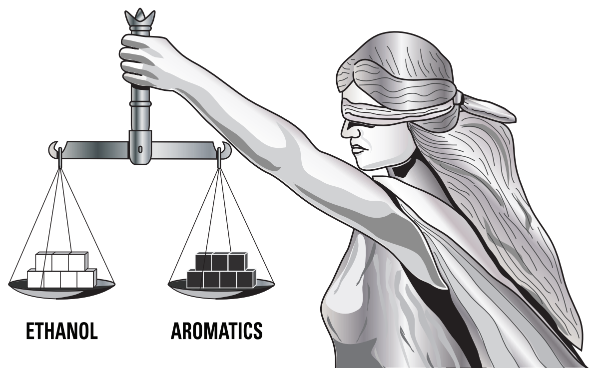
Ethanol's atmospheric boiling point is 173°F, and is represented by a straight horizontal line on the graph. As a pure liquid, and by textbook definition, ethanol boils at one temperature. Gasoline is a mixture of somewhere between 150 and 500 different types of molecules, most of them referred to as hydrocarbons. Mixtures, by definition, boil at varying temperatures depending on the molecular makeup of the mixture.

The graph shows how gasoline has an increasing boiling temperature as the gasoline sample being tested is continuously heated to maintain boiling. As the more volatile components boil first and are removed as vapor from the liquid gasoline tested, the remaining liquid composition is changing. The more-volatile content is being removed, and the liquid is being concentrated with the less-volatile components of the original test sample. The less-volatile components boil at higher temperatures which is why the boiling temperature continues to increase as the test-sample continues to boil away to near 99%.

Based on the scientific principles of Figure 2, a sample of gasoline will never reach 100% vapor. All gasoline will contain 1% to 2% residues; which by definition are not liquids. Residues in gasoline do not vaporize. If the testing is stopped below 500°F, the residues remain in the sample as a solid. These residues do burn, but not nearly as efficiently as any liquid would. Fig. 1 shows that a key contributor to fine particulate emissions are the highest distillation aromatics and residues that are always part of the last 5% of the gasoline, per this gasoline volatility test procedure.

Think of it as an old fashioned balance scale (Fig. 3). T10 and T90 balanced around T50. As shown in Fig. 2, ethanol has a boiling point below the mid-range base gasoline, essentially creating "room" for refineries to blend more T90 compounds to gasoline.

Figure 3 – Blending Scale



This is a windfall for refineries as they now can offload their toxic high boilers at the price of consumer gasoline. The net effect is that consumers all become mobile incinerators for the petroleum industry, burning their highly toxic fuels and emitting a range of particulates and other pollutants. Perhaps most deadly of these are particulates, and specifically ultra-fine particulates. These particulates are so small that they are not filtered out through human lungs and they pass directly into the blood stream. This is of grave concern to many health organizations and researchers as they begin to see a relationship between these tailpipe emissions with various health issues in urban areas. Further cause for concern is the fact that future tailpipe emission controls coupled with increased efficiency standards will require higher octane fuels. High octane ethanol offers the auto industry a clean, quality alternative to the practice of match blending high boiling aromatics.

EPA Ignores Octane

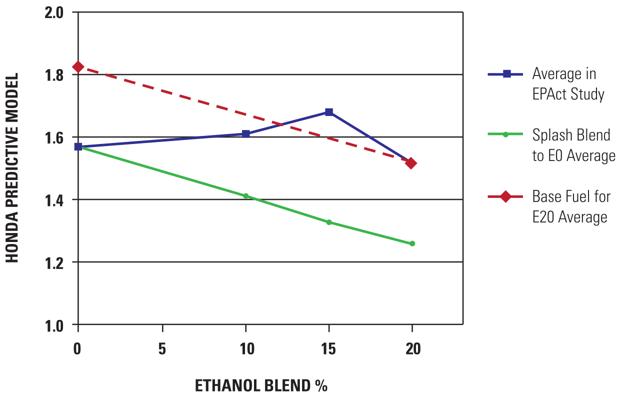
As described in this White Paper, the source of octane in fuel is critical to assessing its pollution impacts. By not holding a set octane point throughout the test, higher levels of dirty octane were added to the test fuels resulting in higher particulate emissions.

The addition of clean octane ethanol improves engine performance and reduces overall carbon emissions. Almost three points of octane (84 to 87) are gained by each 10% of ethanol blended. The auto industry is asking for more octane so they can downsize engines to improve mileage and meet future mandated efficiency. This clean octane also represents a value proposition to both refiners and automakers. Today's premium grade gasoline at 30¢ per gallon additional costs could, and should be, replaced by an additional 10% splash blended ethanol to existing regular E10. This would result in a premium grade gasoline below the cost of regular E10 while further diluting aromatics.

You may ask "What do Figures 1, 2 and 3 have to do with EPA's EPAct E-89 study?" and I say "Everything!" EPA engaged the services of the Coordinating Research Council (CRC), which is funded in part by the petroleum industry, along with a fuels expert from Chevron to formulate the various 27 fuels used in the emissions testing. They also varied T50, T90 and vapor pressure as set points for all fuels. As shown in Fig. 2, ethanol is below T50 so compounds above T50 must be added so the scale balances. Since high-end boilers are the primary sources of particulates (Fig. 1) the *outcome of the modeling exercise is that ethanol pollutes*. Brilliant piece of work! The truth is ethanol is a single molecule that is environmentally benign. You can drink it, cleanse a wound with it, burn it in a closed room, ALL with no harmful side effects. Try that with a cup of gasoline!

To put this EPA study in context, our research at UAI used the Honda Predictive Model Index (PMI) to calculate what the particulate emissions would be for these fuels if the ethanol was removed (see Fig. 4, below). Using EPA match blending data averages for E0, E10, E15, and E20 (the blue line), removing the ethanol from E20 fuels as shown with the red dash line details the emission profile for the base gasoline. This data clearly shows how dirty these fuels were before ethanol was added. Splash blending ethanol to the average E0 resulted in a .3 reduction in fine particulates for E20 (green line).

Figure 4. Utilizing Honda Motor's PMI SAE 2010-01-2115



The Bottom Line

As stated, had octane been a fuel parameter, ethanol blended fuels would have favorably compared to fuels in the test. As a result, its superior health, performance, and economic value is hidden. And, it is important to recognize that none of the 27 test fuels would be available in the market place because the costs of these fuels would be much higher due to the aromatics used for blending. They were simply *match blended to achieve a desired outcome!*

EPA states that each of the test parameters cannot be viewed separately but since several parameters like octane were not part of the blending properties, the value for ethanol is significantly hidden.

Per the data and charts published in the final EPAct report, understanding how fuels respond for each of the five parameters of this match blending, is paramount.

If the EPAct study results show that 19 of the 27 match blended fuels containing ethanol had an increase in tailpipe emissions (Fig.5), how can removal of the ethanol also show increases in these same tailpipe emissions?

The intent of Congress in directing EPA to develop models and conduct testing was to assure that splash blending ethanol with consumer gasoline would maintain air quality. EPA has repeatedly relied on studies and data that penalize ethanol and err on the side of petroleum. Importantly, these studies continually fail to show proper consideration for the impact of aromatics and the toxic components of gasoline. Its high time EPA reevaluates these studies which will clearly show that the splash blending of ethanol with gasoline results in improved fuel quality and protects public health.

Figure 5 – Inconsistencies in the EPAct Study

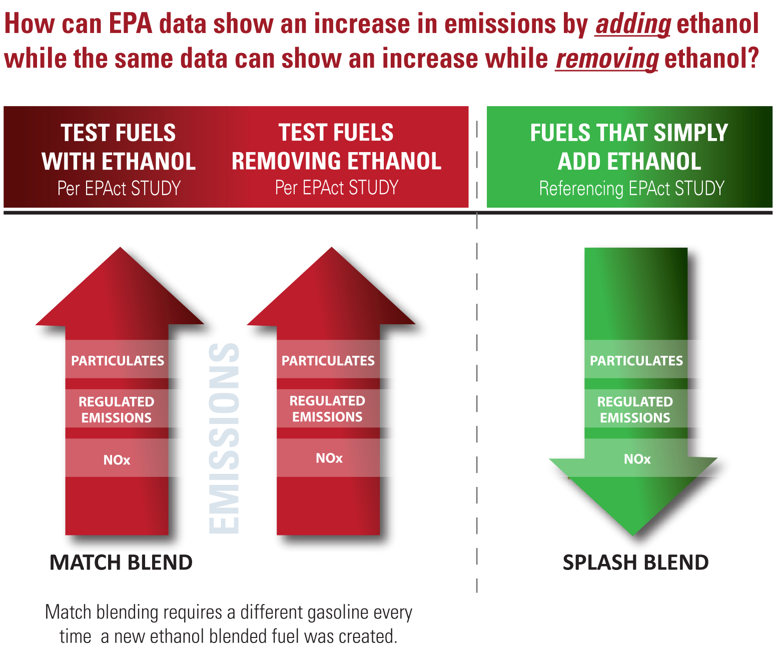


Figure adapted from EPAct Phase 3 (EPAct/VA/E-89) Final Report, page 5.
Emission data based on fuel averages during testing under the LA92 Drive Cycle.

Regulated emissions include: Total Hydrocarbon (THC), Non-Methane Organic Gases (NMOG), Non-Methane Hydrocarbons (NMHC), Methane (CH4) & Carbon Monoxide (CO)

This ***"Understanding the Emissions Benefits of Higher Ethanol Blends: EPA Modeling Fails to Tell the Whole Story"*** **White Paper** was produced and distributed as part of a continuing series sponsored by the Clean Fuels Development Coalition through the Ethanol Across America education campaign. The White Paper series provides an opportunity for public officials, industry, academia and others to express their views on issues relating to the development of ethanol and other alternative fuels. Interested parties are encouraged to submit papers or ideas to **cfdcinc@aol.com**.

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