Unleaded Aviation Fuel: Barriers to Adoption in California

Santa Clara University Environmental Studies and Sciences Capstone Project 2017
Center for Environmental Health

March 2017

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Table of Contents

1. Key Terms and Concepts

100LL- 100LL is the universal standard that meets ASTM D910 specifications for general aviation gasoline (avgas) used in all piston-engine aircraft. 100 refers to its octane rating and LL stands for 'low lead.' 100LL contains 2.12 grams of lead per gallon.

UL94- UL94 is an unleaded, 94 octane avgas that meets ASTM D7547 specifications, developed and sold by Swift Fuels. UL94 can be used in about 54% of the general aviation fleet but is only available at 23 airports across the United States. This fuel is essentially 100LL without the lead.

Automotive Gasoline (Mogas)- Mogas is the industry term for lower-octane automotive gasoline that meets ASTM D4814 specifications and does not contain lead. This fuel is essentially the same as that found at a typical gas station. In many states gasoline is required to have up to 10% added ethanol, which makes it unusable in aviation aircraft. Mogas without added ethanol is not widely sold in the US and its fuel chemistry is generally not compatible with all GA aircraft engines due to oxidation and vapor pressure issues, among others.

Aviation Gasoline (Avgas)- Avgas is a broad term used to describe fuels in general aviation. These fuels range from 80 to 100 motor octane and are considered specialty fuels for piston-engine aircraft as they are only available at airports. 100LL (for 'low lead') is the most widely used avgas and, as the name suggests, it contains lead.

Drop-in Alternative- A drop-in alternative is a fuel that can replace 100LL without requiring engine modifications or a supplemental type certificate (STC).

Fixed-Base Operator (FBO)- A fixed-base operator is a business allowed to operate on airport grounds to provide fueling, maintenance, flight instruction, tie-down and parking, aircraft rental, or similar services. In the context of this report, Rabbit Aviation Services, the fuel vendor at San Carlos Airport, is an FBO.

General Aviation (GA)- General aviation consists of all non-commercial aircraft and most helicopters flown by private entities. This includes all propeller/piston-engine aircraft, as well as all turboprop and turbine-powered private jets, but it excludes all commercial airliners.

Octane Rating- A fuel's octane rating, or simply 'octane,' is a measurement of its resistance to pre-ignition and knock. A higher octane fuel, such as 100LL, is more resistant to pre-ignition and can therefore withstand more compression without combusting before the spark plug is fired. Typically, higher performance engines require higher octane fuels because they use greater compression ratios than standard engines.

Piston Aviation Fuels Initiative (PAFI)- Started in 2014, PAFI is a collaboration between the Federal Aviation Administration (FAA) and fuel-industry stakeholders to propose an unleaded alternative to 100LL.

Supplemental Type Certificate (STC)- An STC is an FAA-issued approval to modify an aeronautical product from its original design. In the context of avgas, an STC may be required to switch to a lower octane alternative such as UL94 for any plane that typically runs 100LL. While some planes can make this switch, many still require 100 octane fuel.

Tetraethyl lead (TEL)- TEL is the lead-containing compound in 100LL. It is added to avgas to increase the octane rating of the fuel.

2. Executive Summary

Leaded aviation gasoline, also known as avgas, is currently the fuel of choice for general aviation (GA) operations such as small piston-engine airplanes and helicopters. Due to the relatively small volume sold every year (compared to automobile gasoline) and lack of an unleaded alternative, leaded avgas has eluded replacement for over twenty years since the completion of leaded automobile gas' phase-out. Recently, however, renewed interest in preventing lead pollution has sparked awareness campaigns, lawsuits, and a government-industry collaboration to get the lead out of avgas.

Using the available literature, we found that lead from avgas poses a serious public health risk, particularly to children who live or attend school near an airport. Close proximity to heavy GA aircraft activity can cause learning disabilities, behavioral disorders, and lower academic performance in these especially vulnerable populations. There is no safe level of lead exposure.

Through interviews with the FAA, fixed-base operators, an unleaded avgas developer/distributor, and local airport officials, we identified the main barriers to adopting unleaded avgas in California. The most apparent barrier is the absence of an FAA-certified, lead-free 100 octane fuel, which would serve as a universal replacement for all planes and engines. The FAA is scheduled to finish testing and approve potential alternatives by the end of 2018. In the meantime, however, there is a 94 octane unleaded alternative which approximately 54% of the general aviation fleet could use. The barriers we identified for this fuel are the scarcity of storage for a separate fuel at airports, high fuel delivery costs, lack of public and pilot demand, and the inability for the other 46% of the GA fleet to use 94 octane unleaded.

We recommend that the Center for Environmental Health builds a coalition of community members and pilots to encourage local airports and fuel vendors to carry 94 octane unleaded avgas. We further recommend that concerned individuals and environmental groups put pressure on local and federal governments to phase out leaded aviation fuel once an unleaded 100 octane alternative is approved.

3. Introduction

Leaded aviation gasoline is the single largest source of lead in the United States' atmosphere and about 45% percent of ambient lead is emitted by small piston-engine aircrafts[1]. In California, general aviation (GA) accounts for about 83% of lead in the atmosphere[2].

Lead in automobile gasoline started being phased out in the 1970s due to overwhelming evidence of its health and environmental consequences. In 1996, the Clean Air Act effectively banned the sale of lead in fuel, however a provision allowing the sale of leaded avgas was appended and still exists today. There are currently about 20,000 airports in the United States

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[1] US EPA. (2014). *Lead Emissions from the Use of Leaded Aviation Gasoline in the United States: Technical Support Document (EPA420-R-08-020)*. Retrieved from: nnsa.energy.gov/sites/default/files/nnsa/inlinefiles/epa%202009a.pdf.
[2] US EPA. (2014). *2014 National Emissions Inventory: California State Summary*. Retrieved from: www3.epa.gov/cgi-bin/broker?_service=data&_debug=0&_program=dataprog.state_1.sas&pol=7439921&stfips=06.

that sell leaded avgas[3] and over 200,000 piston-engine aircraft that continue to use it, with about 2,000 added every year[4]. Between 1970 and 2007, GA aircraft consumed approximately 14.6 billion gallons of leaded avgas, which would account for around 35,000 tons of lead emitted into the atmosphere if it was all 100LL[5]. Given that lead is a persistent pollutant and does not break down in soil, water, or air, all of this lead remains in our ecosystems and can still cause harm decades after being released.

These statistics illustrate the pervasiveness of the issue, but the truly alarming problem is the damage it causes to vulnerable populations. An estimated 16 million people live within one kilometer of an airport and over 3 million children (6% of the total US student population) attend school within one kilometer of an airport[6]. Studies have shown that populations living or attending school within a one kilometer radius of an airport typically have elevated blood lead levels, which can lead to sensory, cognitive, motor, and behavioral issues[7]. Furthermore, ethnic and economic disparities are highlighted as minorities are statistically overrepresented in these schools[8].

Eliminating lead from avgas will be a major win for health, environmental, and social justice causes. Overcoming the barriers to the adoption of unleaded avgas is key to reducing lead pollution and providing a safer and cleaner environment for our current population and future generations to come. The goals of this study are to determine the public health dangers of leaded avgas, pinpoint the barriers to adopting unleaded avgas, and identify next steps in mitigating and eliminating the use of leaded avgas in California.

Our Research Questions include:

1) What are the barriers to the adoption of unleaded aviation fuel in California airports?
2) What are the benefits and drawbacks of using unleaded aviation fuel from the following: the government (EPA and FAA), aviators, airports, and the public.
3) How can we overcome those barriers?

4. Methodology

In order to answer the research questions listed above, a literature review, interviews, and case studies were conducted.

Literature Review

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[3] US EPA. (2010). *Advance Notice of Proposed Rulemaking on Lead Emissions From Piston-Engine Aircraft Using Leaded Aviation Gasoline; Proposed Rule.* Retrieved from: https://www.gpo.gov/fdsys/pkg/FR-2010-04-28/pdf/2010-9603.pdf

[4] General Aviation Manufacturers Association. (2008). *General Aviation Statistical Databook & Industry Outlook.* Retrieved from: http:// www.gama.aero/files/2008_general_ aviation_statistical_databook__ indust_499b0dc37b.pdf

[5] US EPA. (2010). *Advanced Notice.*

[6] Ibid.

[7] Ibid.

[8] Ibid.

We used existing research and literature to provide us with a current status of leaded aviation fuel and a background on the harmful effects of lead. Documents from the EPA and FAA provided us with an updated status on government involvement, if any, in phasing out leaded aviation fuel. We then used academic journals and publicly available government research to understand lead's detrimental effects on human health. We built upon data provided by the Center for Environmental Health by locating schools and vulnerable populations within a one kilometer radius of California airports. Additionally, we researched public policy that has been implemented and proposed at state and federal levels.

Interviews

We conducted interviews with stakeholders from the FAA, Swift Fuels, Rabbit Aviation Services, and the Watsonville Airport. Interviews were conducted in person or via telephone and, with permission, were recorded to provide accurate accounts of the conversations. The interviews were conducted to gain further stakeholder insight into the barriers to adopting unleaded avgas and learn the nuances of unleaded avgas adoption from certain points of view. Each interviewee was asked for their assessment of the barriers to unleaded avgas adoption and what benefits and drawbacks they foresee in the use of unleaded aviation fuel. Based on the background of each interviewee, we were able to ask a more specific set of questions to help clarify the situation of unleaded avgas in California (see Appendix A for lists of questions asked to each stakeholder).

Case Study

The transition to unleaded automobile gas was used as a case study to compare and contrast this process to the possible adoption of unleaded aviation fuel. From this example, we looked at what methods were used to transition to unleaded automobile gas and if any of those could be used in the transition to unleaded aviation fuel. We also identified the obstacles faced in transitioning from leaded to unleaded automobile gas.

5. Literature Review

Public Health Impact of Leaded Aviation Fuel

One of the most troubling issues surrounding the continued use of leaded aviation fuel is its health impacts. Although overall lead levels have decreased dramatically since the phase-out of leaded automobile gasoline, lead-based paint, and lead solder in plumbing, many are still exposed to harmful levels of lead. Leaded aviation fuel is a major source for localized atmospheric pollution around airports and, since it is not dispersed evenly throughout the air, populations around airports using leaded avgas are disproportionately affected. Although it is harder to trace back lead contamination in our local water bodies and soils to avgas, it is still important to mention the effects lead can have on water and soil quality. The high concentrations of lead air emissions seen in California is in part due to the fact that "low lead" avgas still contains up to 2.12 grams of lead per gallon[9]. As mentioned earlier, lead is a persistent pollutant and even small amounts of lead exposure has been documented to affect children's developing nervous system. An EPA study found that in children ages 4-10, impairment of cognitive functions appeared in blood lead levels as low as 2-8 μg/dL,[10] levels which are often seen in children who live within one kilometer of an airport[11]. Furthermore, the EPA, in collaboration with the CDC, NIOSH and medical experts, has declared that there is no safe level of lead exposure that does not have harmful effects on cognitive functions.

Although adults are not at as great a risk as children are to lead exposure, there are still detrimental health impacts on adult health associated with lead exposure. Studies have found that adult lead exposure can cause high blood pressure, hypertension, coronary heart disease, immune effects, and cognitive function decrements resulting in depression and anxiety[12]. This poses a problem for adults who have hobbies involving lead, namely pilots. Pilots, student-trainees, and passengers of small aircraft are among the population of adults at highest risk of lead exposure. Risk to pilots and trainees is especially high because they inhale evaporative emissions of TEL during fueling and pre-flight fuel inspections[13]. Additionally, passengers represent a large portion of the heavily exposed population as general aviation aircraft fly over 27 million hours and carry 166 million passengers annually in the U.S.[14]

Lead emissions are concentrated around airports and pose a concern for people living or frequently spending time around those areas. A study comparing the blood lead levels in children around airports in six North Carolina counties found that lead from avgas may have a small but significant impact[15]. They found that blood lead levels were highest among children living within 500 meters of an airport using leaded aviation fuel and decreased as they expanded the radius to 1,000 meters and then 1,500 meters. They concluded that living beyond 1,000 meters of an airport using leaded avgas does not have a significant relationship with blood lead levels[16]. It is quite alarming when considering the 20,000 airports across the country using leaded avgas and the millions of people living and attending school within one kilometer of these airports[17].

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[9] US EPA. (2010). *Advance Notice of Proposed Rulemaking on Lead Emissions From Piston-Engine Aircraft Using Leaded Aviation Gasoline; Proposed Rule.* Retrieved from: https://www.gpo.gov/fdsys/pkg/FR-2010-04-28/pdf/2010-9603.pdf

[10] EPA, 2013. *Integrated Science Assessment (ISA) for Lead.* Environmental Protection Agency. Available at: https://www.epa.gov/isa/integrated-science-assessment-isa-lead.

[11] Miranda, M. L., Anthopolos, R., & Hastings, D. (2011). A Geospatial Analysis of the Effects of Aviation Gasoline on Childhood Blood Lead Levels. *Environmental Health Perspectives*, *119*, 1513-1516.

[12] EPA 2013. *Integrated Science Assessment (ISA) for Lead.*

[13] US EPA, (2010). *Advance Notice*

[14] US EPA, (2010). *Advance Notice*

[15] Miranda, M., Anthopolos, R., Hastings, D., (2011). A Geospatial Analysis of the Effects of Aviation Gasoline

[16] Ibid.

[17] Kessler, R. (2013). Sunset for Leaded Aviation Gasoline. *Environmental Health Perspective,* 121, a54-7

Furthermore, the time planes fly most frequently correlates with the times children attend school [18].

The distressing rates of lead in closer proximity to airports proves to be an environmental and social justice issue that plagues the state of California as well as the rest of the United States. In data published by the EPA, people living in close proximity to transportation sources are more likely to have a lower income compared to the overall general population[19]. The EPA conducted a study where they looked at the number of students who were eligible for a free lunch, at or below 130 percent of the poverty level, who attended school within a kilometer of an airport. They found that at public schools located within a kilometer of an airport, 47% of the students are registered in the free or reduced lunch program compared to a 40% national average, meaning they are more likely low-income[20]. This disparity reveals the true victims of leaded avgas' health effects; low income families.

Differences Between Leaded Avgas and Unleaded Automobile Gas

There are four critical differences between automobile gas, often referred to as "mogas", and avgas; octane rating, vapor pressure, gums/oxidation, and final boiling point.

	Leaded Avgas	**Unleaded Automobile Gas**
Octane Rating	Octane Rating: 100 Uses TEL to boost octane	Octane Rating: 86-91 Uses ethanol to boost octane
Vapor Pressure	Vapor Pressure: (5.5-7.1 psi) Consistent, low vapor pressure year-round	Vapor Pressure: (7.0-9.0 psi) Vapor pressure is decreased in the summer to reduce evaporation Vapor pressure is increased in the winter to help cold engines start
Gums/Oxidation	Gums are strictly filtered due to long shelf life	Gums are not strictly filtered out because of short shelf life
Final Boiling Point	Boiling Point: 170℃ A lower boiling point means fewer deposits and a cleaner burn	Boiling Point: 225℃ Detergents and catalytic converters are used to clean deposits and control excess emissions

[18] ICF International and T&B Systems. "Development and Evaluation of an Air Quality Modeling Approach for Lead Emissions from Piston-Engine Aircraft Operating on Leaded Aviation Gasoline." (2010).
[19] EPA, 2007. *Regulatory Impact Analysis for the Regulation to Control Hazardous Air Pollutant Emissions from Mobile Sources.* Chapter 3. 3-122.
[20] US EPA. (2010). *Advance Notice of Proposed Rulemaking on Lead Emissions From Piston-Engine Aircraft Using Leaded Aviation Gasoline; Proposed Rule.* Retrieved from: https://www.gpo.gov/fdsys/pkg/FR-2010-04-28/pdf/2010-9603.pdf

Octane Rating

The most commonly used[21] fuel in small propeller planes and helicopters is 100LL, a 100 octane 'low lead' avgas. 100LL is a petroleum-based gasoline blended with 2.12 grams of lead, in the form of tetraethyl lead (TEL), per gallon[22]. Typical automobile gas is about 86 octane, with up to 10% ethanol added in many states. TEL is added to avgas for the same reason ethanol is added to automobile gas today; to increase the octane rating of the fuel, thereby reducing knock, detonation, and preignition. Ethanol cannot be used to increase octane in aviation fuel because it degrades, attracts water, and can eat away at the linings of planes' fuel tanks. Engine knock occurs when a separate pocket of air-fuel mixture combusts after the spark plug has already ignited the main air-fuel mixture in the piston, causing a "knock" or "ping" sound. Detonation is the spontaneous combustion of the remaining air-fuel mixture after the normal combustion cycle occurs. Pre-ignition is the ignition of the air-fuel mixture before the spark plug fires. All of these can cause excess wear and tear, overheating, and even engine failure. Preventing knock, detonation, and preignition is therefore especially important for aviation applications as engine failure is a potentially deadly situation for pilots. All of these fuel-related hazards can be avoided by using a higher octane avgas or reducing the compression ratio of the engine, which also reduces performance.

Vapor Pressure

Vapor pressure is a measure of the volatility of a fuel wherein a higher vapor pressure indicates higher volatility and willingness to evaporate. A lower vapor pressure prevents vapor lock, which is the vaporization of fuel in the fuel line causing interruptions in fuel flow, which can lead to engine cut-outs. While the vapor pressure of automobile gas changes monthly and varies by state to match weather conditions (7.0-9.0 psi), the vapor pressure of avgas is kept intentionally low (5.5-7.1 psi) year-round. In automobile gas, vapor pressure is lowered in the summer months to reduce the evaporation potential of gasoline fumes, which are a significant contributor to ground-level ozone. In the winter months, automobile vapor pressure is brought back up to help cold engines start.

Gums/Oxidation

Insoluble pieces of oxidized fuel, known as gums, exist at much higher levels in automobile gas than in avgas and can deposit on the metal parts of engines when they sit for long periods of time, causing them to "gum up." Automobile gas is designed for a shelf life of about 30 days, meaning they do not have to worry about filtering out all of the gums because it is expected to be used before it can deposit in meaningful quantities. Airplanes, however, can sit

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[21] Windom, B., Lovestead, T., Bruno, T. (2010). Application of the Advanced Distillation Curve Method to the Development of Unleaded Aviation Gasoline. *Energy Fuels*, 24(5), 3275-3284.

[22] US EPA. (2010). *Advance Notice of Proposed Rulemaking on Lead Emissions From Piston-Engine Aircraft Using Leaded Aviation Gasoline; Proposed Rule.* Retrieved from: https://www.gpo.gov/fdsys/pkg/FR-2010-04-28/pdf/2010-9603.pdf

for weeks, months, or years at a time without refueling, meaning gums need to be strictly filtered out of avgas.

Final Boiling Point

Final boiling point is another measure of volatility. A fuel is better able to fully combust when it has a lower final boiling point because it more readily reaches that temperature. Automobile gas has a final boiling point of 225℃ whereas avgas has a final boiling point of 170℃. The hotter compounds in automobile gas (a result of heavier hydrocarbons) cause deposits and higher emissions which, in a car, are resolved by detergents and catalytic converters. Airplanes, however, do not have these systems and therefore must boil at a lower temperature to avoid deposits.

Due to these four critical differences between automobile gas and avgas, unleaded automobile gas leads to performance and safety issues when used in smaller propeller planes. It is important to make these distinctions so that pilots and the public do not think of this as a viable alternative to the use of 100LL for recreational propeller planes and to prevent serious danger that could occur from the use of mogas. Currently, UL94, produced by Swift Fuels, is the only appropriate unleaded alternative to 100LL for 53.7% of GA (refer to Appendix C) because UL94 does not have the same issues that mogas has of low octane rating, variability in vapor pressure, gums, and high boiling point that can be detrimental to recreational piston aviation aircrafts. The other 46.3% of GA cannot use UL94 because they need a higher octane rating of 100, which is why a UL100 alternative needs to be certified and approved.

Piston Aviation Fuels Initiative

The Federal Aviation Administration (FAA), in cooperation with aviation and petroleum industry stakeholders as well as consumer representatives, created the Piston Aviation Fuels Initiative (PAFI) in 2010 dedicated to “developing a path forward for the identification, evaluation and deployment of the most promising unleaded replacements for 100 low lead aviation gasoline.[23]” Originally, 17 proposed fuels were submitted to the FAA in 2014 for stage 1 of PAFI, where they were evaluated for “potentially show-stopping issues” in terms of production, distribution, and operation before significant resources were put into their full FAA approval[24]. This step narrowed down the candidate fuels to just 2: Shell and Swift Fuels.

Stage 2 of PAFI, which began in early 2017, involves testing Shell and Swift Fuels' alternatives at an engine and aircraft level with the goal of ensuring adoption across as much of the existing fleet as possible. In this step, the chemistry of the fuel is evaluated for toxicological and performance indicators and the fuels are run under every possible condition. Engine testing

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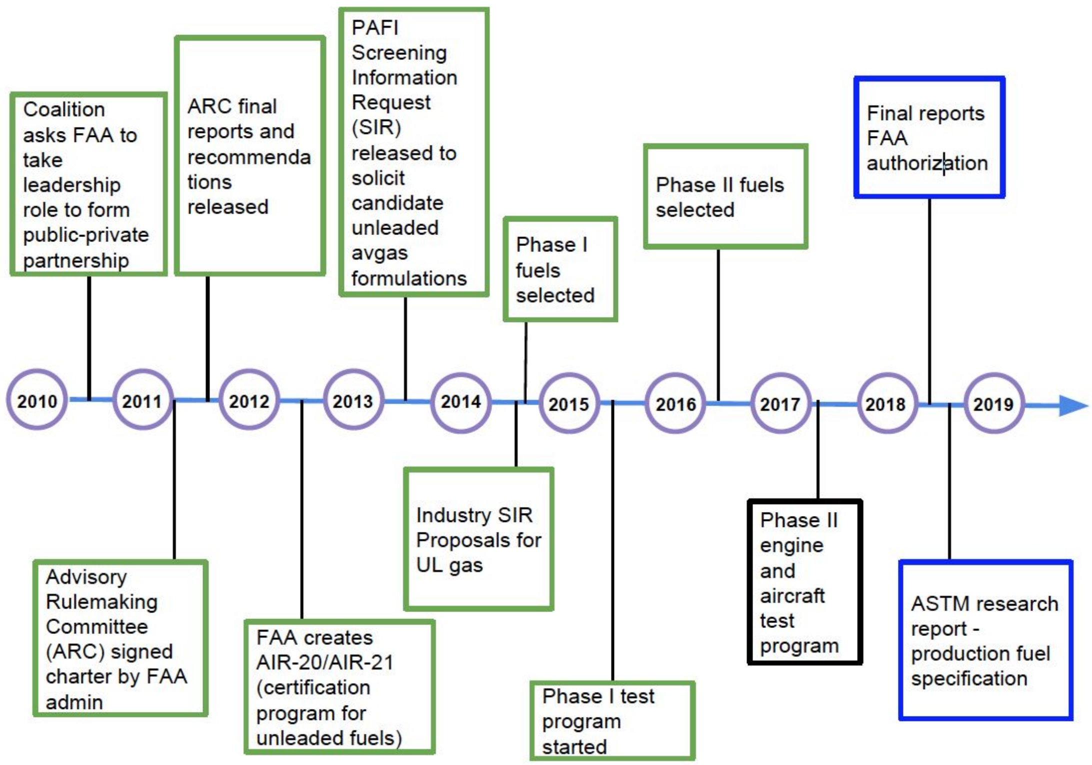
[23] Federal Aviation Administration. (2014). *PAFI White Paper*. Retrieved from: https://www.faa.gov/about/initiatives/avgas/media/media/PAFI_White_Paper.pdf
[24] Ibid.

occurs on the ground and simulates everything from fair-weather to worst-case scenarios. It is expected that the FAA will complete stage 2 and finalize the PAFI approval process by the end of 2018. (See timeline below.)

PAFI is the golden ticket in terms of eliminating leaded avgas from use nationally and in California. Once a universal, or 'drop-in,' unleaded solution for 100 octane avgas is approved, the only next steps are to produce enough to become commercially viable and for the EPA or FAA to mandate the phase-out of leaded avgas in favor of unleaded. Unfortunately, at the time of writing, the new political administration has given rise to questions of whether or not agencies like the EPA or FAA will keep to their timelines and accomplish the goals they established under the previous administration. We are hopeful, however, that children's health and the elimination of lead from our environment can continue to be a bipartisan issue supported by all levels of government.



Above is the Piston Aviation Fuel Initiative timeline that outlines the stages in approving a universal, or 'drop-in,' unleaded solution for 100 octane avgas.

Public Policy

Despite cars phasing out leaded gasoline starting in the 1970's due to the detrimental health and environmental effects emphasized above, aviation fuel continues to be sold legally across the United States with no phase-out yet decided upon or required. Currently, PAFI is the only program actively pursuing an unleaded "drop-in" fuel to replace 100LL for the entire US fleet of GA planes. Once PAFI approves an alternative, ideally by December 2018, the next step to widespread adoption is mandating leaded avgas' phase-out. However, neither the EPA nor the FAA have announced plans to mandate unleaded 100 octane avgas after its approval.

In response to the EPA's inaction, Friends of the Earth (FOE) filed a petition to the EPA in 2006 to create new standards to eliminate leaded fuels from aviation. Four years later, the EPA released an Advance Notice of Proposed Rulemaking (ANPR), but did not file or propose any new legislation. Within this ANPR, the EPA states that section 231 of the Clean Air Act (CAA) sets forth their authority to regulate air pollution from aircraft and section 211 allows the EPA the ability to regulate fuels used in motor vehicles and nonroad vehicles[25]. This section of the CAA was used to remove lead from automobiles. However, the EPA's authority to regulate fuels does not include fuels used exclusively for aviation purposes. These fuels are to be regulated by the FAA using standards set forth by the administrator of the EPA regarding whether or not the aircraft fuel will endanger the public health or welfare[26]. Furthermore, section 231 of the CAA preempts states and local governments from adopting or enforcing any aircraft emissions standards that are not identical to the EPA's standards[27]. In summary, neither the EPA nor the FAA have sole regulatory authority when it comes to avgas, and their administrators must come to a consensus on whether or not leaded avgas may be required to be phased out.

Although states do not have the authority to adopt or enforce emissions standards that differ from the EPA's standards, Oregon has completely sidestepped the issue of regulating emissions by proposing bills that will ban selling, dispensing, or using leaded aviation fuel altogether. If passed, Senate Bill 115 and House Bill 2109 will give Oregon's Department of Agriculture authority to make the rules necessary to ban avgas in Oregon by January 1, 2022. Seeing as these bills were introduced in January 2017 and their first hearing was February 22, 2017, they are still in a very preliminary stage so it remains to be seen whether they will pass and how they will be implemented.

Though the EPA has not taken the necessary steps to ban leaded aviation fuel, it has contributed significantly to the scientific literature on the issue. It conducted 17 studies at airports across the nation to determine the effects on local lead concentrations and found in every case that the soil, water, and air around airports does indeed have higher concentrations of lead than natural ambient levels. San Carlos Airport, one of the subjects of these studies, was shown in 2012 to have over double the maximum lead concentration allowed by the EPA's National Ambient Air Quality Standards (NAAQS), reaching a three month average of .33$\mu g/m^3$ while the requirements were recently lowered to .15 $\mu g/m^3$. While other airports in California were also shown to be close to the limit, only one other airport, McClellan Palomar in San Diego, was above the NAAQS limit. Since these findings, Rabbit Aviation Services, a fixed base operator

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[25] US EPA. (2010). *Advance Notice of Proposed Rulemaking on Lead Emissions From Piston-Engine Aircraft Using Leaded Aviation Gasoline; Proposed Rule.* Retrieved from: https://www.gpo.gov/fdsys/pkg/FR-2010-04-28/pdf/2010-9603.pdf

[26] Ibid.

[27] Ibid.

(FBO) at the San Carlos Airport, started selling UL94 unleaded gas from Swift Fuels, a contender for PAFI certification. Rabbit Aviation Services remains the sole unleaded avgas vendor in California, with only one 750-gallon fuel truck and about 30 regular customers who have received the proper supplemental type certificate (STC) or can run 94 octane without an STC. The San Mateo County Board and Department of Public Works were instrumental in helping Rabbit Aviation Services get unleaded avgas at San Carlos Airport by removing the fuel flowage fee, a tax usually placed on gas sold in the county, on the UL94 they sell. This has allowed Rabbit Aviation Services to sell UL94 at approximately the same price as 100LL despite the costs associated with small-volume transportation from Indiana.

6. Case Study

Transition from Leaded Gasoline to Unleaded Gasoline in Automobiles

Studying the transition to unleaded gasoline for automobiles is a good comparison tool when considering the implementation of unleaded aviation fuel in California airports. U.S. refiners started adding lead to gasoline in the 1920s to increase octane levels and improve the performance of automobile engines. Lead additives were relatively inexpensive compared to other additives and the health impacts of lead exposure were still unknown. The phase-out of leaded gas began in 1974 when the U.S. Environmental Protection Agency, under the Clean Air Act Amendments of 1970, established rules requiring that unleaded gasoline be used in cars with catalytic converters[28]. With the addition of catalytic converters to cars, leaded gas could no longer be used because it destroyed the emissions control capacity of the catalytic converters. Although the transition to unleaded gas would have eventually been made as pre-1975 cars were retired, the EPA also set a number of rules and regulations to expedite the process. First, the EPA mandated that gasoline retailers offer unleaded gas and that new cars have specially designed fuel inlets that only fit unleaded gas nozzles. Additionally, the EPA scheduled performance standards requiring refineries to reduce the average lead content in their gasoline starting in 1979 [29]. This meant that if refineries wanted to continue to produce leaded fuel they could balance their total lead input by increasing production of unleaded fuel. Acceptable levels of lead in gasoline depended on the size of the refinery, with stricter standards for larger refineries. By the early 1980s, lead levels declined by about 80% due to regulations and fleet turnover[30]. In response to complaints from smaller refineries struggling to meet the standards, the EPA was considering easing up on restraints. However, they were met with opposition and ultimately, the EPA continually decreased acceptable amounts of allowable lead and leaded fuel was phased out. In order to help refineries transition to lower levels of lead in their fuel, a system of trading

[28] Newell, R. G., & Rogers, K. (2003). The US experience with the phasedown of lead in gasoline. *Resources for the Future, Washington, DC*, *2*.
[29] Ibid.
[30] Ibid.

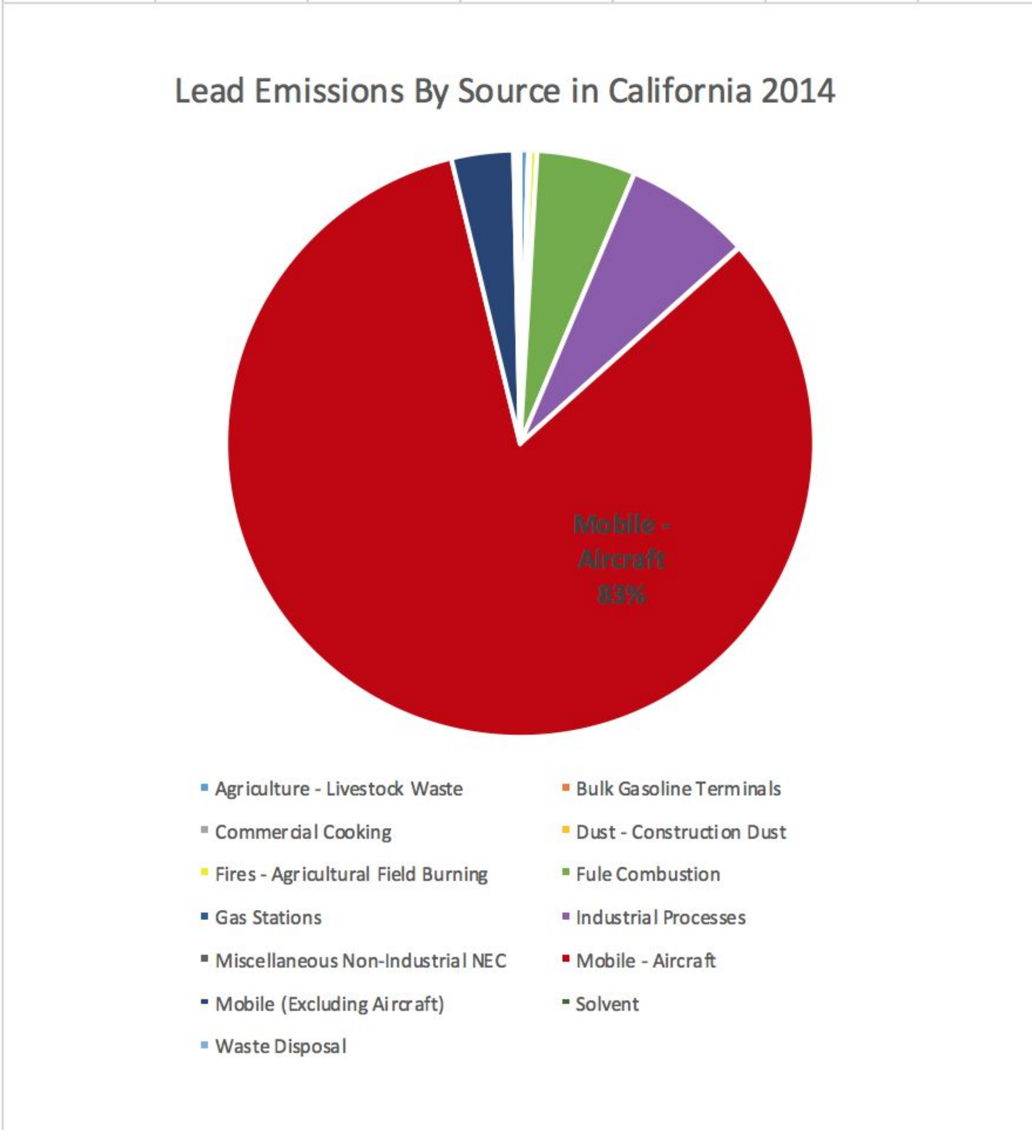
and banking of lead permits was allowed from late 1982 through 1987. This is similar to the cap and trade system of carbon emissions that we have in place today.

By examining the case of the transition from leaded to unleaded automobile fuel, we are able to take away a few main points and apply them toward the transition for unleaded aviation fuel. Firstly, the EPA played a major role in the implementation of laws and programs to help phase out leaded gasoline. This suggests that in order for there to be progress towards unleaded aviation fuel, the EPA must be determined to set standards and timelines. As mentioned earlier, the EPA must work in coordination with the FAA to approve and implement an unleaded aviation fuel substitute for use in general aviation. However, the FAA must continue to work towards approving this solution from an aviation safety standpoint while adhering to their current timeline. Secondly, the transition to unleaded gas was gradual. On the one hand this can be applied toward aviation fuel because airports and refineries need the time and money to develop the infrastructure for proper refining, distribution, and storage. On the other hand, once a drop-in fuel is approved, it will work for all planes and eliminates the necessity for planes to make additional modifications to run on lower octane unleaded fuel and for airports to invest in separate storage. Lastly, the use of incentives like the cap and trade program for lead permits eased the transition. A similar program may be used for unleaded aviation fuels to account for those that have a hard time with implementation, or grants can be awarded to those in most need for this transition. There are a few differences between the transition to unleaded aviation fuel and unleaded automobile gasoline. For example, fleet turnover for airplanes is a lot slower than for automobiles. Additionally, implementation of unleaded aviation fuel has already been accomplished in other states as well as other countries so the need for unleaded aviation fuel is concentrated in areas where there is none readily available, such as California. Despite these differences, much can be learned from the case of leaded gasoline for cars and it can serve as a good reference point when solving the transition to unleaded gasoline for propeller planes.

7. Results and Findings

Data

General aviation aircraft account for over 80 percent of lead emissions in the atmosphere in the State of California. The chart below shows how significant airplanes are on the total lead emissions in the state.



Data to create graphic from 2014 National Emissions Inventory (NEI) Data.[31]

The data below was taken from the official 2014 Airport Lead Monitoring Program Update published by the EPA. This data shows that there are several airports within the Greater Bay Area that are emitting lead into the atmosphere. It is important to draw attention and identify those emitting the highest amounts of lead in order to create more public awareness around the issue.

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[31] *2014 National Emissions Inventory. California State Summary*. US Environmental Protection Agency, 2014, www3.epa.gov/cgi-bin/broker?_service=data&_debug=0&_program=dataprog.state_1.sas&pol=7439921&stfips=06.

Airport Lead Emissions in the Greater Bay Area

Airport	City	Lead (tons/yr)
Palo Alto Airport	Palo Alto	0.65
Livermore Muni	Livermore	0.51
Reid-Hillview	San Jose	0.35
San Carlos	San Carlos	0.29
Nut Tree	Vacaville	0.28
Gnoss Field	Navato	0.27
Oakland International	Oakland	0.24
Buchanan Field	Concord	0.21
Sonoma County	Santa Rosa	0.20
Napa County	Napa	0.14
SF International	San Francisco	0.11
Mineta San Jose International	San Jose	0.10
Sonoma Sky Park	Sonoma	0.04

May 2014 Lead Concentrations at Airports in California

Airport	Lead Concentrations (μg/m^3)
Gillespie Field	0.07
McClellan-Palomar Airport	0.17
Palo Alto Airport	0.12
Reid-Hillview Airport	0.09
San Carlos Airport	0.33
Van Nuys Airport	0.06

Interviews

We were able to gather significant qualitative data through interviewing four individuals who have industry experience and are familiar with aviation fuel.We found the major barriers that were repeated throughout our research included storage, transportation and production.

Swift Fuels

Currently, the only FAA approved unleaded avgas on the market is UL94 made by Swift Fuels out of West Lafayette, Indiana. We had the opportunity to interview Swift Fuels' CEO, Chris D'Acosta, and he provided us with an insider's perspective on the status of the Piston Aviation Fuels Initiative, the benefits to unleaded, and where aviation fuel goes from here.

As discussed previously, PAFI, a cooperative initiative conducted by the FAA and industry stakeholders, was formed to find a drop-in unleaded fuel alternative for 100LL avgas. D'Acosta discussed the history of PAFI and Swift's current involvement. PAFI originated as a series of test programs in 1993 to address the possible alternatives to leaded aviation fuel. By 2013 PAFI tested 300 different aviation fuel variations, but had no concrete alternative plan to replace 100LL. Prior to 2013, Swift Fuels produced a fuel the FAA had previously tested, nevertheless in 2013 the FAA decided to reconstitute a PAFI program that would finally find a solution to replace 100LL. The program would test Swift Fuels' avgas against other unleaded fuels produced around the world. In November of 2013, PAFI received 17 100LL replacement proposals from around the world, including Swift Fuels'. Next, they narrowed it down to two fuels, Swift Fuels and Shell, in March 2016. The PAFI program lasts until the end of the 2018 calendar year, and the goal is that approved fuel(s) will be useable fleet-wide and will potentially be used to phase out leaded avgas.

Currently Swift Fuels has the technology to make both UL94 and the yet-to-be-approved 100LL replacement, but they do not have the capacity to provide the fuel to airports around the country. To solve this, they are hoping to license their fuel to refineries around the U.S. instead of refine it themselves. Swift currently provides about 100,000+ gallons of aviation fuel to 23 airports (shown in the map below) and a small group of individual customers around the country. This is a drop in the bucket compared to the 20,000 airports that currently use 100LL. D'Acosta predicts that by the end of the year, Swift Fuels' UL94 will be available in 3 or 4 airports in California and that soon, closer refineries will start producing Swift's UL94 to combat the price challenges of transporting their fuel from Indiana.

In regards to unapproved fuel alternatives such as mogas, D'Acosta says they have the potential to be extremely dangerous in aircraft. There are some pilots who believe recreational mogas (automobile gasoline without the ethanol) has the potential to replace leaded gasoline but there are critical differences between the two (see p. 8 above, which details the differences between automobile gas and avgas). In short, they are octane rating, vapor pressure, the presence of gums and oxidation, and boiling point. D'Acosta vehemently disagrees with the use of mogas as a replacement to avgas as it is poorly controlled, it is a safety risk, and mogas in aircraft is generally not approved by the major oil producers.

When asked about accuracy of the timeline and the likelihood that a drop-in solution would be implemented, D'Acosta reassured us that a drop-in solution to replace leaded fuel is what the government and public both want. No one likes lead, he explained, and leaded aviation fuel serves as the "last nail in the coffin" in the fight against lead. From D'Acosta's perspective, the expectation is that a fuel will get approved in 2018 and will move on to seeking nationwide approval soon thereafter. He believes that with the public spotlight on lead, now is the time to make the switch to unleaded fuel and ensure that the PAFI program runs smoothly and approves an alternative.

Above is a map of of Swift Fuels' UL94 availability in airports across the U.S.

<u>San Carlos Airport</u>

San Carlos airport is currently the only California airport selling unleaded 94 octane gasoline. We had the opportunity to meet with Dan Demeo, the owner and sole proprieter of Rabbit Aviation Services, a fixed-base operator and fuel vendor selling both 100LL and UL94 at the San Carlos Airport.

According to Demeo, the two biggest barriers in bringing UL94 to airports in California are transport costs and storage. Although the fuel itself costs less than 100LL, Demeo currently sells Swift Fuels' UL94 at slightly more than the price of 100LL, even with his fuel ~$0.15/gallon flowage fee removed by the San Mateo County Board, because he must build in the cost of having it transported from Indiana to California in 350 gallon totes. Once it arrives, he stores the fuel in a 750 gallon fuel truck, which he uses to serve about 30 full-time customers, but he does not have the necessary storage facilities to sell to the flight schools at the San Carlos Airport. He hopes that by the end of the year he will be able to complete a 12,000 gallon storage tank at the San Carlos Airport, at which time he will be able to sell to a much larger customer base. Demeo views unleaded avgas as an issue that the free market can settle. In order for unleaded gas to be more widely accepted, the price point must come down – which will occur as the volume of demand in California increases. If the price is competitive, distributors will start buying it, and aviators will use it because it is cheaper. In order to make the price point competitive with 100LL here in California, facilities in and around California must start producing it to cut down on transport costs. If facilities in the area are able to make Swift Fuels' UL94, and if his 12,000 gallon storage facility is completed as scheduled, Demeo predicts that unleaded fuel could sell at $1 less than current 100LL avgas, which he says would incentivise pilots to fly in from other airports around the state just to fill up.

An additional barrier Demeo explained which prevents aviators from using unleaded is the need for a Supplemental Type Certificate (STC). Although the majority of planes can run on UL94, many planes still cannot due to engine restrictions. In this case, an STC is the FAA's approval to run 94 octane gas in a plane or engine that was not originally certified to do so. Obtaining an STC for any given plane requires taking it to an FAA certified mechanic and costs about $200. In the long run, if the price point of UL94 is reduced, Demeo predicts the cost of the STC will have little influence in aviators' decision to use unleaded as it will be easily made up for in fuel savings. Most aviators do not notice a difference in UL94 versus 100LL, and if the price is lower, aviators will buy it. There is an illusion, especially around 'old-timer' pilots, that prop planes will never be able to run without lead, but as pilots become more environmentally aware and a new generation of pilots takes their place, this mentality is dwindling. Dan is confident that unleaded avgas is the wave of the future.

When asked why he wanted to sell unleaded, Demeo explained that he grew up flying unleaded and he knows it is an eventuality, so he is happy to be on the leading edge of this transition. Additionally, he explained that tetraethyl lead (TEL) is currently only produced by one refinery located in the United Kingdom, and if anything happens, whether a fire or bankruptcy, we need a non-TEL backup. He believes the switch to unleaded is going to happen, but the phase-out of leaded avgas will not be as easy as automobiles, as people buy new cars every decade, but people still fly planes that are 20 to 40 years old.

Above is a picture of Dan Demeo's 750 gallon fuel truck

<u>Watsonville Airport</u>

Rayvon Williams is the current airport manager for the municipal Watsonville Airport. We had the opportunity to interview Williams about his viewpoints on unleaded aviation fuel and whether or not his airport would be able and willing to accommodate an UL100 if approved by PAFI in 2018. From William's perspective the biggest barrier to the adoption of the current UL94, and the reason he believes that no one is selling the product at his airport, is due to performance issues. Williams stated that pilots prefer higher octanes that provide better performance and that many are skeptical of a low octane alternative. If PAFI approves a drop-in 100LL replacement, that fuel will combat this fear as it will be 100 octane. When asked if Watsonville Airport would be able and willing to accommodate a drop-in PAFI-approved replacement fuel, Williams said that logistically, Watsonville has the capacity and storage but the airport would only distribute it if pilots bought it. From a storage standpoint, Watsonville has three underground storage tanks that can hold 3,000 gallons and if with makes economic sense, Williams would be willing to clear one tank and use it to store the PAFI-approved solution.

Williams stated that he doesn't necessarily think the public is entirely aware of the dangers of lead and pilots aren't too concerned with leaded fuel. In his time in the industry he has never heard of a pilot complain or ask for a replacement for lead. Leaded fuel will only be replaced if there is a demand for it to be replaced.

<u>FAA Interview</u>

We reached out to Peter White, the director of the Piston Fuel Initiative, and he directed us to Monica Merrit who serves as a manager for the Fuels Program Branch for the FAA. Merrit was extremely informative in addressing our questions and a transcript of her answers is attached in appendix C.

Interview Summary Table

Name	**Association**	**Barrier to the adoption of unleaded avgas**	**Benefits and drawbacks of avgas**	**Solutions**
Dan Demeo	Rabbit Aviations at the San Carlos Airport	-Price of unleaded (costs associated with transportation and storage) -STCs for use of UL94 -Perception that unleaded fuel may be unsafe to use for flight	*Benefits:* -Environmental and public health benefits -Wave of the future -TEL is currently only produced in one foreign refinery *Drawbacks:* -Price of transport -Storage availability	-Increase Storage -Produce unleaded fuel in closer refineries to cut down transportation cost -Tax break on unleaded fuel to bring price down
Rayvon Williams	Watsonville Airport Manager	-Performance issue -Lack of demand from consumers	*Drawbacks* -Storage -Lack of demand	-Pilot/consumer demand
Chris D'Acosta	Swift Fuel CEO	-Getting UL100 approved -Dispersal of UL94 and UL100 to airports across CA	*Benefits* -Environmental and public health -Safety -Eliminates lead fouling in spark plugs -Eliminates lead seepage into oil, causing acidity and corrosion of the engine -Allows new synthetic lubricants and advanced technology improvements -Reduces maintenance inspections attributed to lead	-Statewide approval -Initiate a program transition -license technology to refineries all over the country
Monica Merrit	FAA	-Requires collaboration between gov. and industry stakeholders to make an orderly and economically viable transition. -Leaded fuel has a proven, 70 year track record. -All GA planes have been designed to be compatible with 100LL. -The FAA has primarily certified airworthiness of aircraft to the specifications of given fuels, rather than certifying a fuel to	*Drawbacks* -The new fuel will not have the history 100LL has on how it performs in certain aircraft and engines or how it affects the environment.	-Collaboration

		the specifications of certain aircraft. -Requiring every pilot/plane to get an amended TC or STC is highly inefficient. -Many of the OEM that produced these planes are no longer active. -The knowledge required to make this transition possible goes far beyond what the FAA is capable of doing by itself. Industry experience is necessary. -The fuel must be standardized across the world to ensure widespread adoption. -Data used in the certification of fuels is proprietary IP. PAFI aims to make this data available to all stakeholders.		

The table above lays out the results we found in our qualitative study. We conducted four interviews with multiple stakeholders to get varying inputs on the barriers to adopting unleaded aviation fuel. As a fuel seller, Dan Demeo discussed the importance of bringing unleaded avgas' price down to be a viable for distributors and sellers. Rayvon Williams, an airport manager, discussed the lack of consumer demand. Airports will only carry a product that will sell and Williams has seen little to no demand for unleaded avgas. Both the representatives of the FAA and Swift Fuels discussed the logistical difficulties and the collaboration that is necessary to launch a state and nationwide initiative to adopt an unleaded drop-in alternative.

Advantages and Challenges of Unleaded Aviation Fuel

Advantages of Unleaded Aviation Fuel	Challenges of Unleaded Aviation Fuel
- Improved public health (especially in children) - Improved environmental health - Unstable production of TEL (only one refinery) - Reduce transport of aviation fuel across seas (less GHG emissions associated with transportation) - Wave of the future - Reduce use of mogas (safety issue with using unleaded automobile gas for planes)	- Concerns over safety and performance of unleaded fuel - Cost of unleaded in CA due to limited number of sellers - Limited number of refineries producing unleaded, resulting in increased transport and storage costs

The table above summarizes both the advantages and challenges associated with adopting unleaded avgas. One of the most significant advantages is the improvement of public health as a direct result of decreasing lead emissions. Additionally, unleaded aviation fuel is the wave of the future. Current 100LL fuel relies on the use of TEL. The production of TEL is unpredictable as it is only produced in one refinery in the UK. If anything, financially or otherwise, were to happen to the refinery, the cost of TEL would rise dramatically and supplies could dwindle or completely dry out. Therefore, it is risky to rely on TEL to supply fuel refiners for decades to come. An additional advantage of switching to unleaded avgas is it would reduce the use of mogas in aviation, an application which it is not intended for. It cannot sit in gasoline tanks for extended periods of time as that can lead to settling and depositing of gums in the tank. Eliminating the use of mogas is essential for the safety of aviators. The challenges of adopting unleaded aviation fuel include price, production, and perception. In order for airports to sell unleaded aviation fuel the price needs to be competitive. As soon as a 100 octane unleaded replacement fuel is approved, the technology needs to be sold to closer refineries to bring the price down. To facilitate this, Swift Fuels hopes to license their PAFI-approved fuel chemistry to refiners across the US. Another challenge surrounds pilot's lack of education surrounding unleaded aviation fuel. Unleaded fuel is becoming more widely accepted among aviators, but there are still many who are concerned about its performance and safety.

Airport Maps

We decided to take a closer look at a three California airports and pinpoint at-risk locations and populations that may be more impacted by lead exposure from leaded aviation fuel. A one kilometer radius around the Santa Monica, Palo Alto, and Reid-Hillview airports were drawn based on a study that found a relationship between elevated blood lead levels in children living within a one kilometer radius of these airports using leaded aviation fuel[32] (refer to public health section for more details). We located schools and childcare centers within the exposed areas to illustrate populations that are most vulnerable to lead exposure. The Palo Alto airport has one of the highest lead emission rates in the bay area with .65 tons of lead emitted per year and there are four schools at a high risk of excessive lead exposure. Similarly, around the Santa Monica Airport there are many high density neighborhoods, 6 schools, and a childcare facility within the one kilometer radius. At Reid-Hillview airport, there are 6 schools within the one kilometer radius and a Raging Waters, which are frequented by children in the summer and may contribute to an increase in lead exposure levels.The areas around these airports represent the ones that are currently being the most affected by leaded aviation fuel and the ones that could benefit the most from adopting the unleaded alternative.

[32] Miranda, M. L., Anthopolos, R., & Hastings, D. (2011). A Geospatial Analysis of the Effects of Aviation Gasoline on Childhood Blood Lead Levels. *Environmental Health Perspectives*, *119*, 1513-1516.

Palo Alto Airport

Airport Map Legend

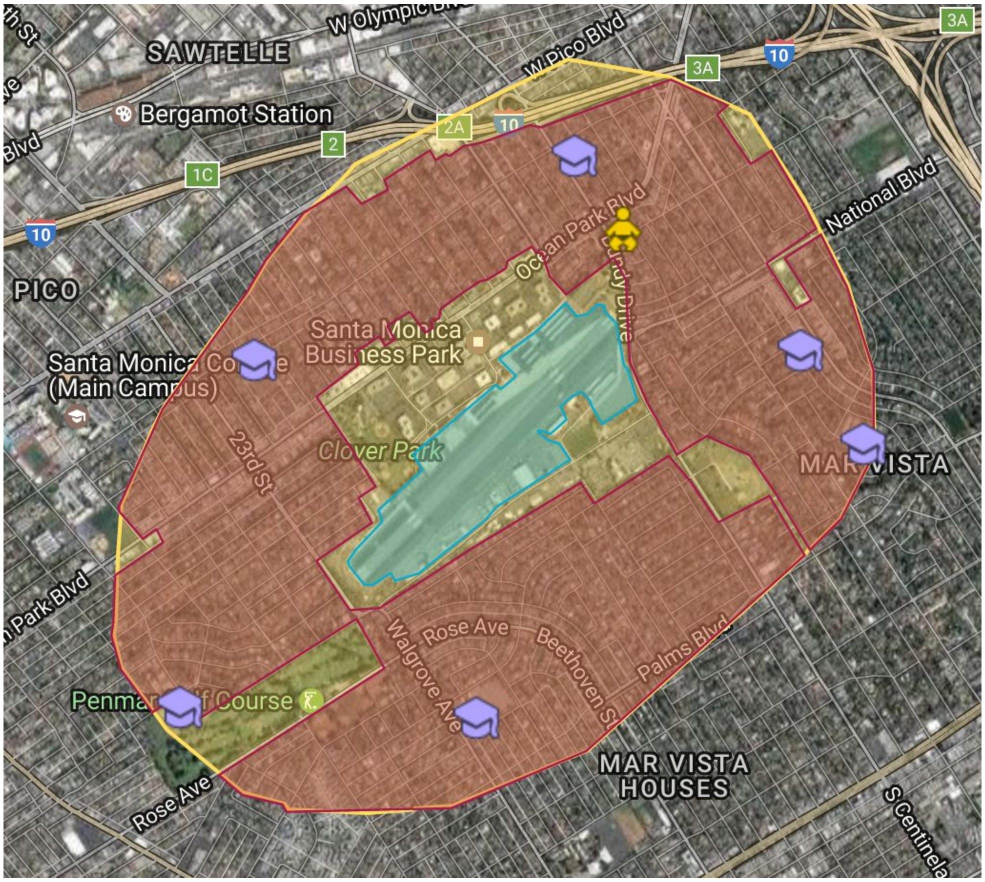
= airport boundary

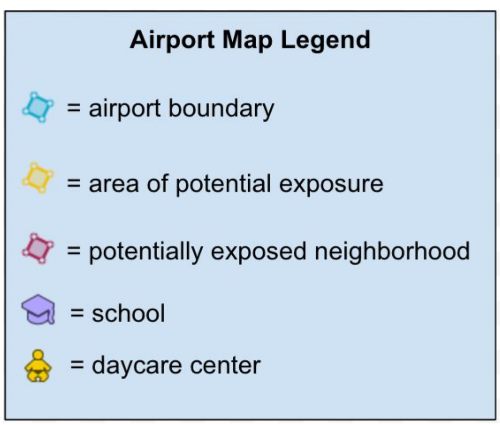
= area of potential exposure

= potentially exposed neighborhood

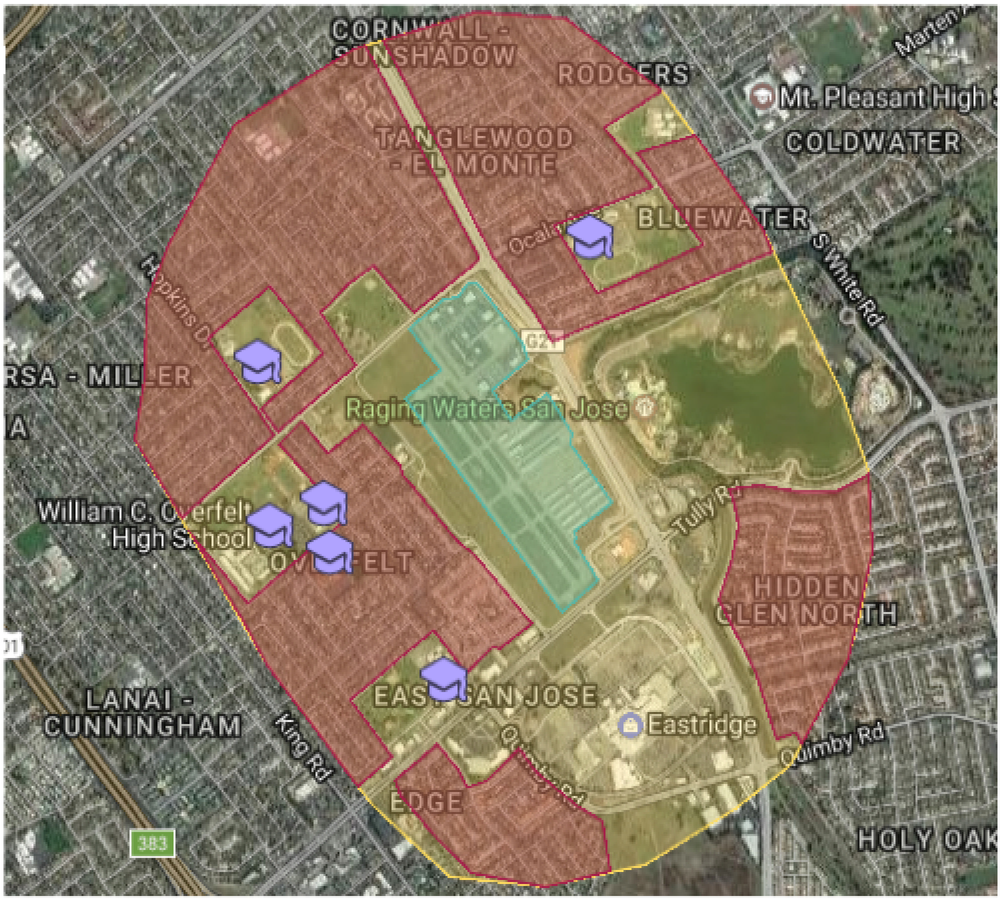
= school

Santa Monica Airport





Reid-Hillview Airport



Airport Map Legend

= airport boundary

= area of potential exposure

= potentially exposed neighborhood

= school

8. Critical Reflection

The mixed methodology approach of analyzing existing literature and federal legislation as well as conducting stakeholder interviews provided us with an in-depth understanding of the background and current status of leaded aviation fuel as well as first hand perspectives of the barriers to adopting unleaded aviation fuel. The interview process proved to be extremely informative and the stakeholders were responsive and willing to assist us in any way.

The biggest limitation we faced was a restricted amount of time. We had less than ten weeks for data collection, stakeholder interviews, and research. Additional time would have allowed us the ability to conduct more interviews to provide further insight on barriers to adoption as well as come up with effective and targeted next steps. That being said, we sought out input from stakeholders representing various industries to hear voices representing different perspectives.

9. Recommendations and Conclusion

Recommendations

As we analyzed our results from each interview, we noted that demand from pilots, distributors, and the general public is needed in order to ensure that both airports and the FAA adopt an unleaded alternative for 100LL avgas in a timely manner. Moving forward, we want to increase public awareness around the fact that lead still exists in gasoline and accounts for the majority of lead in our atmosphere.

In conducting research, we discovered that very few people actually know that lead still exists in aviation fuel. There has been increase in concern regarding lead due to the media attention surrounding the public health crisis in Flint, Michigan. Now is the time to get leaded avgas onto the public agenda because it has resurfaced on a national scale. To promote public awareness, we filmed an interview-based television segment with Breathe California, the State's leading lung-health nonprofit, which will be broadcast on channel 15 (CreaTV San Jose) in the coming weeks. Our 30-minute segment will also be posted on Breathe California of the Bay Area's YouTube page. In addition to raising awareness, organizing a grassroots movement to put pressure on public officials to ensure the FAA sticks to the PAFI timeline and the EPA sets emissions standards for unleaded aviation fuel will be crucial. Outreach and education is a necessary step to creating a coalition that ultimately will put pressure on producers and distributors to sell unleaded aviation fuel.

The CEH has been a strong legal advocate for the use of unleaded aviation fuel, but we suggest that the CEH become more directly involved in building a grassroots coalition by directing and organizing supporters, pilots, and parent groups to put pressure on municipal airports to adopt the use of unleaded avgas. We suggest that the CEH reach out to pilots across the state to sign a petition or pledge stating that they will use unleaded aviation fuel if it was provided in their local airport. This will show fuel distributors that the demand for aviation fuel exists. Secondly, we suggest that the CEH reaches out to schools and parent groups of schools located within the high-risk areas. In appendix B, we have attached a one page document that can be sent to local, state, and federal government officials to call for the adoption of unleaded aviation fuel. We suggest that the CEH reaches out to affected schools and encourage parents and administrators to send a letter or even call municipal airport leadership as well as local and federal officials. Engaging local community members will put pressure on airports to offer unleaded avgas once a drop-in replacement is approved by PAFI and market-ready.

Conclusion

Through interviews with multiple stakeholders, we identified the major barriers to the immediate adoption of unleaded aviation fuel as the following: cost of UL94 (when accounting for transportation and storage), public awareness of lead in avgas, pilot perception of safety and performance of unleaded avgas, and cooperation between various stakeholders. Additionally, through literature reviews and case studies we found the advantages of unleaded aviation fuel include: improved public health, improved environmental quality, improved aircraft engine health, and reduction of greenhouse gases associated with transportation of leaded fuel. In order to keep the government on track with PAFI and for there to be a fleet-wide transition to the unleaded alternative (once FAA approved), there must be public awareness of the issue. With the use of public awareness campaigns and grassroots organization, the public can apply the necessary pressure to get local, state, and federal government to implement a transition to unleaded aviation fuel.

There are multiple policy options that can be implemented to aid in this transition to unleaded fuel. In order to reduce the price of unleaded avgas and therefore stimulate demand, municipal governments can reduce or eliminate the fuel flowage fee on unleaded avgas as in the case of the San Carlos Airport. Secondly, policymakers could implement a tax break on unleaded avgas to help reduce the price, making it more competitive and incentivising pilots to buy unleaded if they are able. Lastly, as soon as a PAFI drop-in replacement is approved, the FAA and legislators could initiate the mandatory phase-out of leaded fuel by passing legislation ensuring certain planes and engine models only run on unleaded avgas.

Everyday, vulnerable populations and fragile ecosystems are exposed to lead pollution from avgas, causing lifelong health consequences and sustained environmental degradation. Although the transition to unleaded avgas is seemingly on-track and making progress, there are still many opportunities to ensure this transition happens quickly, smoothly, and without significant conflict. With leaded aviation fuel accounting for the majority of lead in the atmosphere, it is imperative that this fuel is phased out as soon as possible to minimize exposure moving forward. Public awareness is necessary to achieve this, and with sustained and directed public engagement, important steps can be taken toward adopting unleaded avgas.

The transition from leaded to unleaded avgas will require enormous cooperation from a broad range of stakeholders. The Piston Aviation Fuels Initiative is a promising advancement on the path to eliminate leaded avgas, but it will take public pressure combined with market forces to fully phase out leaded avgas, eliminating the largest source of lead pollution in our atmosphere and ensuring the health and safety of vulnerable populations.

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10. Appendices

Appendix A: Interview Questions for Various Stakeholders

Questions for Dan Demeo (Rabbit Aviation Services at San Carlos Airport):

1. What are the barriers to the adoption of unleaded aviation fuel?
2. What are the benefits and drawbacks for the use of unleaded aviation fuel?
3. Was there any regulatory pressure to adopt unleaded avgas?
4. What are the costs associated with including unleaded fuel for the airport? (specifics)
5. How have aviators responded to the switch to unleaded? How many use it?
6. In your opinion, why is San Carlos the only airport in CA selling unleaded fuels?
7. In 2014 you were buying 700 gallons at a time and selling only to a select group. What was the outcome? Have you expanded your customer base/started selling more?
8. In 2014 unleaded avgas could be used in a third of the aircraft in the San Carlos airport and other aircraft could be modified for a small fee. Is this number still the same? How many aircraft were modified?
9. Do you have data on how your lead emissions have decreased after the adoption of unleaded avgas?
10. Why should other airports switch to unleaded fuel?

Questions for Rayvon Williams (Watsonville Airport):

1. What are the barriers to the adoption of unleaded fuel?
2. What are the benefits and drawbacks of using unleaded aviation fuel?
3. How did you first hear about unleaded aviation fuel?
4. To what extent do you think the public knows about the impacts of leaded aviation fuel? Do you know if there have been organizations or others that have worked to create more public awareness on the topic?
5. From an operational perspective, how do you plan to offer the unleaded alternative, assuming that PAFI approves one? Are there any pre-emptive measures you are taking?
6. How much do you think it would cost to accommodate for this transition?
7. Do you see other airports adopting unleaded aviation fuel once the FAA approves one or do you think there needs to be a regulation set in place by the EPA or some other regulatory body to ensure the adoption of unleaded?

Questions for Swift Fuels:

1. What are the barriers to the adoption of unleaded aviation fuel? Specifically in California?
2. What are the benefits and drawbacks for the use of unleaded aviation fuel?
3. How many refinery locations do you have? Is it just the one in Indiana?

4. Is there activity to make refinery locations of unleaded avgas closer to CA?
5. Are you still working in coordination with the FAA on PAFI?
6. What is your perception on the public's awareness of leaded aviation fuel and its effects?
7. Why is autogas (mogas) not good to use in prop planes?
8. What is the chemical difference between your UL100 avgas and 100LL?

Questions for Monica Merrit (FAA)

1. What are the barriers to the adoption of unleaded aviation fuel?
2. Can we get an update on the progress of the PAFI initiative? Are we still looking at an approval date of late 2018?
3. Has the FAA begun testing the fuels yet? How is the testing of older engines going? Are there significant barriers to approving these engines that have not yet been overcome?
4. Can you estimate a number or percentage of GA planes that could currently fly on UL94 without a new STC? With a new STC?
5. Does the FAA have any grant or funding opportunities to aid in the adoption of unleaded fuels for planes that can currently use UL94?
    a. Are there other agencies that could give local, state, or federal aid?
6. Does the FAA coordinate with the EPA when working on leaded emissions standards and compliance?
7. Do you foresee any effects on the current PAFI timeline in regard to the change in administration?
8. What are the benefits and drawbacks of switching to unleaded aviation fuel?

Appendix B: Template one page document to be sent to local and government to call for the adoption of unleaded aviation fuel.

Mr./Ms./Dr. First and Last Name of Person
Position or Title
Street Address/P.O. Box
City, State Zip Code

Dear ____________,

We are writing you to address a public health and environmental issue that often goes unnoticed. Leaded fuel is still used in small propeller planes and helicopters, accounting for about half of all lead emissions in our atmosphere. Since the 1970s, these small aircraft have emitted approximately 35,000 tons of lead into the atmosphere, putting your constituents, especially children, at risk to lead exposure. With the recent events in Flint, Michigan, lead pollution is in the public's eye and is an issue we care about. You have the opportunity to be a leader in combating lead emissions in your community and the United States. We call on you to stand up and protect public health.

<u>Federal Agency Background</u>

Together the FAA and EPA created the Piston Aviation Fuels Initiative (PAFI), a task force dedicated to "developing a path forward for the identification, evaluation and deployment of the most promising unleaded replacements for 100LL ('low lead') aviation gasoline." After six years of identification and testing, the FAA estimates it will take another two years to approve a "drop-in" replacement for 100 octane fuel. In the meantime, using 100LL gasoline, which contains up to 2.12g/gallon of lead, is still contributing to the higher blood lead levels found in residents near airports. We support PAFI's goal of finding a leaded aviation fuel replacement by the end of 2018 and want to ensure they stick to this timeline. Furthermore, once a replacement is approved by the FAA, the EPA will subsequently need to implement a regulation to require a phase-out. We are worried that under a new administration, this action may be pushed to the wayside or cut out altogether.

Calls to Action:

1. Put pressure on the FAA to make sure they follow the PAFI timeline.
2. Once an unleaded aviation fuel is passed and approved by the FAA put pressure on the EPA to enforce.
3. Introduce legislation to create incentives for airports to adopt unleaded fuels.

Appendix C: Transcript of interview with Monica Merrit of the FAA.

Interview with Monica Merrit of the FAA

Questions for FAA on unleaded fuel adoption -

1. What are the barriers to the adoption of unleaded aviation fuel?

The Piston Aviation Fuel Initiative (PAFI) was established at the request of a broad cross section of the aviation and petroleum industries and consumer representatives to develop a path forward for the identification, evaluation and deployment of the most promising unleaded replacements for 100 low lead aviation gasoline. The mission of PAFI is to evaluate candidate unleaded replacement fuels and identify those fuels best able to technically satisfy the needs of the existing aircraft fleet while also considering the production, distribution, cost, availability, environmental and health impacts of those fuels. Mounting environmental and economic pressure necessitates a transition to unleaded fuel. Unfortunately, the aviation and petroleum marketplace, in concert with existing government regulations and policies, do not support an orderly and economically viable fleet-wide transition to a new fuel or fuels, hence the need for the joint government and industry collaborative initiative known as PAFI.

Aviation gasoline has remained largely unchanged for seventy years and the existing fleet of piston aircraft was designed to be compatible with its chemical and physical properties to achieve superior levels of safety, reliability, durability and performance. The FAA's certification activities and supporting policies have therefore not focused on certifying an existing fleet of aircraft to a new fuel or evaluating the properties and performance of fuels themselves, but rather on ensuring the airworthiness of products operating on known fuels conforming to long-established specifications.

To date, the only paths for approving a new fuel for use in existing products was for the OEM to amend their type certificate (TC), or for a third party to obtain a supplemental type certificate (STC) from the FAA, a process intended to ensure flight safety of an existing aeronautical product when operating on the specific fuel to which it was tested. This approval process requires a separate showing that each aircraft and engine complies with all of the airworthiness standards when operated on the new fuel. This process was identified by industry as being too costly and inefficient to be successful in transitioning the entire existing aircraft fleet to any new fuel, particularly because much of the fleet is no longer supported by an active manufacturer. It was also identified that existing evaluation paths examine the airworthiness of the aeronautical products but are not designed or intended to evaluate the chemistry and properties of the fuel. While there are options available for approved model list supplemental type certificates (AML-STC) that can cover a range of aircraft and engine models, such an approval process can be complex and would not likely result in the orderly fleet-wide transition necessary to maintain the economic viability of the piston aircraft fleet. Other available avenues for approval such as amended type certificates or the issuance of manufacturer service instructions authorizing the use of a new fuel across a range of models pose similar barriers and complications to an orderly and comprehensive transition and do little to address the orphan fleet of aircraft and engines no longer supported by an active manufacturer.

Aviation fuel commercial development and deployment over the past seven decades has relied on industry organizations comprised of a diverse group of industry stakeholders possessing experience and technical knowledge in the areas of powerplant engineering, fuel system design, combustion engineering, chemical engineering, toxicology and emissions, and fuel production and distribution, among others. These industry stakeholders require that a new fuel must both be shown to operate safely across the fleet of existing engines and aircraft, and must be able to be produced and distributed across existing infrastructure safely and efficiently. Thus, it is recognized that significant additional information beyond that required for FAA airworthiness approval is necessary to bring a fuel into actual production and distributed as a commodity in the marketplace.

Fuels move seamlessly around the globe because of broad-based understanding and acceptance of the products, their properties and behaviors, and commonality between production, distribution and testing methods. Such acceptance is necessary to ensure widespread, reliable, and economically viable production, distribution, and usage wherever aviation gasoline is needed. This global acceptance is the result of open consensus-based processes that permit peer review and significant standardization among both the products and their respective testing methods and specifications.

Inherently, existing FAA certification procedures such as STCs, amended TCs and service letters are a closed review process between a fuel developer and the FAA office and/or OEM, relying upon data that is often considered to be proprietary intellectual property. While this may work for FAA airworthiness approval resulting in the ability to burn a particular fuel in a particular aircraft and engine combination or list of combinations, it does little to overcome the barriers to the broad acceptance necessary for fleet-wide implementation by the petroleum, specialty chemical, aviation, and insurance industries as well as the end consumer. FAA certification procedures also do not address the concerns of environmental and health advocacy groups and regulators who have a stake in the emissions and toxicology of any new unleaded fuel. Additional peer review, testing, data collection and the development of industry consensus standards are all necessary steps above and beyond FAA airworthiness approval to bring a fuel to the marketplace as anything other than a specialty proprietary product with limited availability and application.

PAFI was conceived and established to overcome these barriers to entry into the aviation fuel marketplace by creating a process that would evaluate all of the properties and conditions necessary for broad production, distribution and usage of a new unleaded aviation fuel, and expeditiously develop data necessary to support FAA approval of the majority of the existing fleet of piston aircraft to operate on that fuel. Further, PAFI was designed to conduct much of the testing necessary for fuel production and distribution acceptance and fleet approval using common test facilities, procedures and industry consensus standards leading to broad marketplace acceptance and adoption. In short, the PAFI process is necessary to take the good ideas of a fuel developer and move them beyond FAA approval in limited applications to fleet wide approval and broad based acceptance in the marketplace. It is the mechanism by which a fuel developer can move beyond having a proprietary product with limited application to become a broadly produced and distributed aviation fuel. In effect, the PAFI process is necessary to help enable widespread market acceptance and fleet-wide certification for a candidate unleaded fuel.

2. Can we get an update on the progress of the PAFI initiative? Are we still looking at an approval date of late 2018?

Through PAFI, the FAA is conducting extensive fuel testing and evaluation with the critical support of aircraft and piston engine manufacturers. Two fuels have been selected for further ground and flight testing on approximately 19 engine and 10 aircraft models.

Currently the PAFI program is on schedule and testing is expected to be completed by the end of 2018. Implementation of any required changes to the aircraft or engines is dependent on the results of the testing.

Additional information about the PAFI program can be found at https://www.faa.gov/about/initiatives/avgas/.

3. Has the FAA begun testing the fuels yet? How is the testing of older engines going? Are there significant barriers to approving these engines that have not yet been overcome?

The FAA has begun testing the fuels. The PAFI process involves a two phase testing program. Phase 1 evaluated candidate fuels for potentially show stopping issues in the production, distribution and operation arenas before significant investment is made in gaining FAA design approval. Among these steps was an evaluation of the chemistry of the fuel and fitness for its intended purpose. Other critical Phase 1 evaluations included; assessing the emissions and toxicology properties and resultant impacts, evaluating whether a fuel can be produced and distributed broadly and economically, and determining that the fuel will perform adequately across its full intended compositional range in the existing fleet of engines and aircraft, effectively ensuring that it will be tested under worst case conditions of fuel composition and operating environment. The PAFI process also examined the business case for candidate fuels looking at projected production, availability, and distribution models in an effort to ascertain whether a fuel would be readily producible and available at a manageable cost.

Having proved the technical, environmental and business case merits of proposed unleaded replacements to 100 LL in Phase 1, 2 fuels were determined to be the most promising and were approved for entrance into Phase 2. As mentioned in question 2 above, these 2 fuels will be tested on the engine and aircrafts. We are currently in the testing phase and do not have enough data at this time to determine if there are significant barriers to overcome to approve the engines.

4. Can you estimate a number or percentage of GA planes that could currently fly on UL94 without a new STC? With a new STC?
The DOT/FAA/AR-TN11/22 , Aviation Fuels Research Reciprocating Engine Aircraft Fleet Fuel Distribution Report, on fleet demographics shows that 53.7% of the fleet could fly on UL94. This is only addressing the physics; this is not addressing any limitations or paperwork needed. Special Airworthiness Information Bulletin (SAIB) HQ-16-05R1 clarifies that all aircraft/engines certificated on Grade UL91 and minimum octane 80 or less are eligible to operate on UL94. This results in the capability of 46.3% of the current fleet to be operated on UL94 with no additional approval or authorization necessary.
The follow-on question regarding a new STC is a bit vague as it does not describe the bounds of the modification contained in the STC such as "with no loss of aircraft performance."

5. Does the FAA have any grant or funding opportunities to aid in the adoption of unleaded fuels for planes that can currently use UL94?
a. Are there other agencies that could give local, state, or federal aid?

I am unaware of any grants or funding available to support the adoption of UL94.

6. Does the FAA coordinate with the EPA when working on leaded emissions standards and compliance?
Yes.

Under Section 231 of the Clean Air Act, the EPA is analyzing air quality modeling and monitoring information to make a determination of whether lead emissions from piston engine aircraft cause or contribute to air pollution which may reasonably be anticipated to endanger public health or welfare. Additional information about EPA action regarding leaded aviation gasoline can be found at https://yosemite.epa.gov/opei/RuleGate.nsf/byRIN/2060-AT10.

The FAA has been working closely with the Environmental Protection Agency (EPA) in an effort to find an environmentally and operationally safe substitute for leaded aviation gasoline.

7. Do you foresee any effects on the current PAFI timeline in regard to the change in administration?

At this time it is too early to know what the change in administration will bring.

8. What are the benefits and drawbacks of switching to unleaded aviation fuel?

The benefits are why the PAFI program began, to remove lead from the fuel. A drawback is that the new fuel will not have the history that the current 100 LL has on how it performs in the aircraft and engine or how it affects the environment. At this time we will only be able to make assumptions with the information and testing we have to date. Any other drawbacks or barriers that weren't previously discussed above won't be known until the end of the test program and years after the aircrafts are using the new unleaded fuels.