

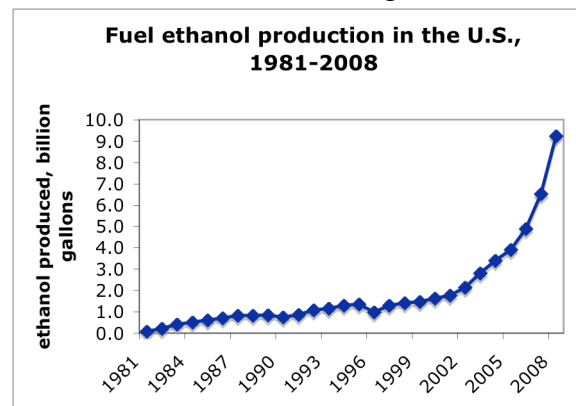
DRAFT**Ongoing Studies of E15 and E20 Ethanol Blends Indicate Risks to Human Health as well as Safety and Performance of Motor Vehicles and Non-Road Engines**

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The U.S. supplied 142.3 billions gallons of finished motor gasoline in 2007 and 137.8 billion gallons in 2008 according to the Energy Information Administration (EIA 2008a, b). As the number of cars on the road continues to grow, government and industry efforts to maintain or improve air quality must include lowering vehicle emissions and minimizing the release of toxic air pollutants. Since the enactment of the Clean Air Act in 1970, Congress and Environmental Protection Agency (EPA) have promoted a series of air quality regulations to bring less-polluting gasoline blends to the market, resulting in measurable improvements in air quality nationwide. In order to solve the energy and environmental challenges of the 21st century, we need to preserve and expand these air quality gains and protect public health by minimizing motor vehicle-related air pollution.

Ethanol was introduced into the U.S. fuel supply in 1978 through a statutory default and without proper review by EPA. For most of the past three decades, formulators have mixed very low levels of ethanol with gasoline, contrary to the industry claim that there is a successful history of “over thirty years’ experience with use of ethanol-gasoline fuel blends” (Growth Energy 2009). Only a small fraction of vehicles and equipment nationwide has been exposed to 10% ethanol (E10) fuel until recently. For example, according to statistics from Energy Information Administration, 1.6 billion gallons of fuel ethanol were produced in 2000 (EIA 2008a). If this amount of ethanol were used primarily as E10, only 12% of the 130 billion gallons gasoline sold that year would have contained ethanol (EIA 2008b). Ethanol production and fuel blending grew rapidly after 2000, increasing nearly 6-fold over the course of 8 years and reaching 9.2 billion gallons in 2008 (EIA 2008a).

Panel A: Fuel ethanol production in the U.S since 1981. Source: Energy Information Administration statistics, available at http://tonto.eia.doe.gov/dnav/pet/hist/m_epooxe_yop_nus_1A.htm.



According to the Energy Information Administration and the U.S. Department of Agriculture (USDA) statistics, 95% of fuel ethanol is produced from corn (EIA 2008a; USDA 2006; Yacobucci 2008). Several factors have led to the expansion of corn ethanol production. First, MTBE, an oxygen-enhancing fuel additive (oxygenate), was banned by multiple states after it was found to readily contaminate groundwater. The industry substituted ethanol as an alternative source of oxygen for fuel blends. The expansion of the ethanol market was also driven by the Renewable Fuels Standard (RFS) under the Energy Policy Act of 2005 and RFS revisions under the Energy Independence and Security Act of 2007, both of which provided a major political and economic boost for corn ethanol producers. The corn

ethanol industry also benefits from a 45 cent per tax credit—the Volumetric Ethanol Excise Tax Credit—that is provided for every gallon of ethanol blended with gasoline. In March 2009 corn ethanol producers asked for more help from the federal government to expand their industry. Growth Energy, a consortium of ethanol producers, petitioned the EPA to allow 50% more ethanol in gasoline, requesting approval for E15 (Growth Energy 2009).

EWG’s review of available scientific data finds that such an increase in fuel ethanol content may involve multiple human health and safety hazards and a risk of increased air pollution. Scientific consensus has not been reached on a number of issues central to an ongoing debate over corn ethanol’s benefits, including if its use reduces greenhouse gas emissions when full life-cycle impacts of the fuel additive are considered; the extent to which it might damage engines and emission systems; and whether or not emissions from fuels with increased amounts of ethanol would lead to an overall increase in health impacts from automobile-related air pollution. Also in question are the cost and safety of the extensive distribution of fuel with increased ethanol content, and the impact of higher than E10 ethanol blends on life-time performance of non-flex fuel vehicles. These outstanding questions are the subject of multiple ongoing studies that have yet to generate a comprehensive dataset suitable for definitive scientific or regulatory assessment.

A wide range of experts – including vehicle, engine, and equipment manufacturers, gasoline producers and refiners, EPA, public health experts, and the academic community – have strongly opposed introduction of E15 fuel nationwide without adequate testing. Available data clearly indicate that non-road engines and a significant fraction of older vehicles that are still on the road could be damaged by increased levels of ethanol in fuel. Comprehensive scientific analysis and testing need to be carried out before allowing E15 to be burned in the current fleet of 247 million cars, trucks, and buses and 400 million non-vehicle gasoline engines (American Lung Association 2009; Drevna 2009; Outdoor Power Equipment Institute (OPEI) 2009; U.S. EPA 2009b).

Four central concerns emerge regarding the use of intermediate ethanol blends by the current vehicle fleet and non-road engines as well as the current fuel distribution system, and are addressed in this document:

- Effects of ethanol on lifetime performance of vehicle emissions control systems;
- Emissions of toxic air pollutants associated with production and combustion of ethanol;
- Fuel economy and cost of ethanol distribution;
- Impact of ethanol fuel on non-road engines and outdoor equipment.

These issues need to be addressed and resolved in a science- and data-driven, public process before a conclusion can be reached regarding the safety and advisability of widespread use of intermediate ethanol blends (blends exceeding E10). The analysis below reviews the currently available data for each of the current health and safety concerns.

1. Effects of ethanol on lifetime performance of vehicle emissions control systems

A comprehensive review of the current state of the evidence regarding the potential impact of E15 on cars and non-road engines reveals that higher blends of ethanol can degrade emission control systems and

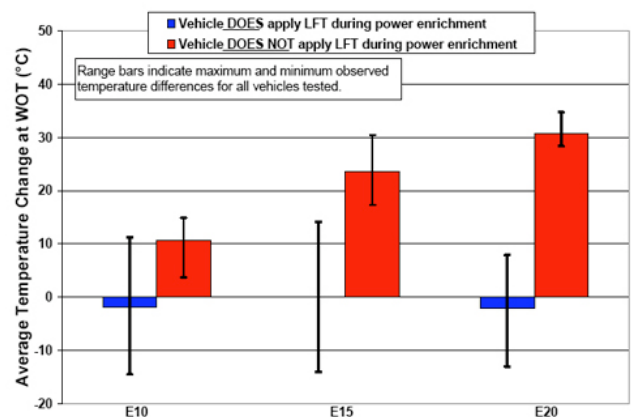
increase emissions of acetaldehyde, PM2.5 particulate air pollution, ground-level ozone and other toxic air pollutants. Optimal vehicle performance, durability, and emissions require an effective match among engine design, vehicle emission controls and cleaner-burning fuels. Technological breakthroughs achieved in the last decade brought to the market a new generation of low-emission vehicles able to adapt to a wide range of fuels. But older, legacy vehicles constitute a significant portion of the current fleet. These legacy vehicles were not designed to protect engines and emission systems by adjusting operating conditions to accommodate a wide range of fuels. Early catalyst burnout and materials damage from incompatibility with ethanol fuels would likely lead to increased vehicle and non-road engine emissions and worsening air quality (American Lung Association 2009; Australian Government 2004).

In 2007 the DOE, the National Renewable Energy Laboratory (NREL) and the Oak Ridge National Laboratory initiated a test program to evaluate the impact of E15 and E20 ethanol blends on legacy vehicles and small non-road engines (Bechtold 2007; DOE 2009). The DOE data, together with the findings of an E20 study commissioned by the Australian government and published in 2004, concurred in reporting increased exhaust and catalyst temperatures associated with ethanol fuels blends, especially for older vehicles (Australian Government 2004; DOE 2009).

Modern vehicles equipped with oxygen sensor-based, closed-loop control systems are calibrated during manufacturing to appropriately compensate for higher levels of oxygen in ethanol blends. Under open-loop conditions such as wide-open throttle, increased fuel ethanol content generally leads to leaner (less fuel-rich) operation. Many newer vehicles can adjust to ethanol-blend fuel in open-loop conditions by applying a procedure called long-term fuel trim (LFT). Modern engines are calibrated to apply the same type of fuel trim in open-loop as in closed-loop conditions and thus can maintain stable fuel/oxygen ratio. In contrast, older vehicles and even some recent models cannot perform such adjustments for higher ethanol oxygen content in fuel under open-loop conditions, resulting in hotter exhaust.

In the DOE study, 7 out of 16 vehicles tested (43%), including two 2007 model-year vehicles, ran significantly leaner during wide-open throttle as ethanol content in the fuel increased (DOE 2009). Vehicles that ran leaner during wide-open throttle compared to E0 baseline also experienced higher catalyst temperatures. Compared to E0, catalyst temperature was higher by ~10°C for E10, over 20°C higher for E15, and up to 35°C higher for E20. Increased catalyst temperatures due to ethanol blends would lead to accelerated long-term catalyst degradation, potentially causing significantly higher emissions of toxic air pollutants, the need for expensive, unplanned replacements that may fall outside of the original manufacturer’s warranty, and a shorter useful life of a vehicle.

Panel B. Increase in catalyst temperature for E10, E15, and E20 fuels compared to E0 for vehicles operated at wide-open throttle (WOT) open-loop conditions. 43% of tested vehicles (red bars) experienced higher catalyst temperatures; the rest of the tested vehicles (blue bars) were able to maintain stable catalyst temperatures. Source: Figure 3.5 in the DOE (2009) report.



Information on the expected rate of catalyst degradation is not yet available. However, if the DOE findings were representative of the overall state of the vehicle fleet, a sizable fraction of the vehicles on the road would fail to maintain stable exhaust and catalyst temperatures when operated on fuels with higher ethanol content. The potential for catalyst burnout may be indicative of a potentially wide spectrum of materials incompatibility problems for ethanol fuels (Bechtold 2007; Drevna 2009). As summarized in the 2007 DOE review, *Technical Issues Associated with the Use of Intermediate Ethanol Blends*, multiple studies found materials compatibility issues with E20, evidence of fuel filter obstruction even with E10, and likely impacts on driveability (Bechtold 2007). The Australian study reported that “greater levels of wear were observed for engines run with E20 than for those run with gasoline... [which] can result in compromise of the combustion system and lead to poor engine operation with resultant higher pre-catalyst emissions and increased fuel consumption” (Australian Government 2004). Widespread use of fuel with ethanol exceeding 10% could impact 100 million vehicles currently on the road that may be vulnerable to higher catalyst temperatures in wide-open throttle mode (American Lung Association 2009).

The DOE research has not yet addressed the lifetime effect of ethanol fuels on vehicle performance and emissions, leaving a data gap that must be addressed to know the extent to which ethanol blends are incompatible with the current vehicle fleet. Moreover, there has been no testing of the impact of ethanol on vehicle engines and emissions systems for vehicles that have run more than their estimated full life (120 thousand miles) (American Lung Association 2009). To assess the impact of intermediate ethanol blends on the full useful life of catalyst systems, DOE is now planning an 80-vehicle study of catalyst temperature, performance, and durability (DOE 2009). As EPA stated in congressional testimony recently, it will take at least a year for the completion of these lifetime vehicle performance studies, and it seems very rational to wait for these data before approving higher ethanol fuel blends (U.S. EPA 2009c). Other experts estimate that research to collect all the necessary data will require up to two years (Drevna 2009).

2. Emissions of toxic air pollutants associated with production and combustion of ethanol

Ethanol at concentrations up to 10% has served a valuable role as a fuel oxygenate, promoting more complete combustion of gasoline and reducing carbon monoxide (CO) emissions. The DOE study agreed with the original EPA findings, demonstrating an average of 15% reduction of CO emissions for E10 compared to E0. Importantly, no further CO reduction was observed with E15 and E20; in fact, vehicles operated on E20 produced slightly higher CO emissions compared to E10 (DOE 2009). E10 also reportedly reduces emissions of inhalation carcinogens benzene and 1,3-butadiene (Whitney 2007). However, EPA-mandated reformulation of gasoline and introduction of better-performing engines and vehicle emissions control systems resulted in reduced CO and benzene emissions for conventional, unoxxygenated fuels as well (U.S. EPA 2009a). Extensive research and testing carried out by the California Environmental Protection Agency Air Resources Board confirms that there might be better alternatives than ethanol or oxygenate additives in general for reducing vehicle emissions, including CO emissions (CARB 2008). These alternatives need to be thoroughly considered so that EPA and industry can implement the most economically and environmentally sound option.

While oxygenated fuels have been promoted for their potential ability to decrease certain air toxics, multiple studies have reported higher emissions of the hazardous air pollutants acetaldehyde and formaldehyde linked to increased ethanol content in fuels (Ban-Weiss 2008; Black 1998; DOE 2009; Grosjean 2002; Whitney 2007; Winebrake 2001). Both acetaldehyde and formaldehyde are considered by EPA to be probable human carcinogens (U.S. EPA 2007a). Additionally, formaldehyde is associated with respiratory tract irritation, chronic bronchitis, and airway inflammation (U.S. EPA 2007a). Acetaldehyde is a strong respiratory irritant and toxicant especially dangerous for children and adults with asthma. As demonstrated by a recent study, acetaldehyde air pollution is already above the 10^{-6} cancer risk level at most sites nationally (McCarthy 2009). Further increase in acetaldehyde could lead to increased cancer incidence and wider prevalence of respiratory problems. The table below summarizes current findings on the air pollution profile of ethanol fuel blends, indicating that instead of providing better air quality, ethanol fuel could well result in no measurable improvement, substituting one set of air pollutants for another, and possibly worsening air pollution overall (American Lung Association 2009).

Air pollutant	Findings	Human and environmental health consequences
Carbon monoxide (CO)	Decreases for E10, no further improvement for E15 and E20 (DOE 2009)	Reduces the ability of blood to carry oxygen to body tissues and vital organs; aggravation of heart disease (U.S. EPA 2008)
Benzene and 1,3-butadiene	Decrease due to dilution of gasoline with ethanol (E10) (Whitney 2007); no DOE data available so far.	Inhalation carcinogens (U.S. EPA 2007a)
Acetaldehyde	Increases by two- to three-fold (Australian Government 2004; DOE 2009), especially when the vehicles are started at cold temperature (Whitney 2007).	Respiratory toxicant, irritant, inhalation carcinogen, strongly contributes to ground-level ozone formation (U.S. EPA 2007a)
Formaldehyde	Increases for all ethanol blends compared to E0 (Australian Government 2004; DOE 2009)	Respiratory toxicant, inhalation carcinogen, contributes to ground-level ozone formation (U.S. EPA 2007a)
Oxides of Nitrogen (NO _x)	Some increase for E15 (37% of vehicles in DOE study) and notable increase for E20, especially for older, high-mileage vehicles (Australian Government 2004; DOE 2009). Increases for non-road engines at every ethanol concentration tested (E10, E15, and E20).	Aggravates respiratory disease; contributes to ground-level ozone formation; increases acidification and eutrofication of soil and surface water (U.S. EPA 2008)
Ethanol (precursor to acetaldehyde)	Released during both ethanol production and ethanol fuel combustion (Brady 2007; DOE 2009)	Health effects due to acetaldehyde formation in the air.
Volatile organic chemicals (VOCs)	Emissions increased at ethanol production facilities (Brady 2007)	Respiratory toxicants, contribute to ground-level ozone formation
Ozone	May increase with increased ethanol use due to the projected increases in VOCs and NO _x emissions (American Lung Association 2009; Jacobson 2007; U.S. EPA 2007b)	Aggravates respiratory and cardiovascular disease, higher rates of asthma, and respiratory infection. Increases premature death. Causes damage to vegetation such as trees and crops (Jerrett 2009; NRC 2008; U.S. EPA 2008)
Particulate matter (PM _{2.5})	Significant increases due to corn ethanol production compared to conventional gasoline (Hill 2009)	Aggravation of respiratory and cardiovascular disease, decreased lung function, increased asthma and premature death. Environmental influence: impairment of visibility, effects on climate (U.S. EPA 2008)

A decision to adopt a particular fuel mix should take into consideration the full spectrum of air quality effects, including the potential air pollution from all stages of production, transportation, and combustion for the fuel. Without such a complete analysis and deliberation, it would be premature to make a determination to approve increased amounts of ethanol in fuel on the basis of partial and subjectively selected data points. As clearly demonstrated by the air quality studies above, introduction of corn ethanol could well fail to produce significant improvement in air quality and instead simply substitute one set of air pollutants for a different ones, at a significant cost to society.

3. Fuel economy and cost of ethanol distribution

In addition to potentially increased vehicle emissions, ethanol blending in fuel is also associated with several hidden costs that are passed directly to consumers. Compared to gasoline, ethanol is a lower energy fuel. As a result, ethanol fuel blends are associated with significant decrease in fuel economy, which has been observed by car owners nationwide (Learn 2009). According to DOE research, E10 has 3.6% fuel economy loss compared to E0, E15 has 5% loss, and E20 has 7.7 % loss (DOE 2009).

From the infrastructure perspective, ethanol transportation and distribution is a significant economical and technical challenge, since current pipelines cannot transport ethanol. As described in a report by the Energy Information Administration:

“Ethanol cannot be moved effectively through today’s pipeline system, as it tends to get pulled into the water that usually exists in petroleum pipelines and tanks. Instead, it is blended at terminals near the end users. Splash blending, in which ethanol is added directly to a tanker truck along with the base gasoline, is commonly used. Ethanol-blended product must be kept separate from non-ethanol blends. This includes separation through to the gasoline pump. The separation is needed because adding a small amount of ethanol (from the ethanol-blended mixture) to gasoline without ethanol can increase the vapor pressure of the mixture substantially, potentially pushing it above required VOC limits. Thus, ethanol will need to be moved through an independent distribution system until it is close to the end user, where it is added before being delivered to retail stations (EIA 2002).”

Since using existing pipelines is not an option, fuel ethanol can be transported only by rail or truck (EIA 2002). Currently, the majority of ethanol fuel distribution terminals are not connected to rail. Other areas are outside economic trucking distances from production plants. A recent study from Carnegie Mellon University calculated the average delivered ethanol costs, in 2005 dollars, to be in the range of \$1.30–2.80 per gallon, depending on transportation distance and mode (Wakeley 2009). The study also noted that ethanol transportation would produce significant CO₂ emissions and thus lead to larger total life cycle effects. Researchers concluded that long-distance transport of ethanol, whatever the means of delivery from production sites to distribution locations, would likely negate any potential economic and environmental benefits of ethanol relative to gasoline (Wakeley 2009).

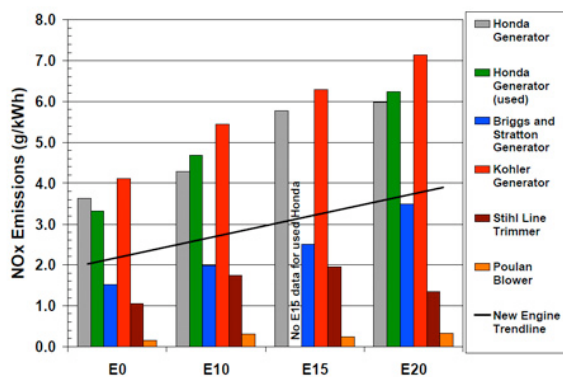
In addition to infrastructure gaps, fire safety concerns are also an issue with ethanol, since transporting and blending ethanol fuels could pose a significant fire hazard (DOT 2008; Niles 2007). Due to ethanol solubility in water, the use of water spray may be inefficient when fighting fire involving ethanol/gasoline blends mix (Missouri Department of Natural Resources 2008). Ethanol blend fuel fires cannot be readily smothered with standard fire fighting foam (Associated Press 2008; Missouri Department of Natural

Resources 2008). Distribution and dispensation of ethanol fuels above E10 could pose a significant fire hazard that requires specialized training and custom-made fire-fighting foams (DOT 2008; TRANSCAER 2009). Furthermore, current gasoline pumps have been developed to handle only up to 10% ethanol and are not certified by Underwriters Laboratories (U.L.) as safe for use with E15 (Lane 2009). While it may be possible for these pumps to handle ethanol levels up to E15, U.L. will not guarantee them for 1 percent more (for 16% ethanol concentration), a situation that can readily occur during splash-blending of ethanol-gasoline fuels (Jensen 2009) (Piller 2009; Underwriters Laboratories 2009). Premature approval of E15 could pose multiple risks due to potential leaks, fire hazard, involuntary accidents and other mishaps that would severely affect gas station owners and their customers (Jensen 2009).

4. Impact of ethanol fuel on non-road engines and outdoor equipment

Hundreds of millions of non-road engines are used across the country, including leaf blowers and line trimmers, lawn mowers, motor boats, generator sets, and small tractors. For many small engines, ethanol fuels could also be associated with increased emissions of hazardous air pollutants and ozone generators such as hydrocarbons and nitrogen oxides (American Lung Association 2009; Sahu 2009). The DOE study noted that NO_x emissions increased by 50-75% for small engines operated on E10 and E15 ethanol

blends (DOE 2009) compared to E0, as demonstrated by data in Panel C. Air pollution with nitrogen oxides leads to aggravation of respiratory disease and increase susceptibility to respiratory infections. NO_x also contributes to formation of ozone and particulate pollution with associated adverse respiratory effects (U.S. EPA 2008).



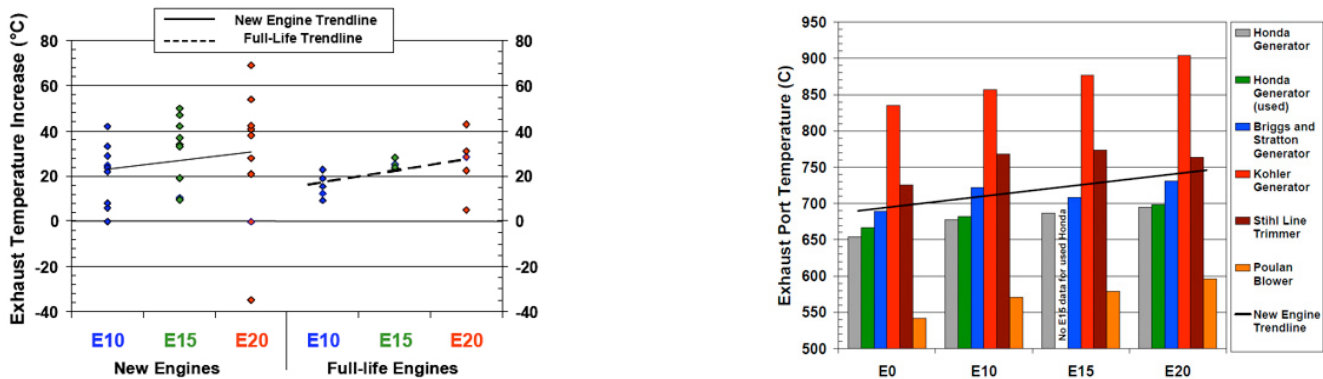
Panel C. Nitrogen oxide (NO_x) emissions for small non-road engines versus fuel ethanol content. Source: Figure 3.12 in the DOE (2009) report.

A growing body of data indicates operation of these engines on ethanol fuel blends would likely lead to both performance and safety problems. Unlike modern cars, small engines lack an oxygen sensor feedback control and are unable to compensate for higher oxygen content in ethanol-containing fuels. As a result, engines operate under “lean” or oxygen-rich conditions, which leads to engine overheating. Higher temperatures were detected for non-road engines operated on every level of ethanol in fuel (E10, E15 and E20) in the DOE study. Using an inappropriate fuel mix would impact the longevity of the engine and pose a hazard to the person operating it (Drevna 2009; Holshouser 2009; Johnson 2008; Oregon State Marine Board 2009; Outdoor Power Equipment Institute (OPEI) 2009; Williams 2008; U.S. EPA 1995).

With its initial testing of a small sample of currently sold non-road engines, the DOE study already identified serious risks to the engine user (DOE 2009). In the study, three handheld trimmers demonstrated higher idle speed and experienced unintentional clutch engagement when operated on fuels with greater ethanol content. This means that small equipment could turn on spontaneously with higher

ethanol blends, posing particular risks for equipment with exposed moving parts and blades like lawn mowers and chain saws.

Small engines also experienced “missing” and “stalling” during operation on ethanol blends in DOE’s study. As DOE reported, “small engines such as those in lawn mowers and lawn tractors, generators, line trimmers, chainsaws, and other similar equipment are open-loop engines, in that exhaust-sensing feedback is not used to control the fueling rate. Open-loop engines are commonly air-cooled and customarily operate in the fuel-rich regime to achieve cooler combustion temperatures. With a fixed fueling calibration, [increased ethanol content leads] to a higher combustion temperature and hence higher component temperatures (DOE 2009)”. The DOE detected higher exhaust temperatures for all non-road engines tested on every ethanol blend (Panel D). Relative to E0 baseline, exhaust temperatures rose by 16-42°C for E10, 19-47°C for E15 and 31-69°C for E20 (data from Table 3.13 in the DOE study).



Panel D. Exhaust temperature increased for all non-road engines operated on ethanol blends. **Left panel.** Exhaust temperature increase for all small non-road engines tested in the new and full-useful-life (full-life) condition with ethanol blends, as compared to E0 baseline. Source: Figure 3.6 in the DOE (2009) report. **Right panel** Exhaust port temperature for pilot study engines at hottest condition versus ethanol blend level. Source: Figure 3.15 in the DOE (2009) report.

DOE detected adverse performance impacts that are consistent with multiple reports by small engine owners who observed a deleterious influence of ethanol fuels on their lawn mowers, trimmers, and motor boats (Holshouser 2009; Johnson 2008; Williams 2008). In addition to performance and safety concerns, ethanol compatibility with existing engine materials is a key issue for non-road engines (Outdoor Power Equipment Institute (OPEI) 2009). The risk is especially dire for marine engines (U.S. EPA 1995). When water gets into the fuel tank, as often happens for boats, the ethanol-gasoline mixture separates, affecting boat performance or even shutting down the engine completely (Oregon State Marine Board 2009).

In a recent statement to the Senate from the National Petrochemical & Refiners Association, National Marine Manufacturers Association and Outdoor Power Equipment Institute, a wide range of safety concerns were identified for ethanol blended fuel: higher exhaust gas temperatures; possible irreversible damage to engines; loss of durability due to incompatibility of materials; disputes over warranty validity (Drevna 2009). For many small engines, ethanol fuels could also be associated with increased emissions of hazardous air pollutants and ozone generators such as hydrocarbons and nitrogen oxides (American Lung Association 2009; Sahu 2009).

Finally, most small engines are fueled from regular gas stations where the distinction between ethanol-containing and ethanol-free fuel may not be readily apparent (Fuel-Testers 2009). Thus, at the present moment small engine owners are facing a nearly impossible challenge of ensuring safe operation with fuels that are inappropriate for the task, while often lacking access to information of what fuel they are pumping into the tank. In summary, the broad range of risks that ethanol-containing fuels may pose to small non-road engines revealed in available studies does not support a decision to approve the use of intermediate ethanol blends.

Conclusion: Data gaps must be urgently addressed

The data currently available on the effects of intermediate ethanol blends indicate a potential for significant effects on human and environmental health, and do not support a decision to approve the use of ethanol above E10 levels in the U.S. A comprehensive assessment of ethanol fuel impacts on air quality should consider air emissions from all stages of fuel production, transportation, and combustion as well as fuel compatibility with the current vehicle fleet, such as effects on catalyst durability, materials compatibility and driveability. As summarized by a DOE report, “the U.S. legacy fleet is too diverse to predict E15/E20 impacts from the limited available data” (Bechtold 2007). Until these data are generated and assessed, consumer safety, public health, and environmental protection may be at risk from adoption of mid-level ethanol blends.

References

- American Lung Association. 2009. Testimony of A. Blakeman Early presented on behalf of the American Lung Association before the Senate Environment and Public Works Committee Subcommittee on Clean Air and Nuclear Safety Wednesday, April 1, 2009 Available: http://epw.senate.gov/public/index.cfm?FuseAction=Hearings.Hearing&Hearing_ID=3fdd18ff-802a-23ad-4378-d21b6beb4d5a [accessed April 1, 2009].
- Associated Press. 2008. Ethanol fuels fire concerns. A little-recognized risk: Fires require special firefighting foam [accessed February 16 2009].
- Australian Government. 2004. Department of the Environment, Water, Heritage and the Arts. 20% Ethanol (E20) Report. Available: <http://www.environment.gov.au/atmosphere/fuelquality/standards/ethanol/e20.html> [accessed February 16, 2009].
- Ban-Weiss GA, McLaughlin JP, Harley RA, Kean AJ, Grosjean E, Grosjean D. 2008. Carbonyl and nitrogen dioxide emissions from gasoline- and diesel-powered motor vehicles. *Environ Sci Technol* 42(11): 3944-50.
- Bechtold R, Thomas JF, Huff SP, Szybist JP, Theiss TJ, West BH, et al. 2007. Technical Issues Associated with the Use of Intermediate Ethanol Blends (>E10) in the U.S. Legacy Fleet: Assessment of Prior Studies. Oak Ridge National Laboratory ORNL/TM-2007/37. Available: http://www.osti.gov/bridge//product.biblio.jsp?query_id=0&page=0&osti_id=936789 [accessed January 19, 2009].
- Black F, Tejada S, Gurevich M. 1998. Alternative fuel motor vehicle tailpipe and evaporative emissions composition and ozone potential. *J Air Waste Manag Assoc* 48(7): 578-91.

Brady D, Pratt GC. 2007. Volatile organic compound emissions from dry mill fuel ethanol production. *J Air Waste Manag Assoc* 57(9): 1091-102.

CARB. 2008. California Environmental Protection Agency Air Resources Board. California Request for Oxygenates Waiver. Available: <http://www.arb.ca.gov/fuels/gasoline/oxy/oxywav.htm> [accessed April 1 2009].

DOE. 2009. Effects of Intermediate Ethanol Blends on Legacy Vehicles and Small Non-Road Engines, Report 1 – Updated. Knoll, K., West, B.H., Clark, W., Graves, R.L., Orban, J., Przesmitzki, S., Theiss, T.J. NREL/TP-540-43543 ORNL/TM-2008/117. Available: http://ferc.ornl.gov/publications/Int_blends_Rpt1_Updated.pdf [accessed March 6, 2009].

DOT. 2008. U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration Advisory Guidance: Emergency Response Involving Ethanol and Gasoline Fuel Mixtures. *Safety News*: September 19, 2008.

Drevna C. 2009. Joint Written Statement of the National Petrochemical & Refiners Association, National Marine Manufacturers Association, Outdoor Power Equipment Instituted delivered by Charles T. Drevna, President, National Petrochemical and Refiners Association before the United States Senate Environment and Public Works Committee, Subcommittee on Clean Air and Nuclear Safety concerning “Implementation of the Renewable Fuel Standard and Mid-Level Ethanol Blends.” April 1, 2009 Washington, DC Available: http://epw.senate.gov/public/index.cfm?FuseAction=Hearings.Hearing&Hearing_ID=3fdd18ff-802a-23ad-4378-d21b6beb4d5a [accessed April 1, 2009].

EIA. 2002. Energy Information Administration (EIA). Analysis of Selected Transportation Fuel Issues Associated with Proposed Energy Legislation - Summary. Available: <http://www.eia.doe.gov/oiaf/servicerpt/fuel/gasoline.html> [accessed April 7 2009].

EIA. 2008a. Energy Information Administration. Official Energy Statistics from the U.S. Government. Petroleum Navigator. Annual U.S. Oxygenate Plant Production of Fuel Ethanol. Available: http://tonto.eia.doe.gov/dnav/pet/hist/m_epooxe_yop_nus_1A.htm [accessed May 1 2009].

EIA. 2008b. Energy Information Administration. Official Energy Statistics from the U.S. Government. Petroleum Navigator. Annual U.S. Product Supplied of Finished Motor Gasoline. Available: <http://tonto.eia.doe.gov/dnav/pet/hist/mgfupus1A.htm> [accessed May 1 2009].

Fuel-Testers. 2009. Ethanol Laws - State by State Guide. Ethanol Gas Pump Labeling Laws. Available: http://www.fuel-testers.com/state_guide_ethanol_laws.html [accessed April 7 2009].

Grosjean D, Grosjean E, Moreira LF. 2002. Speciated ambient carbonyls in Rio de Janeiro, Brazil. *Environ Sci Technol* 36(7): 1389-95.

Growth Energy. 2009. Application for a waiver pursuant to section 211(f)(4) of the Clean Air Act for E-15 submitted by Growth Energy on behalf of 52 United States ethanol manufacturers in partnership with American Coalition for Ethanol, Renewal Fuels Association, National Ethanol Vehicle Coalition, Cellulosic Stakeholders: Khosla Ventures, Coskata, BioGasl, TMO, Microbiogen, Edenspace, ZeaChem Inc., Qteros. March 6, 2009. Available: <http://www.growthenergy.org/2009/e15/learnmore.asp#waverinfo> [accessed May 1, 2009].

Hill J, Polasky S, Nelson E, Tilman D, Huo H, Ludwig L, et al. 2009. Climate change and health costs of air emissions from biofuels and gasoline. *Proc Natl Acad Sci U S A* 106(6): 2077-82.

Holshouser G. 2009. Ethanol can be a headache for boaters. Available: <http://www.myrtlebeachonline.com/sports/story/782564.html> [accessed February 16 2009].

Jacobson MZ. 2007. Effects of ethanol (E85) versus gasoline vehicles on cancer and mortality in the United States. *Environ Sci Technol* 41(11): 4150-7.

Jensen C. 2009. Laboratory Will Not Certify Pumps for Gas With 15 Percent Ethanol *New York Times* May 10, 2009.

Jerrett M, Burnett RT, Pope CA, 3rd, Ito K, Thurston G, Krewski D, et al. 2009. Long-term ozone exposure and mortality. *N Engl J Med* 360(11): 1085-95.

Johnson A. 2008. Mechanics see ethanol damaging small engines. Available: <http://www.msnbc.msn.com/id/25936782/> [accessed February 16 2009].

Lane J. 2009. UL says most US gas pumps not certified for E15, as USDA, EPA meet over potential increase in ethanol blend levels. Available: <http://biofuelsdigest.com/blog2/2009/02/09/ul-says-most-us-gas-pumps-not-certified-for-e15-as-usda-epa-meet-over-potential-increase-in-ethanol-blend-levels/> [accessed February 16 2009].

Learn S. 2009. Oregon Legislature weighs ethanol bills. *The Oregonian* Thursday March 26, 2009. Available: http://www.oregonlive.com/news/index.ssf/2009/03/oregon_legislature_weighs_etha.html [accessed April 7, 2009].

McCarthy MC, O'Brien TE, Charrier JG, Hafner HR. 2009. Characterization of the Chronic Risk and Hazard of Hazardous Air Pollutants in the United States Using Ambient Monitoring Data. *Environ Health Perspec* 117(5): 790–96.

Missouri Department of Natural Resources. 2008. Ethanol and Gasoline Fuel Blend Releases. Environmental Emergency Response/Division of Public Safety - Division of Fire Safety fact sheet. 2/2008 Available: www.dnr.mo.gov/pubs/pub2240.pdf [accessed April 7, 2009].

Niles D. 2007. Paving the Way for Higher Blends. *Ethanol Producer Magazine*: October 2007.

NRC. 2008. Estimating Mortality Risk Reduction and Economic Benefits from Controlling Ozone Air Pollution. Report by the Committee on Estimating Mortality Risk Reduction Benefits from Decreasing Tropospheric Ozone Exposure, National Research Council. Available: http://www.nap.edu/catalog.php?record_id=12198 [accessed April 6, 2009].

Oregon State Marine Board. 2009. E-10 (Ethanol) in Gasoline and Where to Find Non-Blended Gas. Available: <http://www.oregon.gov/OSMB/news/E10.shtml> [accessed April 7 2009].

Outdoor Power Equipment Institute (OPEI). 2009. Premature Rush to E15 Fuel Could Injure Consumers. Available: <http://www.opei.org/ht/d/sp/i/1913/pid/1913> [accessed May 11 2009].

Piller D. 2009. UL gives green light to E15 ethanol pumps. Available: <http://www.desmoinesregister.com> [accessed February 25 2009].

Sahu R. 2009. Preliminary Comments on the DOE report titled “Effects of Intermediate Ethanol Blends on Legacy Vehicles and Small Non-Road Engines, Report 1 – Updated,” NREL/TP-540-43543 and ORNL/TM-2008/117, dated February 2009. Dr. Ron Sahu, Consultant to the Outdoor Power Equipment Institute Available: www.opei.org/ht/a/GetDocumentAction/i/1926 [accessed April 7, 2009].

TRANSCAER. 2009. Transportation Community Awareness and Emergency Response. Missouri TRANSCAER Ethanol Training Tour. Available: <http://www.transcaer.com/events.aspx?ID=19> [accessed April 9 2009].

U.S. EPA. 1995. Reformulated Gasoline and Your Motor Boat. EPA 905-F-95-002. Available: <http://www.epa.gov/otaq/rfgboats.htm> [accessed April 7 2009].

U.S. EPA. 2007a. Health Effects Notebook for Hazardous Air Pollutants. Available: <http://www.epa.gov/ttn/atw/hlthef/hapindex.html> [accessed March 17 2009].

U.S. EPA. 2007b. Regulatory Impact Analysis: Renewable Fuel Standard Program EPA420-R-07-004. Available: <http://www.epa.gov/OMS/renewablefuels/420r07004-sections.htm> [accessed April 6, 2009].

U.S. EPA. 2008. National Air Quality - Status and Trends through 2007 EPA-454/R-08-006. Available: <http://www.epa.gov/airtrends/2008/index.html> [accessed January 20, 2009].

U.S. EPA. 2009a. Mobile Source Air Toxics. Available: <http://www.epa.gov/otaq/toxics.htm> [accessed April 1 2009].

U.S. EPA. 2009b. Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program. Notice of proposed rulemaking. EPA-HQ-OAR-2005-0161. Available: <http://www.epa.gov/otaq/renewablefuels/rfs2-nprm-preamble-regs.pdf> [accessed May 5, 2009].

U.S. EPA. 2009c. Written Statement by Margo T. Oge, Director, Office Of Transportation And Air Quality, Office Of Air And Radiation, U.S. Environmental Protection Agency to the Committee On Environment And Public Works, Subcommittee On Clean Air And Nuclear Safety, United States Senate. April 1, 2009 Available: http://epw.senate.gov/public/index.cfm?FuseAction=Hearings.Hearing&Hearing_ID=3fdd18ff-802a-23ad-4378-d21b6beb4d5a [accessed April 1, 2009].

Underwriters Laboratories. 2009. UL's support of AHJ's approving fuel dispensing equipment pumping fuels with a maximum of 15% Ethanol. Available: <http://www.ul.com/global/eng/pages/offerings/perspectives/regulator/e85info/ahjupdate/> [accessed April 7 2009].

USDA. 2006. Ethanol Reshapes the Corn Market. Available: <http://www.ers.usda.gov/AmberWaves/April06/Features/Ethanol.htm> [accessed March 17 2009].

Wakeley HL, Hendrickson CT, Griffin WM, Matthews HS. 2009. Economic and Environmental Transportation Effects of Large-Scale Ethanol Production and Distribution in the United States. Environ Sci Technol: in press.

Whitney K, Fernandez T. 2007. Characterization of Cold Temperature VOC and PM Emissions from Flex Fuel Vehicles Operating on Ethanol Blends. In: 17th Coordinating Research Council (CRC) On-Road Vehicle Emissions Workshop. San Diego, CA.

Williams F. 2008. Ethanol May be Harmful to Your Lawnmower. Available: <http://www.thetruthaboutcars.com/ethanol-may-be-harmful-to-your-lawnmower/> [accessed February 16 2009].

Winebrake JJ, Wang MQ, He D. 2001. Toxic emissions from mobile sources: a total fuel-cycle analysis for conventional and alternative fuel vehicles. J Air Waste Manag Assoc 51(7): 1073-86.

Yacobucci BD. 2008. Fuel Ethanol: Background and Public Policy Issues. Congressional Research Service Report for Congress RL33290. Available: <http://opencrs.com/document/RL33290/2007-07-30> [accessed January 22, 2009].