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Demonstrating the Feasibility of Methanol Gasoline Blends to Reduce Petroleum Use in the United States

Final Report

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Executive Summary

Methanol gasoline blends have the potential to provide a value proposition to consumers—less expensive fuel at their local fuel station. These blends will decrease petroleum consumption and our dependency on foreign imports and can reduce local and global emissions. Although these societal benefits are significant, it is the lower price fuel at the corner retail station that will change the purchasing habits of flexible fuel vehicle owners and may lead to an overall solution of continuing to decrease our use of petroleum in passenger cars and light duty trucks. Methanol gasoline blends are a solution that does not need a technology break through to reduce costs or to increase range/utility of vehicles.

Methanol today is mostly produced from natural gas. With newer drilling technologies and fracking technology, most energy experts believe the U.S. will be awash in natural gas supplies for many decades. This coupled with increasing world demand for oil—primarily from developing countries—has and will continue to decouple the price of oil and natural gas. Natural gas prices are projected to remain relatively flat in $2012, and oil is expected to more than double. This price delta will make methanol gasoline blends the least cost option for light duty vehicles.

However, there are many barriers that have to be overcome before methanol gasoline blends can enter the market place. First are the vehicles to operate on these blends. Very preliminary data on one vehicle suggests that FFVs certified to operate on E85[1] and gasoline will also operate on a methanol gasoline mixture that matches the fuel properties of E85. This mixture has 56 percent methanol by volume and 44 percent gasoline by volume (M56). Again, preliminary data on tailpipe emissions and driveability looked very promising. Importantly, OBD systems in limited testing appeared to function correctly. Missing from these initial tests was testing for evaporative emissions, which are more challenging for methanol gasoline blends due to the higher vapor pressure (as measured by RVP) of the blends. Longer-term durability and fuel system material compatibility testing are needed to ensure that these blends will be successful in the market place and meet all regulatory requirements.

The second barrier is fuel blending. Methanol's RVP increase when mixed with gasoline is 3.4 psi compared to ethanol's increase of 1 psi. This means in order to meet gasoline or gasoline blend vapor requirements a lower RVP gasoline feedstock is needed. Removing RVP from gasoline increases costs and this will have to be investigated further. Also, there is a tendency for methanol gasoline mixtures to separate with the presence of as little as 4 percent water in the mixture (depending on percent methanol in blend and temperature). Adding co-solvents to the mixture reduces this tendency, but then may complicate meeting RVP or tailpipe emission requirements. Using methanol gasoline mixtures in FFVs also brings in the possibly of fueling on gasoline only, thus commingling methanol gasoline blends with ethanol gasoline blends. These effects on vehicle emissions will need investigation.

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[1] Nominally 85 percent ethanol and 15 percent gasoline, but higher gasoline percentage is used in winter to enhance cold starting.

The third barrier is fuel distribution. Although M85 was successfully demonstrated at scale in the California Methanol Program, only ethanol stations have since been built. Questions arise on the ability to use these stations for methanol gasoline blends or to design and build new stations. Methanol is more corrosive than ethanol so fuel station equipment has to be qualified for methanol blend use.

These three barriers are all technical and with time and resources can be solved. A demonstration program involving industry stakeholders and government (a public private partnership) is a first step in overcoming these barriers. This demonstration needs to include vehicle procurement, vehicle emission testing, vehicle optimization and recalibration if required, testing of fuel system materials on methanol gasoline blends, driveability and fuel economy testing, and longer term vehicle driveability and durability monitoring and testing. Fuels testing and fuel design are needed to develop a commercial product for the market place meeting current gasoline regulations. Finally, the demonstration should include the design and construction or retrofit construction of at least two-methanol gasoline blend fueling stations.

The fourth barrier is needed approvals from EPA and perhaps state agencies to perform a demonstration of methanol gasoline blends. If the demonstration is successful, then the next major effort is providing EPA with enough vehicle, material, and environmental, health and safety data to gain approval to market methanol gasoline blends. The envisioned demonstration will provide some, but not all, of the data to meet EPA requirements, and additional work and resources will be necessary.

The fifth and final barrier is establishing a policy that encourages the use of methanol gasoline blends. It could turn out, for example, that current FFV fuel systems are not compatible with methanol. In this case automakers would need some incentive to produce methanol FFVs to cover higher costs or pass these costs on to the consumer. Consumer demand will depend on the strength of the value proposition for methanol gasoline blends. It is also not clear why gasoline suppliers would want to supply methanol gasoline blends, since these blends would offset petroleum use (which for energy companies is most likely a higher margin fuel). Perhaps there needs to be a fuel standard that requires the reduction of petroleum and the fuel suppliers have the option to develop fuels that would meet this standard—in California this was called fuel pool averaging.

Vehicles and fuels impact society not only from the economics of owning and operating a vehicle but also from the impacts of emissions and our dependency on petroleum. An energy policy that brings to market vehicles and fuels that reduce local pollution, decrease greenhouse gas emissions, and displaces petroleum is needed to reduce the impact of our transportation system. Methanol gasoline blends may be a part of this policy.

1. Introduction

1.1 Objectives

The objective of this research was to determine the opportunities and issues of using methanol in the light-duty vehicle transportation market. We were asked by the Fuel Freedom Foundation to determine how methanol could be distributed and dispensed at local fueling stations. We investigated the current storage and fueling equipment capabilities for handling methanol and methanol gasoline blends. Today's fueling equipment and materials are compared to the experience gained in the California Fuel Methanol Program performed in the 1990's (ref). As part of this effort, we also reviewed past work on the issues associated with using methanol in vehicles as well as environmental, health and safety concerns. Methanol gasoline blends could potentially be marketed as "drop-in" fuels for existing and new flexible fuel vehicles (FFVs) and possibly for retrofitted newer model year gasoline vehicles. We developed an economic model to investigate how methanol gasoline blends compete with gasoline (either with 10% ethanol—E10 or 15% ethanol—E15). Based on our findings on distributing methanol gasoline blends, issues, and economics, we developed a blueprint plan to demonstrate the feasibility of using methanol to displace gasoline—and, therefore petroleum. Finally, we reviewed past policies to promote the use of alternative fuels and recommended possible policies that would help methanol gain market share in the light duty vehicle transportation fuels market.

1.2 Background

Despite years of research and development and the introduction of commercial vehicles with advanced technologies to improved fuel economy and to use alternative fuels, the U.S. transportation is still over 90 percent depended on petroleum. The light duty fleet in the U.S. depends primarily on gasoline, although automakers have introduced vehicles capable of operating on ethanol (FFVs), natural gas, propane, plug-in electric, battery electric, and hydrogen fuel cells. Alternative fuels have always been challenged by higher vehicle cost, the lack of fueling infrastructure and matching the infrastructure to increasing vehicle populations (increasing fuel demand).

The most successful implementation of alternative fuels to date has been blending ethanol with gasoline. Today some 14 billion gallons of ethanol are blended with gasoline blend stock to give a 10% ethanol gasoline blend (so-called E10). EPA has also recently approved the use of E15 (15% ethanol with gasoline blend stock) in newer model year vehicles.[2] The success to date of other alternative fuels by comparison is shown in Figure 1. As indicated, the population of vehicles capable of operating on alternatives to gasoline or petroleum is very small compared to vehicles operating on gasoline and diesel fuels. Although there is a fairly large population of

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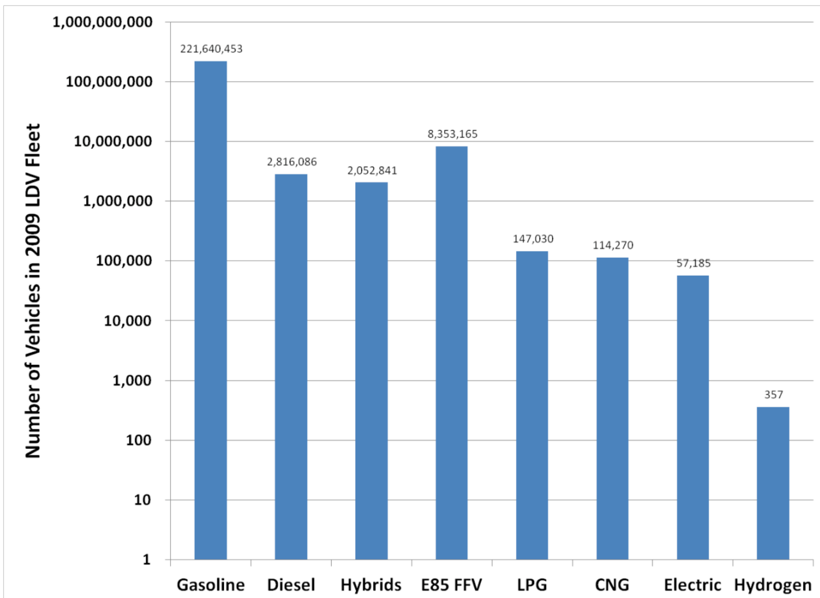
[2] EPA has approved the use of E15 in newer vehicles, see http://www.epa.gov/otaq/regs/fuels/additive/e15/

E85 FFVs, the estimate of those actually using E85 is more in line with the other alternatives at 618,505 or less than 10 percent of E85 FFV population.[3]



Source: Transportation Energy Data Book: Edition 30-2011

Figure 1. Light Duty Vehicle Population of Advanced and Alternative Technologies in U.S. in 2009

Table 1 shows the amount of alternative fuels used in the U.S. light duty fleet in 2010. With the exception of ethanol blended in gasoline the total use of all alternatives is equivalent to 700 million gallons of gasoline per year. This compares to light duty vehicle gasoline consumption of 133.1 billion gallons of gasoline (includes ethanol) or less than 0.5% penetration. Conversely, ethanol blending displaced 8.6 billion gallons of gasoline or nearly 7% of the gasoline pool.

These data indicate how difficult it is to grow alternative fuel vehicle population and alternative fuel use and how much more effective the strategy of blending ethanol with gasoline is. A blend strategy that can be used in the existing fleet and that makes use of the existing fueling infrastructure is far easier to implement than an alternative fuel strategy that requires new vehicles and a separate new fueling infrastructure (as indicated by the data shown in Figure 1 and Table 1).

The key to either strategy, however, is economics. Alternative fuel vehicles compete with the gasoline fuels sold commercially—E10 in most states today in the U.S., although E0 is also still used. Alternative fuel vehicles using natural gas, electricity, or hydrogen are more expensive than conventional fueled vehicles. These higher upfront costs are offset by the lower priced fuel

[3] Davis, Stacy C., Susan W. Diegel, Robert G. Boundy, "Transportation Energy Data Book: Edition 31," Oak Ridge National Laboratory, July 2012, http://cta.ornl.gov/data/index.shtml

or increased efficiency. Drop in fuels—like E10—become the baseline fuel, against which the alternatives compete.

Ethanol is an anomaly since it competes well as a low-level blend component to gasoline, but is too expensive as an E85 fuel. This is because ethanol is valued on a volume basis as a low level component (E10-E15) but needs to be valued on an energy basis for E85 to compete with E10 or E0. This has led to small sales volumes of E85 compared to the potential fuel volumes possible given the large number of E85 FFVs capable of using E85. The question then arises: Are there cheaper fuel components that could be added to gasoline that could be used in E85 FFVs and compete, or better yet, be less expensive than the gasoline it replaces?

Table 1. Alternative Fuel Consumption in U.S.

Alternative Fuel	2007 (thousand gge)	2008 (thousand gge)	2009 (thousand gge)	2010 (thousand gge)
Liquefied petroleum gas	152,360	147,784	129,631	126,354
Compressed natural gas	178,585	189,358	199,513	210,007
Liquefied natural gas	24,594	25,554	25,652	26,072
E85	54,091	62,464	71,213	90,323
Electricity	5,037	5,050	4,956	4,847
Hydrogen	66	117	140	152
Biodiesel	367,764	324,329	325,102	235,188
Ethanol in gasoline	4,694,304	6,442,781	7,343,133	8,527,431

Source: Transportation Energy Data Book: Edition 31-2012

Methanol use in vehicles was demonstrated in the past—primarily in California—as a replacement for gasoline.[4] A mixture of 85% methanol and 15% gasoline (M85) was used in light and heavy-duty vehicles in California in the late 1980s early 1990s. Gasoline was added to methanol to help with cold starting, provide a luminous flame, mitigate in tank combustible mixtures, and to discourage human ingestion. California investigated both alcohols before choosing methanol due to its potential to be a less expensive than ethanol.[5] The idea was to use less expensive shut-in natural gas resources located throughout the world to produce competitively priced methanol. However, with oil prices in the low $20 per barrel, methanol was still too expensive to compete with gasoline. There was some hope that M85 could compete with premium gasoline for its octane benefit, but this required economies of scale and this was only achieved with very large capital investments.

Today horizontal drilling and fracking technology in the U.S. has significantly changed the outlook for U.S. natural gas supply. U.S. shale resources of natural gas are estimated to be on par with natural gas resources of the Middle East and Russia—the two largest known reserves of natural gas in the world.[6] It is estimated that the U.S. at current natural gas consumption has well over 100 years of supply. The U.S. natural gas shale resources have resulted in downward

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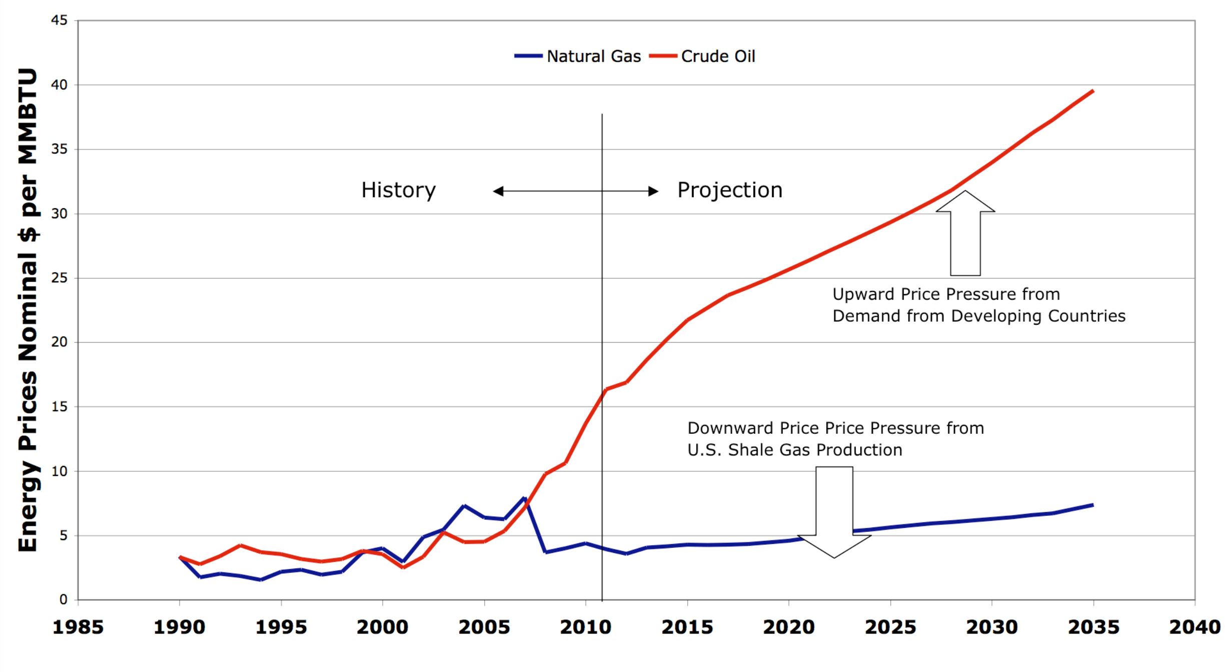
[4] ref on California Methanol Program

[5] Blaisdell, T.B., M.D. Jackson, C.B. Moyer, and S. Unnasch, "California's Methanol Program Evaluation Report, Volume II, Technical Analysis," CEC Report P500-86-12A, July 1986

[6] U.S. Energy Information Administration (EIA), "Annual Energy Outlook 2012 with Projections to 2035," June 2012, http://www.eia.gov/forecast/aeo

natural gas price movement, especially compared to oil prices. In their 2012 annual energy outlook, EIA projected an ever-increasing price advantage of natural gas compared to oil as shown in Figure 2.



Source: EIA Energy Prices

Figure 2. Oil will be more Expensive than Natural Gas in the future on an energy basis

With growing world oil demand from developing countries, the U.S. and other developed countries will see increasing oil prices even as the developed countries reduce their demand through policies such as improved fuel economy and the use of more alternative fuels. It is for this reason that natural gas and natural gas derived products now have an opportunity to compete in the transportation market.

Using natural gas to produce methanol and then blending methanol with gasoline to be used in existing and new vehicles could substantially decrease our demand for, and dependence on, petroleum. Lotus Engineering introduced the concept of blending gasoline, ethanol, and methanol—GEM fuels—as a way to reduce the costs of FFV alternative fuels.[7] They have shown that GEM fuels can be formulated to have equivalent combustion characteristics as E85 and, therefore, be able to replace E85 without any vehicle changes.[8] One such mixture is 56% methanol and 44% gasoline. Given the low prices of methanol (nominally $1 per gallon or

[7] Pearson, R.J., J.W.G. Turner, M.D. Eisaman, K.A. Littau, "Extending the Supply of Alcohol Fuels for Energy Security and Carbon Reduction," SAE 2009-01-2764

[8] Fueling system components may have to be replaced to be compatible with methanol. This is discussed in more detail in subsequent sections.

$17.70 per million BTU) compared to ethanol ($2.30 per gallon or $30.26 per million BTU) or gasoline blend stock ($3.00 per gallon or $26.55 per million BTU) it would make economic sense to minimize both the use of ethanol and gasoline.

A considerable amount of work was done on methanol as a transportation fuel in California and much more work will be required to elevate methanol gasoline blends as a viable option in the market place. However, there is a significant strategic advantage for methanol gasoline blends given the work previously performed and the potential price advantages of a liquid fuel used in flexible fueled vehicles. The previous experience can be used as a foundation from which the issues associated with introducing methanol gasoline blends can be researched and resolved.

1.3 Our Reliance on (or Addiction to) Petroleum

The light duty transportation sector is 92% dependent on petroleum.[9] Until the great recession of 2008[10] fuel use and vehicle miles travel (VMT) had continued to increase year over year. The economic impact of the recession reduced VMT and corresponding fuel consumption especially in the LDV sector. This trend is shown in Figure 3. This figure shows our domestic production of liquid fuels and our demand for these fuels. As indicated for the last four decades the U.S. has relied on imported supplies of liquid fuels (primarily crude oil and refined products) to meet our energy demands. Our imports peaked in 2005 at 60% and have declined to 49% in 2010. This trend is projected to continue as demand is reduced and domestic production increased. More efficient gasoline and more alternative fueled vehicles entering the LDV fleet further mitigate this demand. Supply increases as the U.S. continues to produce more domestic oil from its shale and off shore resources. EIA is predicting that our import dependence will drop to 36% by 2035.

Although we are reducing our imports we still rely on countries that belong to the Organization of Petroleum Exporting Countries (OPEC) for 52% of our imports in 2011.[11] Figure 4 shows that the largest OPEC suppliers in 2011 were Saudi Arabia and Venezuela. Canada and Mexico combined provide over a third of our imports. There are economic costs to our dependence on imported oil and a number of studies have point to our balance of payments, lost of jobs, and the costs of our military in regions such as the Middle East. It has also been point out that we are purchasing oil from many countries that do not like us. In 2011, even as our import reliance dropped, our imported costs of petroleum exceeded $300 billion.

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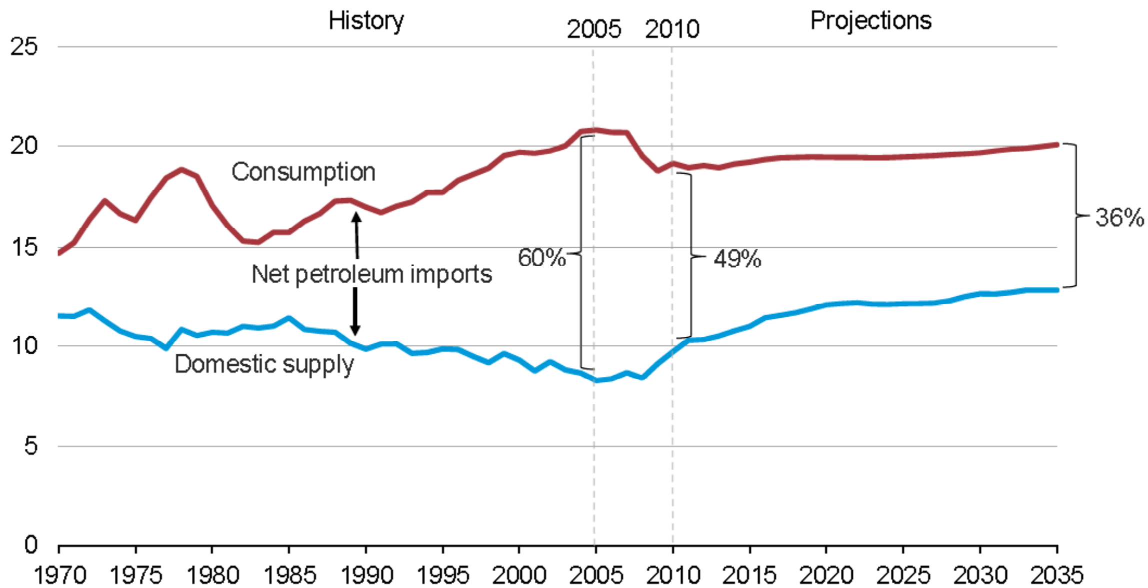
[9] EIA Annual Energy Outlook 2012

[10] December 2007 to June 2009 as defined by the National Bureau of Economic Research (NBER)

[11] EIA, "U.S. Imports by Country of Origin," http://www.eia.gov/dnav/pet/pet_move_impcus_a2_nus_ep00_im0_mbbl_m.htm



Source: EIA AEO2012 Early Release Overview, Figure 1.

Figure 3. U.S. Imports of Liquid Fuels Peaked in 2005 and is Projected to Decrease Due to Advanced Vehicles and Increase Domestic Supply (million barrels per day)

Top Five Countries Importing Crude Oil and Petroleum Products to U.S. (2011)

Canada	29%
Mexico	8%
Venezuela	11%
Nigeria	10%
Saudi Arabia	14%

OPEC 52% — non-OPEC 48%
Total imports 8,518,000 bbls/day

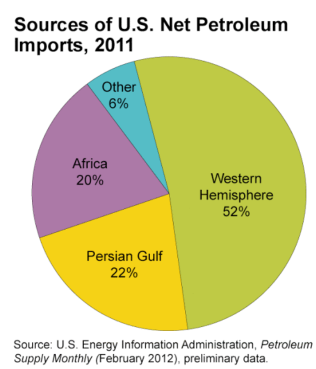


Figure 4. U.S. Oil Imports in 2011 still rely heavily on OPEC

Our dependency on oil has two other impacts. First, because of OPEC's market power the price of oil in the world market is higher than normal free market conditions. Second, sudden and large increases in oil prices have been a contributing factor in each of the U.S. recessions since 1970 as shown in Figure 5. Researchers at Oakridge National Laboratory have quantified the economic effects of oil prices in the long run, U.S. import costs, short-run disruption premium, and effects on output of the overall economy and are calculated to be $0.462 per gallon of petroleum fuel.[12] For the U.S. LDV sector, these indirect or societal costs the U.S. an additional $57 billion per year over and above the $400 billion consumers paid for gasoline.

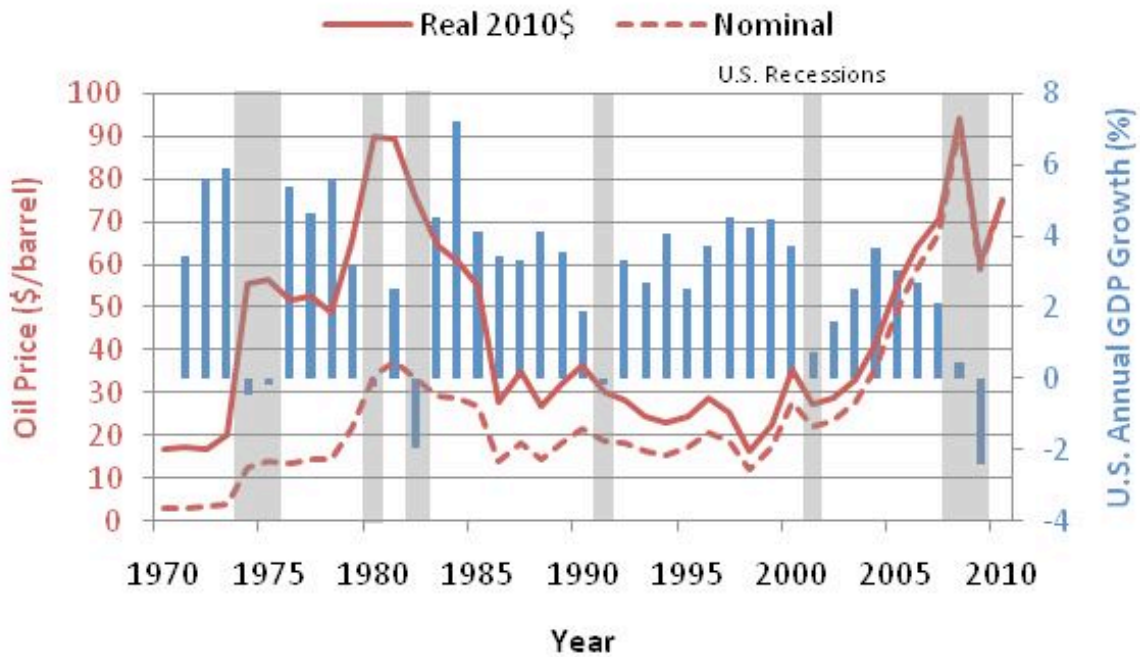


Figure 5. Correlation between rapidly increasing oil prices and recessions in U.S. (source U.S. DOE)

Environmental costs are another societal cost associated with our dependency on petroleum. Although vehicles today are considerably cleaner than those of the past, today's vehicles still emit pollution of oxides of nitrogen (NOx), hydrocarbons, carbon monoxide (CO), and particulate manner (PM) as well as toxic emissions like benzene and 1, 3 butadiene. Vehicles also contribute to greenhouse gas emissions (GHG) including carbon dioxide (CO2), nitrous oxide (N2O), and methane (CH4). Additionally, the production and distribution of transportation fuels also contributes to all of these emissions. Current analysis of the societal impact of these emissions now includes the "upstream" fuel production and distribution as well

[12] Green, D. L., J.L. Hopson. "The Costs of Oil Dependence 2009." Oak Ridge National Laboratory. http://www1.eere.energy.gov/vehiclesandfuels/facts/2010_fotw632.html. 2010.

as the “downstream” direct emissions from vehicles. These are referred to as well to tank and tank to wheels respectively and collectively is referred to as well to wheels.

A number of studies have quantified these costs and the Fuel Freedom Foundation is currently working with TIAX LLC to update these costs for methanol and methanol fuel blends. The TIAX work will estimate the societal costs of methanol fuel blends to those of gasoline blends. Based on past analysis we would expect the societal costs of criteria, toxic, and GHG emissions to be less than those of gasoline. It is possible the emissions benefit of methanol blends could be quite comparable to the energy security benefits of 46 cents per gallon.

1.4 Report Organization

The following sections of this report look at various aspects of the impact and possible benefits of introducing methanol into the LDV sector. Methanol could also be used in the heavy-duty sector but unlike the LDV market a separate fueling infrastructure would be needed since methanol could not be blended with diesel.[13] The next section—Section 2--provides an overview of the potential issues associated with using methanol. Section 3 provides an analysis of how methanol could be shipped, stored, and distributed within the existing fueling infrastructure. Section 4 provides an overview of the business case of selling methanol fuel blends into the LDV market. Section 5 outlines the components for demonstrating methanol fuel blends in E85 FFVs and Section 6 discusses possible policies that could be used in the short and long term to encourage the use of methanol in the transportation sector.

[13] Natural gas could be convert directly to diesel fuel via the Fischer Tropsh process and then blended into diesel

2. Blending Methanol with Gasoline—Possible Issues

The technical issues for dispensing and use of methanol are generally well understood. The California experience in the 1980s and 1990s provided a valuable platform to develop a sound knowledge base for methanol use: flexible fuel vehicles (FFVs) capable of running on gasoline and methanol were commercialized, fueling stations were built, and this was done at scale, not on a trial basis. In addition, many studies were performed to look at possible environmental, health, and safety impacts of a methanol transition and these studies as well as newer analysis are used here to assess the impacts and issues of methanol use in the LDV fleet. Today, while there are no methanol vehicles produced—the U.S. manufacturers have continued to produce FFVs but only for ethanol. Thus, one of the key issues is whether the ethanol FFVs can use methanol. This is explored first, followed by issues associated with methanol gasoline fuel blends. Environmental, health, and safety issues, concerns, and possible mitigation are discussed next. The final section briefly discusses regulatory issues that must be addressed.

2.1 Vehicle Issues

There are many vehicle changes that are necessary to produce a flexible fuel vehicle. Figure 6 illustrates the changes that are made for the Ford FFV designed and calibrated for E85. May of these changes would also have to be made for methanol, but some of the changes could be minimized if a methanol gasoline mixture had similar combustion related fuel properties such as energy density. In this case, the sizing or bandwidth of fuel injectors and fuel pump are the same as E85. The key difference is material compatibility, which has to be modified for E85 and quite likely will have to be further modified for methanol gasoline blends. Another possible major difference is emission calibration. These issues are discussed further below.

2.1.1 Vehicle Emissions Calibration

Automakers are required to certify their vehicles to meet the emission standards of the U.S. Environmental Protection Agency (EPA) and in states adopting the California standards of the California Air Resources Board (CARB). Both EPA and CARB have a series of standards for various vehicles like light duty passenger cars and light duty trucks. CARB recently developed newer, more stringent standards for light duty vehicles and have harmonized the requirements for light duty passenger cars and trucks—LEV III; and EPA is considering a similar rulemaking—Tier 3. The requirements of these agencies include exhaust emission standards over standard and supplemental driving cycles and evaporative emission standards for diurnal, running losses, and hot soak emissions. The agencies specify testing requirements and certification fuel—now mostly gasoline but also specifications for E10 certification fuels. Regulations also include requirements for on-board fueling vapor recovery (OFVR) and on-board diagnostic (OBD) monitoring. Additionally the agencies also require automakers to warranty their emissions systems for the useful life of the vehicle—120,000 miles for EPA and 150,000 miles for CARB.

Meeting the emissions regulations requires automakers to develop advanced hardware systems like advanced catalyst and advanced software systems for controlling combustion, and

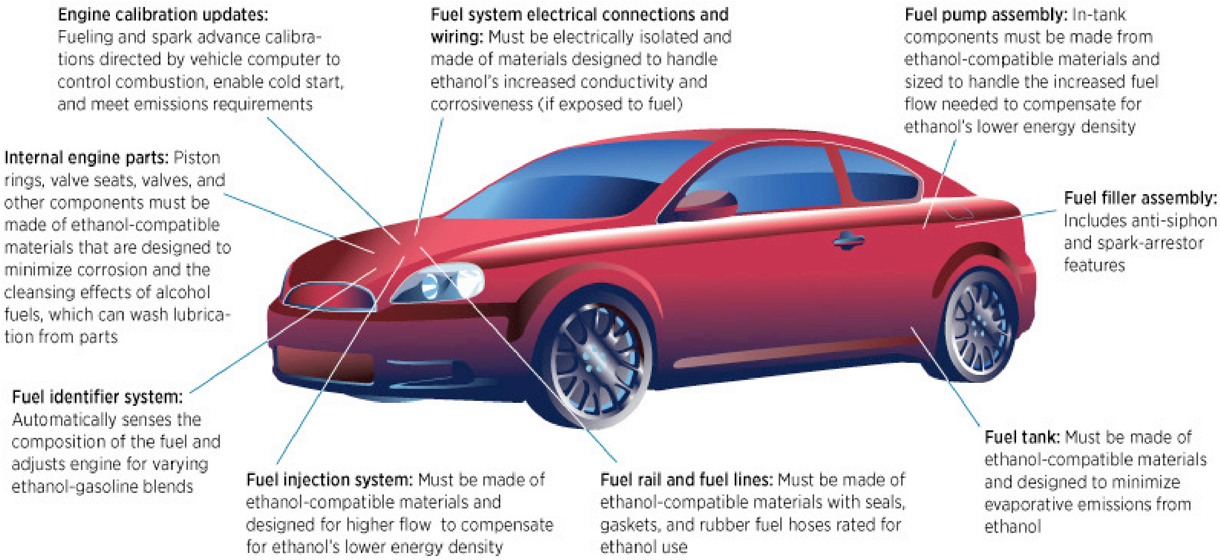


Figure 6. Special components of an E-85 FFV compared to conventional gasoline LDV (Source: U.S. DOE, http://www.afdc.energy.gov/vehicles/flexible_fuel.html.)

monitoring the emission and engine performance. Malfunction lights are now common in today's vehicles to indicate a problem with emissions or vehicle operation. Combining all these requirements for new vehicles is expensive and time consuming. Adding fuel flexibility with E85 FFVs adds additional testing for exhaust and evaporative emissions—increasing the cost of certifying these vehicles.

Both agencies and automakers realize that the emission and vehicle performance is an integration and optimization of the vehicle's system components and the fuel used. Changing the fuel has implications on emissions performance and vehicle driveability. The automakers and the oil companies collaborated to assess the effects of gasoline and oxygenate properties on 1990 automotive technologies in the so-called Auto Oil Program.[14] This program and subsequent testing on newer vehicles has lead to an understanding of how various gasoline and additive components interact with modern vehicle emissions hardware.

One would expect then changing the fuel use in a vehicle designed for gasoline would have a significant effect on both emissions and driveability. Consider the possibly of using E85 in a gasoline vehicle. It is quite possible that fuel injectors would not be sized for higher volume flow needed with the lower energy content ethanol. Similarly, the vehicle's fuel pump may also be undersized. Together performance would be limited with power limited by the bandwidth of the injectors or fuel pump capacity. Although maybe not as straightforward, emissions would also be affected since the fuel air ratio for optimum control is considerably different for gasoline and ethanol. It may be possible to retrofit the software contained in the engine control module

[14] Burns, Vaughn R., Jack D. Benson, Albert M. Hochhauser, William J. Koehl, Walter M. Kreucher, Robert M. Reuter, "Description of Auto/Oil Air Quality Improvement Research Program," SAE 912320, also in SAE SP 920, February 1992.

but if other hardware changes are needed such as different catalyst, a retrofit option could become more expensive. For more discussion on retrofit possibilities refer to the recent TIAX report.[15]

Tailpipe Exhaust Emissions

For the natural gas to methanol concept, using E85 technology with an acceptable methanol gasoline blend, has been demonstrated. Lotus engineering has shown that fuels containing gasoline, ethanol, and methanol can have comparable combustion and vehicle performance as gasoline only or E85 only fuels.[16,17] Table 2 shows comparable fuel properties for several gasoline, ethanol, methanol blends. As used in this table, G refers to gasoline, E to ethanol, and M to methanol. The number after the fuel designation letter refers to volume concentration; so M56 refers to methanol at a volume concentration of 56% (Blend D).

Table 2. Lotus Methanol, Gasoline, Ethanol Blend Characteristics (source SAE 2012-01-1279). Sensitivity is RON-MON

Fuel	Gasoline	Blend A	Blend B	Blend C	Blend D
GEM Component Ratios	G100 E0 M0	G15 E85 M0	G29.5 E42.5 M28	G37 E21 M42	G44 E0 M56
Stoichiometric AFR	14.18	9.69	9.69	9.71	9.69
Density (kg/l)	0.731	0.781	0.773	0.769	0.765
Gravimetric LHV (MJ/kg)	43.12	29.09	29.38	29.56	29.66
Volumetric LHV (MJ/l)	31.52	22.71	22.70	22.71	22.69
Carbon Intensity (gCO_2/l)	2297.3	1627.9	1624.2	1623.9	1620.2
Carbon Intensity (gCO_2/MJ)	72.88	71.69	71.56	71.49	71.41
RON	95.3	109.0	108.7	108.5	108.2
MON	85.0	90.7	90.3	90.3	90.0
Sensitivity	10.3	18.3	18.4	18.2	18.2

As shown E85 or Blend A properties can be reproduced by varying the amounts of gasoline, ethanol, and methanol. Blend D a mixture of 44% gasoline and 56% methanol has the same stoichiometric AFR as E85 Blend A. Further, energy density as measured by volumetric lower heating value (LHV) and Research Octane Number and Motor Octane Number are essentially the same. Lotus also tested heat of vaporization of the above blends and found them to be roughly constant varying by only 4% from Blend A to Blend D. This means that an E85 designed vehicle would not be able to distinguish between these fuel blends. The vehicle would detect the amount of oxygen in the fuel and through the engine control fuel tables adjust the fuel flow to the engine. Spark timing would also be adjusted. No changes would be needed for E85 or the other blends since energy density and octane ratings are the same.

Lotus also performed a limited set of emissions testing on a SAAB 9^3 1.8T BioPower station wagon equipped with a manual transmission and certified to Euro 5 emission standards. Lotus tested this vehicle using the New European Drive Cycle (NEDC). The cold start results are

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[15] Leonard, Jonathan H., Pere Margalef, Michael D. Jackson, and Helena Chiang, "Technical Opportunities and Challenges to Reduce Gasoline Consumption from the In-Use LDV Fleet through Retrofit and Alternative Fuel Conversions," TAIX Report D0626, for NRDC and Fuel Freedom Foundation, October 2012

[16] Turner, J.W.G., R.J. Pearson, R. Purvis, E. Dekker, K. Johansson, and K. ac Bergstrom, "GEM Ternary Blends: Removing the Biomass Limit by using Iso-Stoichiometric Mixtures of Gasoline, Ethanol, and Methanol," SAE 2011-24-0113

[17] Turner, James W. G., Richard J. Pearson, Mark A. McGregor, John M. Ramsey, Eelco Dekker, Ben Iosefa, Gregory A. Dolan, Kenth Johansson, and Kjell ac Bergstrom, "GEM Ternary Blends: Testing Iso-Stoichiometric Mixtures of Gasoline, Ethanol and Methanol in a Production Flex-Fuel Vehicle Fitted with a Physical Alcohol Sensor," SAE 2012-01-1279

shown in Figure 7. The NOx Euro 5 emissions limit is 0.06 g/km and as shown this vehicle had no difficulty achieving this standard on gasoline or any of the blends. On average, the four blended alcohol gasoline mixtures were 50% lower NOx than the results when operated on gasoline. Lotus also stated in that hydrocarbon and CO emissions where as reduced.[18]

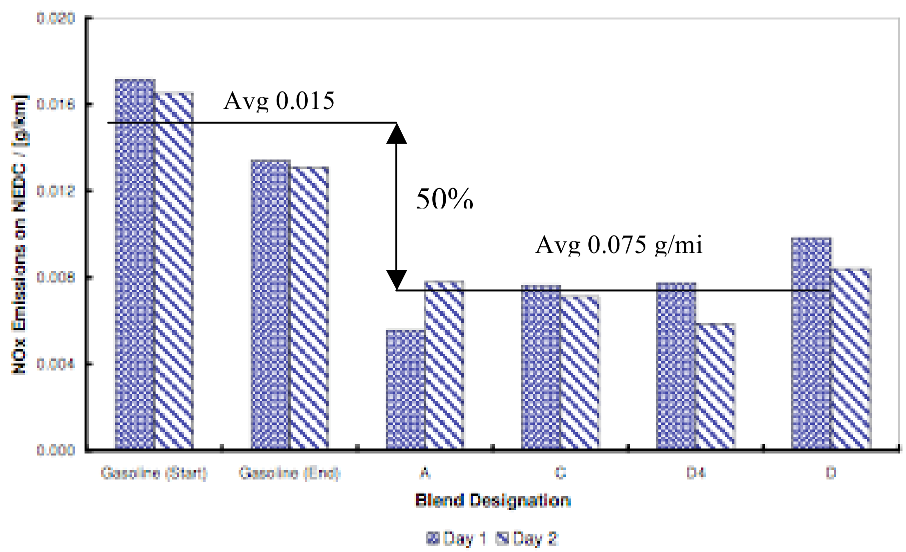

Figure 7. Emission Saab 9[3] 1.8T Station Wagon on GEM fuel Blends over the NEDC showing 50% reduction in NOx emissions

These results are similar to findings of the emissions reductions from FFVs operating on gasoline. In a recent paper, Yassine and Pan provided emissions results for various ethanol gasoline blends.[19] They tested a 3.3L Chrysler Town & Country FFV at various ambient temperatures for total hydrocarbons, CO, NOx, CH_4, and CO_2 as well as carbonyls (acetaldehydes, formaldehydes, and others). This vehicle was certified to Tier 2 Bin 5. Table 3 compares the average emissions at 75^{o} F.

In an earlier paper, Yanowitz and McCormick reviewed FFV emissions test data from specific tests as well as from the EPA certification database for Tier 1 and Tier 2 1979-2007 MY vehicles.[20] A summary of the EPA certification results is shown in Table 4. These data contain a variety of vehicles certified at different emission standards so these results should not be interpreted as representative of any one vehicle. Yanowitz and McCormick concluded that on average using E85 results in reduced NOx, CO, benzene, and 1,3-butadiene, and increased ethanol, formaldehyde, and acetaldehyde emissions. They also conclude that overall toxicity of emissions is likely to be unchanged since the increase in aldehyde emissions is offset by decreases in benzene and 1,3-butadiene emissions. They also suggested that the ozone forming potential would be slightly reduced with E85 due in part to ethanol's lower reactivity. The

[18] Turner, James, "Evolution of Alcohol Fuel Blends Towards a Sustainable Transport Energy Economy," presented at 2012 MITEI Symposium on Prospects for Flexible- and Bi-Fuel Light Duty Vehicles, April 19, 2012

[19] Yassine, Mahmoud and Morgan La Pan, "Impact of Ethanol Fuels on Regulated Tailpipe Emissions," SAE 2012-01-0872

[20] Yanowitz, Janet and Robert L. McCormick, "Effect of E85 on Tailpipe Emissions from Light-Duty Vehicles," Journal of the Air and Waste Management Association, 59:2, 172-182

NMOG Tier 2 data suggests that FFVs control NMOG emissions better than an equivalent gasoline vehicle. This could be due to differences in calibration or differences in catalyst hardware. It would not be surprising if more precious metals were used in order to control aldehydes in the FFVs but this is not known.

Table 3. Emissions Reductions with E85 compared to E0 for 2006 Chrysler Town and Country Vehicle (results from SAE 2012-01-0872)

Fuel/Emissions	NMOG (g/mi)	CO (g/mi)	NOx (g/mi)	Carbonyls (g/mi)	CO2 (g/mi)
E0	0.07217	3.5835	0.05903	0.00163	464.55
E85	0.04035	0.6426	0.01530	0.00958	423.07
Standard (120,000 miles) Tier 2 Bin 5	0.09	4.2	0.05	0.018[b]	n/a
% Difference	-44.09	-82.07	-74.08	486.83	-8.93

[a] (E85-E0)/E0

[b] Formaldehyde (HCHO) standard

Table 4. Comparison of Emission Changes for FFVs on E85 and RFG and FFVs on E85 and non-FFVs on RFG (EPA Certification Data Set MY 1979-2007) Source Yanowitz and McCormick.

Vehicle Technology	NMOG (%)	CO (%)	NOx (%)	HCHO (%)
Tier 1	-18/0	-15/-7	18/49	102/-18
Tier 2	28/-6	-20/-15	-19/-28	54/28

Notes: 1st number in emission is the % change from E85 to RFG in an FFV; 2nd number is the % change from E85 FFV to non-FFV fueled with RFG

A fourth set of data was a test program sponsored by the Coordinating Research Council to investigate the emissions performance of late model FFVs to various gasoline ethanol blends including E6, E32, E59, and E85.[21] Seven 2006-07 model year FFVs from Dodge, Ford, and Chevrolet were subject to a battery of emissions testing. A summary of the testing results for exhaust and evaporative emission is given below (taken from Haskew and Liberty):

[21] Haskew, Harold M. and Thomas F. Liberty, "Exhaust and Evaporative Emissions Testing of Flexible-Fuel Vehicles," CRC Report No. E-80, August 2011

Exhaust Emissions Summary – The average emissions for the seven FFVs tested did not indicate an emission trend with increasing ethanol level on the cold start FTP emission evaluation**.** The US06 high speed/load driving schedule indicated a statistically significant trend of decreasing non-methane hydrocarbon emissions (NMHC) with increasing ethanol content in the fuel. The average NMHC value decreased from 0.047 g/mile with the E6 fuel to 0.020 g/mile with E85. The CO and NOx emissions, on average, did not indicate a trend with ethanol level. The cold start Unified Driving Cycle test results did not show a trend with increasing ethanol level for the NMHC, CO or NOx. That said, there were individual vehicles that did show reducing emissions with increasing ethanol content.

Evaporative Emission Summary --The diurnal test data suggested that the higher ethanol blends (E59 and E85) result in higher diurnal emission levels. Permeation was the majority component of the diurnal emissions in this test program. The emission levels of roughly 300 mg per day were observed in this test program.

In summary, FFVs calibrated for emission standards on gasoline and E85 perform as well on gasoline methanol mixtures at least in the limited testing performed by Lotus. The Lotus testing confirms that the FFV engine and emission control system are able to detect the amount of oxygen in the fuel and adjust engine conditions accordingly to achieve nearly identical NOx emissions. Lotus has also indicated that hydrocarbon and CO emissions were also similar to E85. This substantially decreases the amount of development work needed to certify vehicles on gasoline methanol blends. The one exception will be the emissions of aldehydes and for the methanol mixtures formaldehyde will dominate compared to acetaldehyde for ethanol. However the E85 results show some promise that the FFV emissions systems may also adequately control formaldehyde emissions. This, however, will need to be verified.

Although more testing is required on gasoline methanol blends it is expected that the tailpipe emissions from FFVs using these fuels could be lower than with gasoline. This will depend on how the vehicles are calibrated. The CRC E-80 project results showed lower NOx emissions for the Dodge FFV on E85 vs. gasoline--similar to the findings of Yassine and Pan on the Chrysler Town and Country vehicle. Neither Ford nor Chevrolet data showed this trend indicating differences in calibration strategy. It also appears that FFVs compared to similar gasoline makes and models will have lower emissions when operating on gasoline. This suggests that some software or hardware changes have been made to the FFVs. Lower emissions of hydrocarbons, CO, and NOx will reduce the impact of these emissions and subsequent atmosphere reactions to form ozone and secondary particulate manner. Toxic emissions will increase for the aldehydes but decrease for benzene and 1,3-butadiene due to displacement of gasoline in the mixture (due to dilution).

Evaporative Emissions

Modern vehicles control evaporative emissions with an on-board system that collects, stores, and purges collected hydrocarbons back into the engine. This is done to collect emissions during vehicle operation (running losses), while vehicle is parked and ambient temperature changes over several days (diurnal), and during hot soaks while the engine cools. The on-board system also collects hydrocarbons during refueling. Evaporative emissions that are not directly controlled are those that permeate through various fuel system materials (permeation emissions). Automakers control these emissions by material selection; although these emissions can take many days,[22] better performing materials are needed to meet the current EPA and CARB evaporative standards.

Evaporative emissions depend on the volatility of the fuel, which is represented by RVP (Reid Vapor Pressure). RVP is typically measured in psi and carbureted, throttle body, and port fuel injected engines need a minimum RVP in order to vaporize the fuel for combustion. Too low an RVP and the engine will not start or will be hard starting. RVP too high could result in poor starting due to vapor lock. For these reasons, gasoline RVP is controlled in the summer and winter seasons. This will be also covered in the fuels section.

When alcohols are mixed with gasoline, the RVP of the mixture increases more than the RVP of either the alcohols or gasoline. Ethanol for example when blended with gasoline will raise the RVP of the blend by about 1 psi at around 5% ethanol by volume. Methanol is even higher and increases the RVP by 3.4 psi also in the range 10% methanol by volume. These are rough estimates and depend on the base gasoline RVP that ethanol or methanol is blended into.

The implications are that FFVs have to be designed to capture the increased evaporative emissions associated with the higher RVP fuel. However, since E10 has been adopted in the market place E85 FFVs do not need large storage systems since the non-FFVs have to be designed to capture the higher emissions associated with low-level ethanol blends. At higher ethanol gasoline blends the RVP decreases and E85 has an RVP of around 4 psi (again depending on the base gasoline). For this reason winter time E85 in colder climates needs to have less ethanol and/or more volatile gasoline components like butane.

It is likely that for methanol the current E85 evaporative systems will not meet standards for all combinations of blends unless the gasoline blend stock is modified and/or additional vapor storage is added to the vehicle. Commingling is a problem. Also unclear is how the current E85 FFV will handle the more aggressive methanol relative to permeation emissions (this will also be discussed in material compatibility relative to corrosivity)

2.1.2 Vehicle Driveability and Performance

There currently is little data on the performance of newer vehicles operating on methanol gasoline blends. The California Methanol Program successfully demonstrated the use of M85 in FFVs designed for this fuel. Today only E85 FFVs are produced. Lotus has shown that equivalent E85 fuels can be blended with gasoline and methanol (e.g. M56). They performed emission testing on this blend in two Saab production vehicles—one equipped with a virtual alcohol sensor the second was equipped with an alcohol sensor. The virtual sensor uses the emissions system's oxygen sensors plus the level sensor in the fuel tank to estimate the air to fuel ratio and then to adjust fuel flow and spark timing. An algorithm in the engine control module performs this calculation and continues to correct/adjust according to the oxygen sensors. The alcohol sensor conversely is placed in the fuel line and senses electric permittivity or the resistance of the fuels flowing through them. Lotus found that these sensors had different responses to methanol gasoline and ethanol gasoline blends. However, at the blend levels giving

[22] much longer than the evaporative tests required by EPA or CARB

equal stoichiometry (M56 and E85), the sensor output was the nearly the same. Whether this is the case for all conceivable gasoline, ethanol, methanol mixtures is not yet known.

Lotus reported no starting or driveability issues with either of these vehicles. On one test they filled the tank of one car with M56 and then later added gasoline, drove the vehicle, and then added gasoline again, then on the fourth fill up added M56. Thus, the vehicle was able to handle a variety of methanol gasoline mixtures in the true fashion of a flexible fuel vehicle. They did have one E85 issue occur when the vehicle would not start at 20^{o}C. This was not unexpected since the E85 tested was a summer blend, which had a lower RVP.

Modern vehicles today are also equipped with on-board diagnostic hardware and software. If the engine control module (ECM) detects a fault either due to hardware or sensor malfunctions a malfunction indicator light (MIL) will register. For the majority of the Lotus testing with a variety of gasoline, ethanol, and methanol blends there was no MIL activity. They did have two MIL events both associated with M56 blends. The event was associated with the O2 sensor going out of range and occurred after the vehicle was left overnight. Lotus speculated phase separation of the gasoline methanol had occurred and caused these MIL events. They suggested that a co-solvent be used to prevent this. Although in subsequent testing with a different but similar vehicle they did not observe any MIL activity. Lotus points out that ethanol is a good cosolvent to mitigate phase separation of gasoline methanol blends and subsequently tested several of these blends (see SAE 2012-01-1279).

Again, it appears that gasoline methanol blends or gasoline, methanol and ethanol blends can be used in current E85 vehicles today—with respect to good driveability, starting performance, and tailpipe emissions. The ternary mixtures do not cause any vehicle performance issues or compromise the emissions equipment. With one possible exception due to possible phase separation of gasoline and methanol, there were no OBD events indicating the system works as designed for these fuels.

2.1.3 Material Compatibility with Alcohol Blends

Probably the biggest issue with methanol blends is material compatibility. Methanol is more aggressive than ethanol for a variety of materials including metals, plastics, and elastometers all that are used in vehicle fuel systems. All carmakers warn against the use of methanol in their vehicles. The Alliance of Automobile Manufacturers testified that methanol vehicles would require distinct changes from ethanol FFVs.[23]

Methanol is more aggressive than ethanol relative to materials compatibility. Methanol is known, for example, to be very corrosive to aluminum whereas ethanol is not as corrosive. Automakers, therefore, have to pay more attention to the wetted fuel system components of methanol vehicles compared to ethanol and gasoline-fueled vehicles.

[23] Karr, Shane, "Statement of The Alliance of Automobile Manufacturers before the Energy and Commerce Committee, The Subcommittee on Energy and Power, U.S. House Of Representatives," Hearing on Open Fuel Standard, July 10, 2012

TIAX recently reviewed vehicle compatibility issues in a report to the Methanol Institute.[24] The following summarizes much of the comments in the TIAX report.

The vehicle fuel system components that need modifications for material compatibility include fuel cap, fuel lines, fuel pump, fuel tank, and elastomers such as o-rings. There are no showstoppers to specifying that these components be compatible with methanol, it is more an issue with costs of materials and the number of the components to be specified.

Ford in a supplement to their owner's manual provided a list of changes made to the gasoline Taurus for flexible fuel operation.[25] Table 5 shows the changes made. "Alcohol fuel compatibility" was defined by Ford to mean that the component performs satisfactorily, is durable, and does not contaminate the fuel when tested in worst-case methanol-gasoline and ethanol-gasoline blends up to 85 percent alcohol. Ford also indicated in this owner's manual supplement that "the same special materials and procedures developed for the Taurus Methanol FFV are used in the Taurus Ethanol FFV.

Ford tested all materials that came in contact with the alcohol fuel or fuel vapors. For the Taurus, they upgraded fuel lines and rails and used stainless steel or glass filled poly phenylene sulfide resin. Ford indicated for ethanol FFVs the conditions are less severe and that less costly materials give acceptable results. For elastomers like o-rings, Ford found that high fluorine content fluoroelastomers demonstrated compatibility with alcohol fuels. Material selection for fuel pumps, injectors, and fuel sensors is also very important to ensure durability.

Ultimately the use of oxygenate fuels led the automakers to form a consortium to develop an approach for qualifying materials for use in vehicles.[26] This consortium led to the SAE standard J1681.[27] This standard covers commercial automotive fuel components, defines components of test fuels, describes test fluid preparations, and recommends fluids for testing fuel system materials. Recommended test fuels are designed to simulate typical, severe, real world conditions that can be encountered and the test fuels are meant to minimize the testing required, reduce variability in test fluids, and standardize testing of fuel system materials.

[24] Sheehy, Philip, Karen Law, and Michael D. Jackson, "Methanol Fuel Blending Characterization and Materials Compatibility," Report for the Methanol Institute, TIAX D5607, August 27, 2010 Rev A

[25] Ford is used here as an example. GM and others also provided similar list of changes necessary for alcohol FFVs.

[26] Harrigan Sr, Michael J., Allan Banda, Ben Bonazza, Pamela Graham, Bryant Slimp, "A Rational Approach to Qualifying Materials for Use in Fuel Systems," SAE 200-01-2013 also published in "State of Alternative Fuel Technologies 2000, SP-1545.

[27] SAE Standard J1681, January 2000

Table 5. Example of FFV Component Changes (1998 Ford Taurus FFV) [28]

Item Changed	Description
Spark Plug	Has a colder heat range and the wire electrode is wider for better heat transfer
Engine	Internal engine changes for "alcohol fuel compatibility"
Fuel Injectors	Higher fuel flow capacity, modified spray nozzle design and material changes for "alcohol fuel compatibility"
Engine Oil	Specifically designed for engines operated with methanol and ethanol fuels
Fuel Rail	Material changes are made for "alcohol fuel compatibility"
Fuel Pressure Regulator	Material changes are made for "alcohol fuel compatibility"
Engine Block Heater	Use to assist in cold start below -12 deg C
PCM processor	Calibration is utilized to optimize engine function for alcohol fuel operation
Wiring Harness	Wiring changes have been made to connect with the fuel sensor
Fuel Sensor	Determines the percentage of methanol in the fuel for methanol FFVs or percentage ethanol for ethanol FFVs
Fuel Supply and Return Lines	Material changes are made for "alcohol fuel compatibility"
Fuel Pump Assembly/Fuel Sending Unit	Fuel pump specifically designed for alcohol fuels. Stainless steel parts are used.
Vapor Control Valve	Control vapor flow to charcoal filter
Filler Tube	Improved coating is applied and anti-siphon screens installed
Fuel Filter	Material changes are made for "alcohol fuel compatibility"
Charcoal Canister Tray	Protective enclosure
Evaporative Emission System	Charcoal canister system enlarged and modified for additional alcohol fuel vapor capacity and higher vapor flow
Vapor (Rollover) Valves	Helps to increase fuel capacity and vapor flow. Material changes are made for "alcohol fuel compatibility"
Fuel Tank	A specially coated steel fuel tank is used for "alcohol fuel compatibility"

Figure 8 summarizes the test fluid recommendations for qualifying materials for gasoline and diesel fuel system components and for alcohol based FFV fuel system components. As shown recommendations include at least one test fluid with 15% methanol. Component suppliers have the option for FFVs to use ethanol instead of methanol for the higher blend alcohol test fluids. Thus, it is not clear whether the current and legacy fleet of FFVs would be compatible with higher methanol gasoline blends. Testing with M15 gives some promise but further qualification would be needed to verify compatibility.

[28] Ford, "Taurus FFV Supplemental Owner Guide," 1998.

Recommendations for test fluids for **gasoline and diesel fuel** system applications are:

1. 85% hydrocarbonTI (50% toluene and 50% isooctane) plus 15% aggressive methanol (containing water, sodium chloride, and formic acid) or 85% hydrocarbonTSIS (50% toluene and 50% substitute isoparaffin solvent) plus 15% aggressive methanol
2. same as 1 except MTBE is used for methanol
3. hydrocarbon used in 1 with addition of peroxide
4. hydrocarbon used in 1 with corrosive water (for metals testing only)

Recommendations for test fluids for qualifying materials for **alcohol base FFV** system applications are:

1. All test fluids for gasoline (1-4 above)
2. 85% hydrocarbonTI plus 15% aggressive ethanol (water, sodium chloride, sulfuric acid, glacial acetic acid) or 85% hydrocarbonTSIS plus 15% aggressive ethanol
3. 70% hydrocarbonTI plus 30% aggressive methanol or 70% hydrocarbonTSIS plus 30% aggressive methanol OR same but substitute ethanol for methanol
4. 50% hydrocarbonTI plus 50% aggressive methanol or 50% hydrocarbonTSIS plus 50% aggressive methanol OR same but substitute ethanol for methanol
5. 15% hydrocarbonTI plus 85% aggressive methanol or 15% hydrocarbonTSIS plus 85% aggressive methanol OR same but substitute ethanol for methanol
6. 65% hydrocarbonTI plus 20% aggressive methanol plus 15% MTBE or 65% hydrocarbonTSIS plus 20% aggressive methanol plus 15% MTBE OR same but substitute ethanol for methanol

Purpose of testing with six additional fuels is to identify the fluid composition that causes the greatest effect on the material being evaluated and then to use this worst-case fluid in subsequent tests.

OEMs or component manufactures may also require vendors to test other fuel such as EPA certification gasoline or Brazilian Gasohol (see J1681 for complete list)

Figure 8. Surface Vehicle Recommended Practice (SAE J1681, Jan2000) to qualify materials for gasoline and flexible fuel vehicles

A key point on J1681 is that this standard is only for qualifying materials. Component manufactures have to qualify their component for use with the intended fuels that the OEM design their products for.

One last point should also be made. Methanol cosolvents have also been used to mitigate some material concerns and well as phase separation discussed previously. Cosolvents that have been used include TBA, GTBA, and other C2-C8 alcohols. These cosolvents could reduce the aggressive natural of methanol. Most likely the addition of gasoline will also reduce the aggressiveness of methanol as well as the addition of gasoline and ethanol. However, we were not able to find any evidence of this in the literature. More work is needed to determine test fuels for qualifying materials that are exposed to ternary blends of gasoline, ethanol, and methanol.

Another important issue associated with material compatibility is permeation of fuel system materials. Any solvent that can absorb into a material will also permeate through it. The phenomenon of solvent permeation is therefore limited to polymeric materials. Greater permeability is observed in elastomers (hoses, seals, gaskets, packing) relative to thermoplastics (flexible piping, vapor recovery, tubing) and composites (rigid piping). In general, fluorinated elastomers and thermoplastics offer better permeation resistance than nonfluorinated materials.

The permeation rate of gasoline containing ethanol is greater than gasoline containing MTBE.[29] Testing has also shown that vehicles manufactured prior to enhanced evaporative emissions (pre MY 1996) also had higher permeation emissions, whereas FFVs tested lower and were comparable to vehicles meeting the enhanced standards. This could indicate that the OEMs changed fuel system materials in response to the tighter evaporative standards and that these material changes where similar or comparable the materials use in E85 FFVs. This would make sense from a number of perspectives—lowering overall costs with common components and simplifying parts across the OEM's product lines.

Generally, methanol blends are more aggressive than ethanol blends towards both metals and non-metals. Methanol blends with TBA (Tertiary-Butyl Alcohol) are offered which mitigate some materials concerns. Metal corrosion issues include: general and localized corrosion of active metals, galvanic corrosion, electrolytic corrosion, wear, and aqueous phase separation. Issues for polymeric materials include: swelling and softening due to absorption of alcohol, extraction of plasticizers, and antioxidants. Generally, compatible material alternatives are available but they may not be currently in service.

2.2 Fuel Issues

The EPA and CARB set standards for gasoline and gasoline additives. In general, RVP, sulfur, and benzene levels are regulated. States have the opportunity to adopt various levels of gasoline controls depending on their air quality needs and their ability to meet the National Ambient Air Quality Standards (NAAQS).

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[29] Haskew, Harold M., Thomas F. Liberty, Dennis McClement, "Fuel Permeation from Automotive Systems," CRC Project No. E-65, September 2004.

2.2.1 Fuel Volatility RVP Standards

EPA established RVP standards to reduce evaporative and permeation emissions. Current standards are typically 9.0 psi for winter months (nominally Sept 16 through May but depends on air quality needs of a given county) and 7.8 psi for summer months (typically June through September 15; some counties start the summer in May).[30]

EPA allows a 1 psi wavier for gasoline alcohol blends that meet the requirements of 40CFR 80.27(d) unless state has adopted a SIP-approved RVP standard, state has received approval by EPA to opt out of wavier, or the state uses reformulated gasoline which has more stringent VOC performance standard. Utah, for example, allows the wavier provided various conditions are met including specifications for distillation requirements of the base gasoline (or RBOB) and ethanol gasoline blends (9-10% ethanol) shall not exceed ASTM D4814 vapor pressure by more than 1.0 psi from June 1 through September 15.[31] Gasoline with less than 9% ethanol by volume must meet ASTM limits. Gasoline blends containing up to 10% ethanol by volume shall not exceed the ASTM D4814 vapor pressure limits by more than 1.0 psi from September 16 through May 31. Table 6 summarizes these RVP or fuel volatility requirements for the U.S.

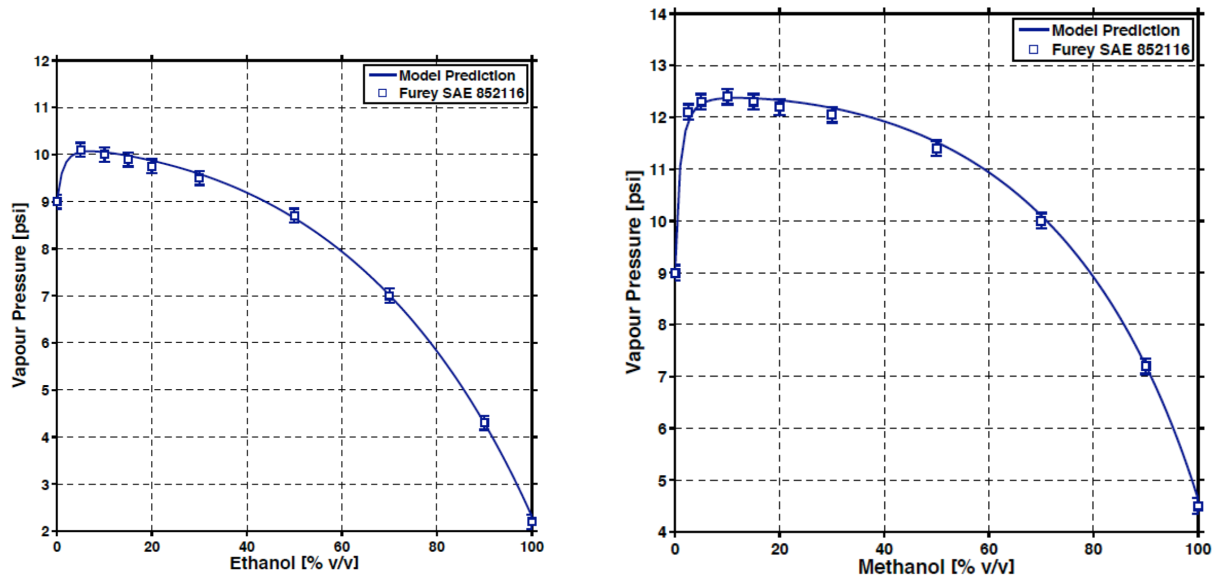
Table 6. Federal RVP Requirements with Ethanol Blend (9-10% vol in gasoline) Wavier

Time of Year	EPA Standard RVP (psi)	E9-E10 Standard with Waiver RVP (psi)
Summer (June 1-Septemeber 15)	7.8	8.8
Winter (September 16-May 31)	9.0	10.0

When alcohols are mixed with gasoline the vapor pressure of the mixture increases higher than the vapor pressure summed total of the individual components. The blending response is also not linear—low levels of alcohols in gasoline result in the highest blend RVP and then the RVP gradually decreases as the alcohol concentration increases. This behavior is illustrated in Figure 9a for ethanol and 9b for methanol. As shown the vapor pressure increases rapidly by 1 psi at about 6% vol ethanol and then decreases to about 5.3 psi at E85. Conversely, with methanol, the increase is about 3.4 psi and peaks around 9% by volume of methanol decreasing to 8.2 psi at M85. At M56 this data suggests a vapor pressure of 11.2 psi. This would exceed either of EPA's RVP standards (assuming a wavier would also be given for methanol blends). Thus controlling RVP of the methanol gasoline blends will require reducing the RVP of the base gasoline or reformulated blend stock for oxygenate blending (RBOB). For M56 at 9 psi, the vapor pressure of RBOB would have to be reduced by 2.2 psi to 6.8 psi. For a summer blend limit of 7.8, the RBOB RVP would have to be reduced by 3.4 psi to 5.6 psi. Reducing volatility, while possible, is costly.

[30] See EPA website on Federal and State Summer RVP Standards for Conventional Gasoline at http://www.epa.gov/otaq/fuels/gasolinefuels/volatility/standards.htm

[31] R70. Agriculture and Food, Regulatory Services R70-940 Standards and Testing of Motor Fuel



a) Ethanol Blending **b) Methanol Blending**

Figure 9. RVP of Ethanol and Methanol Mixtures when added to 9 psi RVP Gasoline or RBOB (source: Martin H. Davy, "Modeling the Effects of Methanol Blending in Gasoline in the Range M70-M85: Status Report)

Although it is doable to blend M56 summer and winter fuels meeting RVP requirements, a bigger issue results when M56 is mixed with gasoline or gasoline ethanol blends—so called commingling. In this case high in tank RVP mixtures are possible as the methanol or ethanol content of the fuel is reduced. Again this is shown in Figure 9. Extrapolating from a M56 blend at 9 psi gives a high of 10 at around M10. Similarly, from a M56 blend at 7.8 gives a high of 9 psi at around M10. Thus, depending on how often fuel flexibility is used there is an increase in RVP of the mixtures that would result in increased hydrocarbon emissions.

2.2.2 Sulfur and Toxics Regulations

EPA also has standards for the amount of sulfur in gasoline (Tier 2 Sulfur Regulations).[32] These regulations limit sulfur to 30-ppm average and cap sulfur at 80 ppm for large and small refiners. Downstream (at terminals and retail outlets) the sulfur limit is 95 ppm. Adding methanol to gasoline would help refiners meet these standards since methanol contains no sulfur. A RBOB fuel could conceivably have higher sulfur levels than an E10 gasoline.

EPA also has a program to reduce mobile source air toxics (MSAT).[33] This rule reduces the annual average benzene content in gasoline to 0.62 volume percent. This program also allows for some flexibility with a credit banking and trading program. Maximum average benzene standard is 1.3 ppm volume percent. This benzene regulation was coupled with tighter non-

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[32] U.S. EPA Emissions Standards Reference Guide, Gasoline Sulfur Standards. http//:www.epa.gov/otaq/standards/fuels/gas-sulfur.htm

[33] U.S. EPA, "Control of Hazardous Air Pollutants from Mobile Sources: Final Rule to Reduce Mobile Source Air Toxics," Fact Sheet, EPA420-F-07-017, February 2007 http://www.epa.gov/oms/regs/toxics/420f07017.pdf

methanol hydrocarbon (NMHC) standards to further reduce the emissions of air toxics such as 1,3 butadiene. Again, refiners could use methanol blending to meet the benzene regulation.

2.3 Environmental, Health, and Safety Issues

Environmental, health, and safety was investigated and discuss as part of the California Methanol Program when the California Legislature asked the California Energy Commission and the CARB to study the implications of mandating the sale of cleaner vehicles and fuels as a strategy to reduce air pollution and displace petroleum. A blue ribbon advisory panel was formed including methanol and energy producers, domestic and imported automakers, the general public, and state and local officials. The advisory board held workshops with experts from around the world to provide state of the art research and assessment of the introduction of cleaner fuels relative to environmental health and safety, economics, energy security, mandates and incentives.[34] This work was completed in late 1989 but much of research on various issues is still relevant. This is especially the case regarding the toxicity of methanol, which is well understood, as well as issues associated with fires and possible explosion issues. Consequences of fuel spills were also discussed. The board was unique in that after hearing the experts' discussion of the issues they came to agreements as to what the next steps should be to mitigate issues that needed to be addressed before cleaner fuels and vehicles could be introduced into the transportation market. This section addresses methanol toxicity, fire and explosions, and, environmental impact of spills.[35]

2.3.1 Toxicity of Methanol

Methanol is a clear odorless liquid that is toxic to humans. Although methanol is a natural substance that occurs in the human body and in many foods, even small doses of methanol can overload the ability of the body to metabolize it. When directly swallowed, as might occur while siphoning, methanol can cause blindness and even death if not promptly diagnosed and treated.

Methanol has not been identified as a carcinogen or a reproductive toxin. Methanol vapors most likely represent less of a health threat than gasoline or diesel fuel vapors.

Higher levels of formaldehyde are possible with methanol use. In extreme scenarios—disabled vehicle emission controls coupled with confined spaces, such as closed garages or tunnels—could lead to exposures close to permissible limits. This type of exposure is likely comparable to gasoline exhaust and should be avoided.

There are three routes to methanol poisoning—ingestion, skin contact, and inhalation. Ingestion is by far the most dangerous poisoning pathway. Efforts have to be taken to avoid skin contact and mechanics and technicians will need proper education. Also signage and labels at fueling stations are needed. Inhalation, although possible, is unlikely unless there is an unusual event like a larger spill of methanol, such as from a tanker truck or rail car.

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[34] Burnett, Mark W., Michael D. Jackson, Daniel R. Luscher, and Carl B. Moyer, "California Advisory Board on Air Quality and Fuels—Report to the California Legislature," Volume I, Executive Summary, October 1989

[35] Burnett, Mark W., Michael D. Jackson, Daniel R. Luscher, and Carl B. Moyer, "California Advisory Board on Air Quality and Fuels—Environmental, Health and Safety Report," Volume III, Acurex Environmental Corporation, June 1990.

The ingestion pathway would result in higher levels of accidental poison if the same care were taken as with gasoline. Poison Control Center data for gasoline indicates that a majority of accidental poison cases were due to teenagers and young adults involved in ingestion of gasoline nearly always as a result of siphoning from fuel containers or vehicle fuel tanks. Accidental ingestions in children under six years of age accounted for about the same number of cases as young adults. In these cases fuel cans or container transfers were implicated.

Methanol in contrast to gasoline poses a high risk of systemic toxicity with a misleading delay in the appearance of toxic manifestations, and severe clinical outcomes such as death, permanent blindness, and neurologic impairment following failure to obtain appropriate treatment promptly.

Several steps are needed to mitigate these increased health risks and several of these were implemented in the California Methanol Program. Anti-siphoning devices were required in the fill lines of FFVs. Methanol was only dispensed for vehicles—lawn and garden use was not allowed. This would limit the storage of methanol in the home and eliminate possible accidental poisoning of children. Recommendations of childproof containers were also recommended and today's containers to reduce emissions may have also reduced the number of gasoline poisonings.

Gasoline was also added to methanol not solely as a way to mitigate poisoning, but a gasoline methanol mixture may be easier for emergency personnel to detect and more quickly respond. Gasoline adds taste and smell and may discourage accidental poisoning. Gasoline may also change how the body responds to the poisoning. Ethanol could also complicate the response, since ethanol added to methanol will delay the symptoms of poisoning.

From a health perspective, mixtures of gasoline, ethanol, and methanol may be similar to gasoline poisoning, but additional work should be undertaken to assess current data on gasoline poisonings to see if there have been any changes from the previous assessments and whether additional mitigation and education will be necessary for these fuels. Also some research is needed on how humans will respond to mixtures of gasoline and alcohol and whether methanol severely adds to mortality or is mitigated by either gasoline or ethanol. It is clear, however, that policies of education, anti-siphoning devices, and possibly prohibiting the use of these types of fuels in lawn and garden equipment need to be pursued.

2.3.2 Fire and Explosion

Methanol gasoline mixtures should be comparable to the fire and explosion risks associated with the transportation and use of gasoline. Concerns with methanol include low flame luminosity especially during daylight and broad flammability limits which can result in flammable fuel tank mixtures. Blending with gasoline mitigates both of these concerns. Gasoline methanol (and ethanol) blends contain less energy per gallon than gasoline, which should help to reduce explosive energy and severity of fires. Like gasoline, gasoline methanol blends are heavier than air so fumes will accumulate near ground level. Ignition sources are therefore typically eliminated or made explosion proof from ground level to several feet above ground level (National Fire Protection Association provides codes for facilities using gasoline and other fuels).

Any transition to a new fuel, however, requires that emergency response personnel be familiar with the fuels and with acceptable fire fighting responses. Methanol as a chemical is safely shipped throughout the U.S. and safety procedures have been developed.[36] Proper procedures for training firefighters are needed. Different labeling of tanker trucks and fuel dispensing equipment should be considered as was done in the California Methanol Program.

2.3.3 Spills

Methanol is biodegradable and soluble in water. Small surface spills will disperse and biodegrade fairly quickly. Larger spills will take longer and will have more adverse effects to plant and wild life. It is unclear how blends of gasoline and alcohols will react with the environment. Methanol gasoline mixtures will separate in the presence of water so it is possible that spills would result in methanol dispersing in the water and gasoline floating on the surface of the water.

The interaction of gasoline alcohol spills in soils and the subsequent migration into ground water will be a concern based on the prior experience with the gasoline additive MTBE. California now requires a multimedia analysis of new fuels. Ethanol gasoline mixtures of 5.7% were studied, for example, to assess the possible risk of ground water contamination.[37] Similar, research and studies will be required for gasoline methanol blends.

2.4 Regulatory Issues

EPA requires that a new fuel be registered for sale in the U.S. EPA will have to determine if the fuel is substantially similar to gasoline and will not result in any degradation of emissions or vehicle emission equipment. EPA can issue a fuel wavier[38] or substantially similar finding.[39]

Section 211 (f) fuel waiver testing protects OEM and producers of new fuels and additives. All gasoline must be substantially similar to fuels used for certification and the producer of new fuel/fuel additive must show that fuel/additive will not cause or contribute to the failure of any vehicle or engine to meet emission standards. This approach protects emissions warranties of automakers/engine manufacturers but also allows new fuels to be introduced. Any EPA waiver would be applicable nationwide, except in California and other states that have adopted California vehicle and fuel regulations. Also, the waiver application goes through a public notice and comment, so stakeholder involvement is needed and encouraged.

Fuel wavier testing includes emissions (current and end of life/durability), materials compatibility/durability, and driveability. Exhaust and evaporative emissions testing using the appropriate certification test procedure for vehicles is required. EPA also requires the testing to include small engines like lawn mowers, snowmobiles, motorcycles, etc.[40] Test fleet

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[36] See for example Methanex's publication "What is Methanol—Save Handling Information" accessed at: http://www.methanex.com/products/documents/Mx_Safe_Handling_Eng.pdf

[37] Rice, D. and G. Cannon, Editors, "Health and Environmental Assessment of the Use of Ethanol as a Fuel Oxygenate," Report to the Environmental Policy Council in Response to Executive Order D-5-99, Volume I, UCRL-AR-135949 Vol. 1, December 1999

[38] Clean Air Act (CAA) Sect 211(f)(4)

[39] CAA Sect 211 (f)(1)

[40] We would recommend that methanol gasoline blends not be used in small engines and lawn and garden equipment. This would eliminate this testing requirement. E15 is also excluded from this segment.

composition, testing procedures (back to back emissions testing of vehicle pairs) statistical testing all has to be included in the test plan and execution.

Materials compatibility/durability testing includes periodic monitoring of long-term mileage accumulation on test fuel typically with control vehicles, as well as in immersion testing where representative fuel-system materials are immersed in a heated, agitated container for the test fuel for several months. Materials are inspected for swelling, cracking, corrosion, and other changes.

Driveability testing is required of vehicles operated on test fuel (driver logs etc). If vehicle has poor driveability an emission control component could be impaired and /or the driver might tamper with the emission controls in an effort to improve performance.

We suspect that concerns EPA might have with gasoline methanol blends include material compatibility of current FFV fleet, emissions performance particularly for formaldehyde, durability of emissions control equipment, commingling and increased evaporative emissions, and toxicity of methanol. Stakeholders will have to work closely with EPA in order to navigate EPA's requirements and the issues raised with gasoline methanol blends.

EPA also has authority under 40 CFR 79 "registration of fuels and fuel additives" to require Tier 1 and Tier 2 testing for manufacturers or refiners with over $50 million in annual revenue from the fuel or additive. Tier 1 includes analyzing exhaust emissions for a wide variety of compounds that are specified in the regulations. A fuel sample (perhaps several in the case of FFVs capable of using a variety of blends) would be speciated for evaporative emissions characterization. A literature survey covering the last 30 years is required for any compound that was not identified in the emissions from the gasoline Tier 1 report (not clear if this will be required since testing has also included ethanol blends).

Tier 2 health testing includes laboratory animals that are subjected to evaporative emissions of a blend and screening toxicity tests are performed. Again this may not be needed depending on the speciated results of the methanol gasoline blends.

States also have regulations that may prohibit the sale of methanol gasoline blends. California, for example, in their Reformulated Gasoline Regulations [41] does not allow methanol without a multimedia evaluation in California. A multimedia evaluation includes engine performance and emission requirements but also health and environmental criteria including air emissions and associated health risk, ozone formation potential, hazardous waste generation and the management of surface and ground water contamination resulting from production, distribution, and use.[42]

These requirements are important to commercializing methanol gasoline mixtures as a fuel sold in the U.S. We strongly advise the stakeholders to work closely with the regulatory agencies to get approval for a fleet demonstration and to make sure the fleet demonstration incorporates the necessary data on emission performance, driveability, and materials compatibility to satisfy EPA

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[41] Title 13, California Code of Regulations, Sections 2250-2273.5, The California Reformulated Gasoline Regulations, California Air Resources Board, effective August 29, 2008.

[42] *Guidance Document and Recommendations on the Types of Scientific Information Submitted by Applicants for California Fuels Environmental Multimedia Evaluations,* Cal/EPA, June 2008, UCRL-AR-219766

and other regulatory agencies that will be involved in approvals and permitting. Based on the toxicity of methanol and, therefore, the potential toxicity of methanol gasoline blends we strongly suggest that stakeholders only request the use of methanol gasoline blends in vehicles capable of using these fuels. This may require that fuel can only be dispensed to these vehicles.

3. Distributing Methanol Gasoline Blends

One of the objectives of this project is to investigate the opportunities and issues of transporting, storing, distributing and dispensing methanol gasoline blends for use in light duty vehicles. Considerable work has been done in this area, especially in the 1980's and early 1990's in California. In the California Methanol Program, the introduction of 'dedicated' methanol vehicles initially, and then the Fuel Flexible Vehicles (FFVs), ran on a fuel methanol configuration of M85 (85% methanol, 15% unleaded regular gasoline).[43] Much was learned in the initial trials of those vehicles, such as; the right percentages of blended methanol/ gasoline (isopentane), the use of co-solvents and corrosion inhibitors in the blended fuel, and materials compatibility. Because methanol is more corrosive than gasoline and ethanol, many of the components, both on the vehicles, and particularly in the fuel transport, storage, distribution and dispensing system were made from materials that were easily attacked by the more corrosive methanol. The issue of "Materials Compatibility" quickly became an area that required particular and focused efforts to overcome.

This section addresses infrastructure material compatibility, fuel quality, methanol distribution and requirements, fuel retail outlet components, and retail outlet construction.

3.1 Materials Compatibility

Methanol, being more corrosive than gasoline, quickly emerged as a liquid fuel with properties that required special attention to the materials that came in contact with it, both in vehicles and in the distribution infrastructure. The auto manufacturers, at the initial stages of M85 Flexible Fuel Vehicle (FFV) introduction, immediately noticed driveability problems with the vehicles, such as fuel filter plugging, fuel pump failure and fuel injector plugging, all of which were rather unexpected initially. While the materials on the vehicles themselves caused some of the problems, it was fuel contamination caused by incompatible materials in the fuel distribution and dispensing systems that quickly became the primary focus. This issue resulted in the forming of a Problem Resolution Team for the Program (including staff of the California Energy Commission, Ford Motor Company, General Motors, fueling equipment suppliers and interested oil companies—the 'hosts' of the M85 fueling stations). This Team met regularly and delved deeply into a range of issues: investigating the cause(s) of contaminated fuel, actively sampling and testing the fuel from established M85 stations, and searching for solutions from a largely 'materials compatibility' perspective.

Underwriters Laboratories (UL) tests and certifies that fuel station equipment is compatible with fuels like gasoline and diesel. UL has also certified some equipment for E85 and some was qualified for M85 as a result of the California Program. UL tests to be sure that the fuel would not cause the fuel storage and dispensing system, or any of its components, to fail or result in significant deterioration. In the California Methanol Program it was determined that methanol's

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[43] Ward P.F. Ward and Teague, JM (California Energy Commission), "Fifteen Years of Fuel Methanol Distribution," Presented at the XI International Symposium on Alcohol Fuels, South Africa, 1996

higher corrosivity caused many fuel system components to deteriorate or "leached out". This led to fuel contamination and affected vehicle driveability. So, it was soon evident that the issue, and definition, of materials compatibility (or incompatibility) should address the dual effects of 1) equipment deterioration (on the vehicle and at the station) in the traditional sense, and 2) fuel contamination to the extent that it affects the vehicle operation. In this context, materials compatibility has come to encompass this dual definition of effects on the equipment and on fuel quality.

These dual issues of materials compatibility were addressed forthrightly, and successfully, in the 1980's by replacing or coating the soft metals (aluminum, zinc, copper, lead, cadmium, and lead/tin solder), and replacing the hose materials, gasket and elastomer materials (Buna-N, nitriles, plasticizers, etc) with more robust, methanol compatible materials. With these material changes the fuel storage and dispensing systems no longer presented the source of contamination, which was detrimental to vehicle and its components. In short, many lessons were hurriedly learned from the introduction of fuel methanol in California. Because of those valuable lessons and quick actions, a system of fuel methanol transport, storage, distribution and dispensing was established and tested under real life conditions. That system can now be replicated, to serve the introduction of methanol gasoline blends into new or existing FFVs, and possible gasoline vehicles of certain types and model years, without affecting the trial and testing of those vehicles in a pilot demonstration. The following discussion outlines the important steps and procedures necessary to assure that the fuel quality of the methanol gasoline blend is maintained as dispensed into vehicles according to a fuel specification (to be determined), and that the quality of the fuel does not play an adverse role in the Pilot Demonstration of Methanol Gasoline Blends in FFVs and gasoline vehicles.

3.2 Methanol Fuel Quality Assurance

Though the vehicle utilization or conversion is critical to this effort, it is the production, transport, distribution and dispensing of the fuel, though a somewhat dependent variable, that is nevertheless the crucial link to the overall project's success. It will require great attention to the care and handling of the methanol gasoline blend at all levels of storage and distribution, maintaining high fuel quality standards, and providing robust public education will all be integral to the project's overall success and could lead to a more simple and straightforward pathway to reducing petroleum use on a large scale.

That said, bringing the fuel to the vehicles in a way that is standard practice today that assures and maintains the fuel quality and specification from production to the vehicle fuel tank, is of the utmost importance. In demonstrating the conversion of vehicles there are enough variables and uncertainties to consider, and having to deal with fuel quality issues or contaminated fuel, should not, and for success, cannot, come into play.

Lastly, while the transport, storage and dispensing equipment can be specified to be alcohol compatible (ethanol E85 systems and equipment components can serve as a proxy for the methanol gasoline blend system), it is however important to establish a fuel quality assurance protocol for the Pilot Demonstration from the outset.

The following ***Methanol Fuel Quality Assurance*** protocol is recommended for the Methanol Gasoline Blend Pilot Demonstration because the fuel quality is an essential element, and is critical for a successful vehicle evaluation. In addition, the distribution of the fuel itself is a demonstration in and of itself, as fuel methanol has not been distributed as a fuel in the United States in well over a decade

- **Terminals-** Fuel samples, "retains", should be taken at two points at the terminal; when the fuel is off-loaded from rail tank cars or trucks, and when loaded into truck tankers for distribution to stations. These fuel samples should be visually inspected, cataloged and stored at the terminal for potential future analysis. In the event that 'off-spec' fuel is discovered anywhere in the supply chain, these fuel retains can be analyzed for quality, and to determine where contamination occurred or where the fuel was otherwise compromised.

- **Tanker Trucks and Stations-** Once loaded with both fuel methanol and the gasoline, and transported to the fuel station, two samples should be taken of the methanol gasoline blend. The first sample should be taken when the fuel is off-loaded into the station storage tank, by use of a receptacle being 'dipped' into the tank, through the same orifice that is used to off-load the fuel from truck to the underground storage tank (UST), or aboveground storage tank (AST). This sample should be visually inspected, cataloged and stored at a secure and safe location at the station.

  The second sample should be taken from the dispenser itself, preferably after the dispenser has been used, and the fuel has some retention time in the dispenser, hose and nozzle. This sample should be taken from the nozzle and placed in a clear glass bottle; then visually inspected, cataloged and stored at a secure and safe location at the station.

  It is possible to perform a 'quick check' of the fuel from the nozzle by use of a hand-held conductivity meter that can determine the level of conductivity of the fuel. Methanol is a conductive liquid, but its conductivity is low when not contaminated by corrosion or other sources. If the reading on the conductivity meter is 'high', the fuel may have been contaminated or be otherwise 'off-spec' and the sample should be analyzed.

  If contamination is suspected from the dispenser sample, it is recommended that another sample be taken from the dispenser after 3-5 gallons have flowed, so the sample will reflect what the quality of the fuel in the piping and/or the storage tank (upstream from the dispenser, hose and nozzle). This sample can also be visually inspected, tested for conductivity, and either analyzed if indicated, or cataloged and stored at a secure and safe location at the station.

- **Fuel Sampling and Testing Frequency-** From the outset of the Methanol Gasoline Blend Pilot Demonstration, the taking of retains and fuel sampling should be performed for every first load to stations, and periodically thereafter, to assure the methanol gasoline blend is 'on-spec', and therefore can be shown to not have a bearing on the fuel testing in the vehicles in the Pilot Demonstration. It is quite important that each station perform as expected, and so the initial fuel sampling and possible testing protocols be followed so a 'constant' of fuel quality is achieved. It is recommended that the retains and samples continue to be taken for assurance purposes, and to be sure that the fuel storage and dispensing system does not deteriorate over time, possibly rendering the fuel quality substandard.

3.3 Methanol Distribution and Infrastructure Requirements

Methanol distribution involves the multi-step movement of the produced fuel from the production plant to the end-user's vehicle, and the process is quite similar to that for gasoline and diesel fuel from refinery to vehicle end-users. The several steps are listed below, and described in the following sections:

- **Transport from Methanol Production Plant**
- **Fuel Storage and Distribution Terminals**
- **Fuel Methanol Distribution from Terminals to Dispensing Stations**
- **Fuel Storage and Dispensing into Vehicles**

Transport from Methanol Production Plant: In discussions with a major North American methanol producer, the transport of methanol from the plant is accomplished via pipeline to railcar loading racks, using methanol compatible pipelines, pumps and other equipment components in a way to assure a very high purity for the product (99.9999%) to the railcar. This initial transport is a well-established practice in the industry, one that guarantees purity and safe handling of a hazardous chemical commodity. [44] This practice would be no different for transporting fuel methanol, as railcars are shipped routinely across the continent every day. The methanol industry has established rigorous protocols for the transport, storage and safe handling of its product, and has been extremely pro-active and diligent in disseminating information to all its customers. [45]

Fuel Storage and Distribution Terminals: Inland distribution of methanol via railcar would result in the railcar being unloaded at a fuel distribution terminal (with a rail spur) that can effectively store the methanol in methanol-compatible bulk storage tanks, pumps and pipelines, for eventual fuel tanker truck-loading distribution to fueling stations. In the Salt Lake City area there are at least two such fuel distribution terminals nearby that could potentially be used. Cardwell Distributing, Inc. has tankage potentially available at several locations in the Salt Lake City and adjacent areas, and their facilities have rail car access. Cardwell has fuel-loading racks that can potentially load both methanol and gasoline, at the methanol gasoline blend specification limits, for transport to fuel dispensing stations. Other distribution companies operate in the Salt Lake City area, such as Christensen Oil (operator of three E85 retail fuel stations in Utah), but attempts to contact these companies were not successful.

Fuel Methanol Distribution from Terminals to Dispensing Stations: Establishing the supply chain for fuel methanol to the distribution terminal has, in the past, been the responsibility of the methanol supplier. In the California Program there existed two bulk storage terminals that were suitable for methanol: one in the north at Richmond, California, and one in the south, at San Pedro, California. The terminals used were called "clean products terminals"[46], as was the standard practice for the methanol industry. Both terminals were capable of receiving the product either by ocean vessel or by rail tank car. These terminals had tanker truck loading capability via

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[44] Personal communication-Ben Iosefa- Methanex Corporation

[45] See References: Methanol Institute- Methanol Safe Handling

[46] See Appendix 1-A- Loading at Chemical Terminals (CEC Station Manual-1996/1998)

a ‘state of the art’ loading rack, but it may be possible to store both fuel methanol and gasoline at the same terminal, eliminating the extra additional time and expense of having to travel to a second terminal to load gasoline.

As a part of the fuel quality-assurance procedures, the truck used to transport the fuel should have transported gasoline prior to picking up the fuel methanol, and should undergo a visual inspection to assure that there is not an unacceptable residual volume of gasoline remaining in the tanker truck. If the truck has carried diesel fuel prior to picking up methanol at the terminal, the recommended practice is to have the tank ‘clean rinsed’ and visually inspected prior to loading methanol onboard. It is important to note that the ‘clean rinse’ material used should not contain chlorides, as the presence of chlorides can activate and exacerbate the corrosive properties of the methanol, all along the distribution pathway, up to and including the fuel dispensing system at the vehicle fueling station.

Once methanol is loaded into the tanker truck, the truck would go to a petroleum products terminal for loading the gasoline component into the tanker truck. For this Pilot Demonstration, it appears that Cardwell Distributing, Inc.[47] has the capability of providing both fuels at the loading rack, and this saves cost by eliminating an additional stop for loading gasoline.[48] It is important to note that the amount of gasoline to be loaded should be, and can be, precisely determined, preferably with the use of a computerized loading rack. This ‘splash-blending’ takes place as fuels are loaded onto the tanker truck, transported to the station, and when downloaded into the underground- or above-ground fuel tanks at the station. So long as the precise volumes of methanol and gasoline are loaded into the tanker truck, the splash blending of transit and down loading into the tank (at about 40 to 60-gallons per minute), yielded a very well mixed and consistent blend- M85 in the California case, and will yield a well-mixed and consistent blend of methanol gasoline blend in this pilot demonstration.

The tanks on tanker trucks are made of a suitably hard aluminum alloy that is resistant to the corrosive properties of methanol for the short amount of time involved in the transport to the stations.[49] Once delivered to the retail or commercial fuel station, and the blended methanol and gasoline is down-loaded into the station storage tank, and with the agitation caused by the combination of loading, transporting and finally down-loading the fuel into the storage tank, the fuel blend is a very uniform mixture.

3.4 Fuel Storage and Dispensing into Vehicles

Fuel retail stations have the following major components or systems: storage tank, piping from storage tank to dispenser and dispenser to vapor recovery, in tank pump, dispensers, jumper and vapor recovery hoses, electronic point of sale system, and vapor recovery. U.S. DOE has published several reports on the handling, storing, and dispensing E85 and these reports are also

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[47] Personal communication with Bill Rawson and Robert York of Cardwell Distributing, Inc.

[48] See Appendix 1-B Loading at Petroleum Terminals (CEC Station Manual-1996/1998)

[49] A 24-hour retention test was performed in the California Program, using the higher methanol content M85, and sampling of that fuel showed no contamination of the fuel resulted, despite being stored in hard-alloy aluminum tanks on the trucks.

good references for establishing a methanol gasoline blend infrastructure.[50,51] These components and their compatibility with methanol are discussed below.

3.4.1 Storage Tanks for Fuel Methanol

The underground storage tank (UST), or aboveground storage tank (AST)[52], must be double-walled, with a pressurized annular space, and interstitially monitored for leaks. Utah is subject to the requirements of the U.S. EPA, and enforces the codes and standards for fueling systems, with either above or below ground systems. The tanks must be made of a methanol-compatible material, typically carbon-steel or methanol-compatible fiberglass. The exterior of the tank may require either a coating for steel (fiberglass-wrapped) and/or cathodic-protection to avoid corrosion caused by soil and underground water. There may be areas in the state or country that do not require double-walled tanks for gasoline, and possibly even for methanol, but it is our strong recommendation that double-walled tanks of either compatible material, with interstitial monitoring and/ or cathodic protection, and automatic shut-off, be used in all cases. When establishing the stations, it is important to insist that the tanks (and all other equipment components) be fully methanol compatible, and it appears there are methanol compatible varieties, and company brands, for both steel and fiberglass tanks that are listed with Underwriters Laboratories (UL)[53]. Four UL listed varieties are recommended for methanol gasoline blends:

- **Type II secondary-containment nonmetallic underground tank for petroleum products, alcohols and alcohol-gasoline mixtures**; — Nonmetallic primary tank completely contained (full 360° containment) within a secondary-containment nonmetallic tank which is physically separated from the primary tank by standoffs creating a defined annular space. These tanks have provision for monitoring the annular space for leakage and employ either steel or nonmetallic fittings for attachment to piping. These tanks are intended for storage of only those liquids specified in the individual Listings and on the Listing Mark attached to the tank. The basic standard used to investigate these constructions is ANSI/UL 1316.

- **Type II secondary-containment underground tank for flammable liquids** — Steel primary tank completely contained (full 360° containment) within a secondary-containment steel tank, which is physically separated from the primary tank by standoffs creating a defined annular space. The tanks have provision for monitoring the annular space for leakage. These tanks are not provided with a corrosion-protection system, which has been investigated by UL. The basic standard used to investigate this construction is UL 58.

- **Jacketed-type tertiary-containment underground tank for flammable liquids** — Consists of Type I or Type II secondary-containment underground steel tank core completely contained within a nonmetallic external tank jacket, which provides both tertiary containment and corrosion protection. These tanks have provision for monitoring both annular spaces for leakage. The basic standards used to investigate this construction are UL 1746 and UL 58.

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[50] Clean Cites, "Handbook for Handling, Storing, and Dispensing E85," NREL, July 2006

[51] Moriarty, "E85 UL Listed Equipment," NREL, August 2010

[52] See Appendix A-2- Equipment Lists for M85 UST/AST Storage and Dispensing Systems (CEC Station Manual -1996/1998)

[53] Underwriters Laboratories, http://www.ul.com/global/eng/pages/corporate/contactus/faq/industries/chemicals/

- **Tertiary-containment nonmetallic underground tank for petroleum products, alcohols and alcohol-gasoline mixtures**; — Consists of a nonmetallic Type I or Type II secondary-containment tank completely contained within an external nonmetallic tertiary-containment shell. These tanks have provision for monitoring both annular spaces for leakage and employ either steel or nonmetallic fittings for attachment to piping. The Listing Mark identifies the extent of wrap in degrees of circumference. These tanks are intended for storage of only those liquids in the individual Listings and on the Listing Mark attached to the tank. The basic standard used to investigate these constructions is ANSI/UL 1316.

The tanks themselves should also be outfitted with methanol-compatible fittings and accessories, such as interstitial probes, wiring, hold-downs, and especially the "drop tube" which is in the orifice that is used to load the tank with fuel. This drop tube is exposed to methanol in the tank 100% of the time, and so it must not be made from aluminum, which is typical, but rather made from another alloy, polyethylene, or some other methanol compatible material. Care should be given to assure that the sumps and fuel caps on the UST are designed and installed to avoid water accumulation, and water seepage into the sump or tanks itself. As methanol is hydroscopic, an accumulation of just 4% water into the methanol can lead to 'phase separation' of the blend, causing the methanol to separate from the gasoline as blended, with the gasoline usually going to the bottom of the tank, and rendering the fuel methanol blend out of specification. The fuel load remaining would likely have to be disposed of, as the methanol will be off-specification and unacceptable due to the water intrusion.

While most retail service stations utilize underground storage tanks, there may be some applications where ASTs will be preferred, often due to the need to avoid the added cost of excavation for UST, or where fuel dispensing is being done at a commercial site where adequate space on the site exists. The ASTs are typically comprised of steel tanks surrounded by concrete, but with an interstitial space that is monitored for leaks. There are methanol compatible ASTs available, and these were used in California for many years at the district offices of CalTrans, for fueling the M85 FFVs in their fleet. These tanks are no longer in methanol service, but are still used for gasoline dispensing.

Finally, there may exist opportunities to utilize ***existing storage and dispensing systems*** for this Pilot Demonstration. The best possibility for using an existing tank is to use an existing E85 storage and dispensing system, either at a fleet or retail site.[54] Other existing gasoline systems should be carefully evaluated, and the manifest for all equipment, components and accessories carefully reviewed to determine its acceptability, including materials compatibility, for use with methanol gasoline blends. It is not an acceptable practice to rely on the word of the owner or operator for this determination, especially if the equipment list for the existing system exists. If

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[54]E85 station locations in Utah:

Station Name	Address	City	Price
JPs American Car Care	1350 East 700 S	Clearfield	$4.00/gal
Christensen Oil Company	524 N 1500 West	Orem	$3.57/gal
Christensen Oil Company	700 E 800 N	Provo	$3.49/gal
Christensen Oil Company	1890 N Main St	Spanish Fork	$3.49/gal

the equipment is determined to be methanol compatible and capable, care should be given to the proper cleaning of the existing tank (using no chlorides, as with tanker truck rinsing), and the pressure testing of the entire system to determine tightness and the adequacy of leak monitoring and prevention.

3.4.2 Fuel Methanol Piping from Tank to Dispenser

Much like the USTs and ASTs, the product piping for fuel methanol must utilize methanol compatible materials. Varieties for both metal and fiberglass double-walled piping exist and are UL rated.[55] Both carbon-steel and cast iron piping are methanol compatible, and as with the fiberglass tanks, fiberglass double-walled pipe that is methanol compatible is also available. Care and diligence should be given to assure that the right type of fiberglass tanks and piping (labeled for non-petroleum use, constructed with the methanol-compatible resins), is both specified and installed, for any stations established for the methanol blend. Once the piping runs are installed and secured to the tank, pump and dispenser, the lines must be inspected and tested for tightness (air pressure testing) before they can be backfilled with soil, and covered with concrete or paved.

3.4.3 Fuel Methanol Pump

The submersible dispensing pump is located inside the UST or AST, and is typically a chemical-approved variety, such as the Red-Jacket or FE Petro ¾ HP pumps. These chemical pumps must be specified and differ substantially from those typically used for gasoline or diesel fuels at fuel stations. These pumps are rarely seen other than when installing into a UST or AST, and so it is quite important that the installation of this chemical pump be assured at the time of station establishment.

3.4.4 Fuel Station Dispensers

Fuel dispensers for the methanol gasoline blends are unlikely to have a UL listing, as it is quite time-consuming and costly to do the testing and certification required. Wayne-Dresser has certified its Ovation model E85 dispenser, and has achieved a UL listing. Gilbarco Encore SODS however is recommended for methanol blends because that company has purchased Tokheim, the company that supplied methanol-compatible dispensers used in the California Methanol Demonstration, and may be used as a 'realistic proxy' for use in a methanol gasoline blend fuel system. This, it should be pointed out, is an assumption based on using the best information available, and verbally confirmed by individuals that worked on the California Methanol Program, but is not a substitute for specific testing and certifications which would lead to UL listing for dispensers operating with specific or varying blends of methanol and gasoline.

With methanol-compatible dispensers, many of the existing metal (copper, aluminum, zinc, etc.) internal parts are changed out for compatible materials (stainless steel, nickel plating). The non-metal internal materials of the dispenser (such as used in seals, o-rings and valves) must be changed out for methanol compatible materials such as Teflon, Kalrez (Dupont), and some forms of polyethylene.

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[55] UL http://www.ul.com/global/eng/pages/corporate/contactus/faq/industries/chemicals/

The graphite **pipe joint compound** used in gasoline station construction is methanol compatible, but because it is also water soluble, and can be washed away if exposed to water and/or moisture when tightness testing the system. An alternative that may be a better fit for the methanol system is Loctite PST- a Teflon-based joint compound.

The **fuel filter** within the dispenser should be a Cim-Tek [56] 1-micron, spin-on fuel filter (or equivalent), using a nickel-plated mounting bracket within the dispenser as adapted for, and used in, the California Program.

Because methanol is hydroscopic, and because methanol blends can phase-separate with the presence of just 4% water, the California Program initially used **desiccant-dryers** on the vent lines to prevent the water intrusion. This practice was discontinued though when a UST was over-filled, pushing methanol up the vent line to the desiccant, and then the fuel receded through the desiccant, leaching the calcium-chloride of the desiccant back down into the storage tank. This contaminated the fuel and required disposal. Desiccant-dryer use was ceased, all were removed from service, and water intrusion was no longer seen or experienced as a problem in the M85 fueling systems.

3.4.5 Product, jumper and vapor recovery hoses

The product jumper and vapor recovery hoses were among the main sources of fuel contamination in the California Program, as the gasoline varieties of these hoses proved immediately problematic. When M85 was initially introduced in the early 1980's, the gasoline fuel hoses, both for the fuel product and vapory recovery return, were made of a black, rubber composite (nitrile) that was found to leach its material constituents readily when in contact with fuel methanol. The more corrosive methanol was in constant contact with these hoses, as fuel is retained in the product and jumper hoses nearly 100% of the time- during fueling events and especially the long intervals when the fuel lies stagnant between fueling events. The leached hose material was not caught in the dispenser filter (it being 'upstream' from the product hose), but was found in the vehicle fuel filter, the vehicle fuel pump and the engine fuel injectors. This contamination of these key vehicle system components resulted in a great number of warranty claims and repairs, and threatened to put a halt to the California Program until these problems were resolved.

The emerging fuel quality problems required a forum of all the Program's partners be established to investigate the established furling systems and equipment components, sample and test fuel, evaluate the vehicle filters, pumps and injectors for causes of failure, and to propose remedial actions that would resolve the problems. The California Energy Commission proposed and led such an effort, called, simply enough, "The Problem Resolution Team" and it was made up of representatives from the California Energy Commission, the automakers (Ford, GM and Chrysler), the major oil companies participating (Arco, Chevron, Exxon, Mobil, Shell, Texaco and Ultramar), and the petroleum equipment suppliers. The Team met monthly to collaboratively discuss developments and improvements based on a great deal of fuel sampling and testing. The team discovered more resilient materials with vehicle and fuel dispensing component manufacturers, and over a year's time started to implement new, nickel-plated methanol resilient

[56] See Appendix 3-A Cim-Tek Filters

nozzles, dispenser internal seals and metals, jumper, vapor recovery and product hoses, and methanol compatible, 1-micron spin-on dispenser filters with an adaptable nickel-plated mounting. A great deal of simultaneous testing and investigation took place during this time, and the effort resulted in the successful resolution of fuel contamination issues, drastic reduction, and near elimination, of warranty claims, and the successful achievement of distribution of 'on spec' M85 or M100, within the large demonstration.

It is important to note that many of the advanced materials and techniques developed from the collaborative, cross-industry actions to seek more resilient materials for vehicles and fueling stations, are still in use today. An outstanding example of this is the equipment specification for E85 stations today. For this report, the E85 station system used today can serve as a very suitable 'proxy" starting point for a methanol gasoline blends. And, by making particular component substitutions should provide at jump-start to a suitable methanol gasoline equipment specification. This should be followed by a regime of fuel sampling and system monitoring.

Beyond the E85 station proxy, Mike Carruth of Fillner Construction (contractors for many of the M85 stations constructed in the 1980's and 1990's) in Rocklin, California, provided an equipment list for a fuel methanol station, circa 2012 system design and components.[57] This list may provide a good comparison with modern E85 compatible station equipment, and the best equipment listing option for methanol gasoline blended fuel.

The hoses used for the E85 proxy are in fact quite similar to those developed and used in the California Program. There are no dual-hose (product and vapor) systems used anymore, as compatible coaxial hoses are available, and cross-linked polyethylene material hoses are available as necessary for other hoses and internals in the dispenser.

3.4.6 Electronic Point-of-Sale (EPOS)

The Electronic Point-of-Sale (EPOS) system utilized for a methanol gasoline blend fuel dispensing system does not require methanol compatible components, but the system's attachment to the fuel dispenser and meter may require specific methanol compatible probes, wiring and attachments. This consideration is not of major concern as it is accomplished for E85 systems across the country.

The EPOS system can serve another useful, methanol gasoline blend specific purpose. The EPOS system was instrumental in the California Program to 'segregate' the M85 fuel from gasoline and diesel fuels also dispensed at the station. Drivers visiting the station may have wanted to fuel with M85 due to its novelty, its attraction as a racing fuel, or its lower price at the pump (M85 was priced on an energy equivalent basis to gasoline- a bit over half of the prevailing gasoline price on a $/gallon basis). Modern EPOS systems are much more capable today, and can do all of the following, which are essential to a limited demonstration, and to widespread commercialization, alike:

- Enable certain customers, restrict others
- Track and pay for volumes dispensed

[57] See Appendix 2-B: Methanol Blend Compatible Equipment Listing, Mike Carrot, Fillner Construction, Rocklin CA.

- Records accumulated mileage
- Utilize and monitor on-board diagnostics
- Prepare monthly reports; fueling incidents, volumes dispensed, deducing fuel economy

3.4.7 Vapor Recovery System

The vapor recovery system used in today's E85 systems should be quite acceptable for the methanol gasoline blend system, if it is required by local jurisdictions. Though the methanol gasoline blend would likely not come into direct contact with the system, only vapor of the fuel blend, it should contain the more durable components present in the E85 system. Additionally, though it is not clear whether existing or future FFVs will require vapor recovery in all cases, for this demonstration, it is recommended that vapor recovery be established to show adherence to the well-established system for vapor emission capture and containment.

3.5 Station Permitting and Construction

3.5.1 Station Permitting

The lead times for obtaining all required permits to design and construction the fueling facility at new or existing sites is approximately 4-6 weeks (appears to be a relatively typical time estimate), depending on the season. In speaking to Leo Creger of Commercial Petroleum Equipment, there is a definite 'seasonality' to the permit-time estimate. Most station construction and refurbishments occur in the late spring, summer and early fall, as the weather, temperature and snow accumulation make this type of construction very difficult if not impossible. Obviously, the winter season may well be the best time to prepare designs and permit applications, meet with planning officials, and gain approval for projects that can start in the spring or summer. As the good-weather season of construction opportunity advances, available crews are busier and become scarcer, culminating with the inevitable rush to complete projects before the snow flies. A cost estimate for permitting expense is approximately $15,000, from a California source familiar with establishing E85 stations across the state. This may well be a 'not to exceed' value given California's strict requirements, as compared to those of U.S. EPA, as enforced by Utah state and local authorities.

3.5.2 Station Establishment

Retail station construction is very time-critical, as one would imagine, since the business interruption can have negative economic consequences. Depending on the site, and assuming no remediation of pre-existing soil contamination; the station can be constructed in approximately six to eight weeks. This assumes all equipment is ordered in a timely fashion, and delivered on schedule that is 'just in time' along the process; this is essential especially where there is no available 'lay-down' space on site to store the equipment until it is installed. While station construction in a non-retail setting is less time and schedule-critical, it is best to work closely with the contractor and equipment suppliers to assure the timely delivery of all components. When scheduled properly, the station construction usually takes approximately six weeks, always depending on the weather, which is not always assured and predictable.

The costs of permitting, equipment, and installation/construction a new underground storage and dispensing system range from $185, 000 to $265,000 for a 10,000 gallon storage tank, monitoring system, submersible pump, product and vapor-recovery piping, dispenser containment sump, EPOS system, dispenser, hoses and nozzles and fittings. It should be noted that the costs of the equipment have increased substantially over the past fifteen years, perhaps due to increasingly stricter standards and procedures and component and materials improvement as well as inflation. We have used station equipment listings from 1999 (for a methanol compatible system)[58], from 2007 for an E85 system and from 2011, also for an E85 system (both E85 systems are for California stations which may have some extras not necessary for this demonstration – such as a new EPOS system instead of using the existing, and construction of a canopy over the fueling island). We were not able to secure response from Utah station construction companies, as it is the height of their season, as mentioned earlier.

From start of permitting, to completion of construction and system testing, approval, shakedown and start-up, the time required ranges from 10-14 weeks.

[58] See Appendix 2-A

4. Economics of Methanol Gasoline Blends

The success of alternative fuels in the retail market place depends on the savings that consumers achieve. These savings can be based on total lifecycle costs expressed typically as a simple payback for retail customers or savings at the fuel dispenser expressed in $ per gallon or $ per equivalent gallon. Technologies like natural gas vehicles or hybrid vehicles have a higher capital cost due to the more expensive compressed natural gas cylinders or the more expensive batteries. Generally consumers will weigh the higher vehicle costs against lower fuel or operating costs, and if the payback is less than 3 years, a certain number of consumers will purchase these vehicles and use the alternative fuel.

The situation for FFVs has been motivated by the automakers that receive a credit to Corporate Average Fuel Economy (CAFE) Regulations by producing and selling these vehicles. The incremental costs of these vehicles certified on gasoline and E85 is small in comparison to the benefits of using these vehicles to meet their CAFE requirements. Although a number of E85 stations have been built, the average use of E85 in the 12 million FFVs in the U.S. is very small. The key problem has been that E85 on an energy basis sells for more than gasoline in every station across the U.S.

Part of the reason for this is that the primary demand for ethanol in the transportation market is as a low level blend in gasoline. As such, ethanol completes with gasoline blend stock (RBOB) and other gasoline additives like alkenes on a volume basis and not on an energy basis. Ethanol's energy content is 66% of gasoline and therefore on energy basis is 50% more expensive than gasoline (1.5 gallons of ethanol is equivalent to 1 gallon of gasoline).[59]

Methanol currently competes primarily in the worldwide chemical market and is priced in that market. Typically the price of methanol is 40% of the price of ethanol. Adjusting for methanol's lower energy content prices, methanol is priced at about 55% of ethanol.

Low-level gasoline blends containing ethanol (like E10) do not compete in the market—gasoline is either sold with 10% ethanol or without. E85, and potentially E15, have to compete with gasoline on an equivalent energy basis since consumers will be offered the choice of these fuels or gasoline (E10). Consumers will discount the price of E85 by at least the difference in energy content and possibility other factors such as E85 station locations and the need to fuel their vehicle more often.

It is in this context that methanol gasoline blends offer the opportunity to provide a fuel that would compete with gasoline, and capture significant market share. The purpose of the next section is to explore the costs and potential pricing of methanol gasoline blends. We first discuss the various cost components of distributing methanol gasoline blends. This is followed by estimated costs of the fueling station and then the costs of transportation and distribution. Methanol gasoline blend pricing is covered last.

[59] Ethanol's lower heating value is 76,760 Btu/gal and gasoline without additives is 114,000 Btu/gal

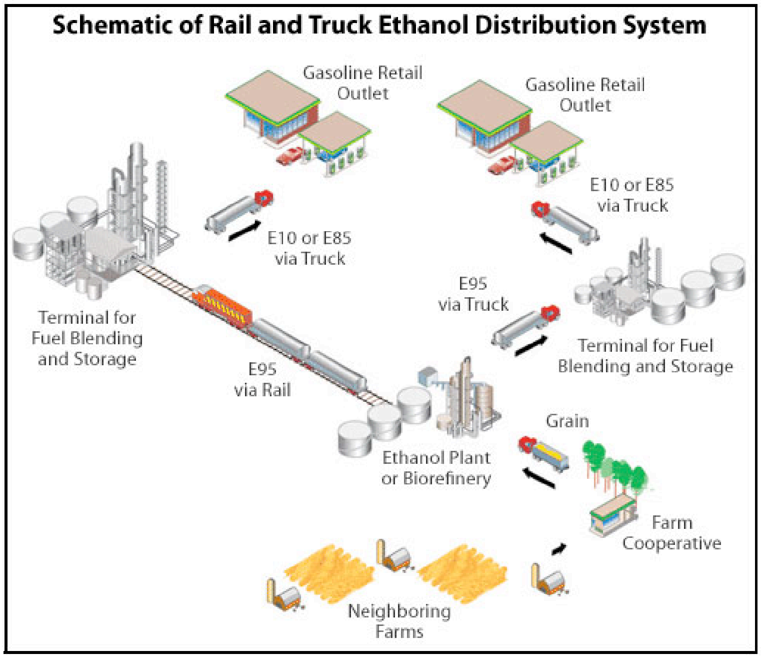
4.1 Overview of Cost Components

Table 7 shows the various steps in the distribution chain for methanol gasoline blends and E85. Methanol will be distributed in a manner similar to ethanol with bulk distribution dominated by rail (and perhaps marine depending on location and volumes). Blending will most likely occur at terminals and be locally distributed by tanker trucks. This liquid distribution system is similar to gasoline except that gasoline is shipped via product pipelines to gasoline terminals. This reduces gasoline transportation costs compared to methanol or ethanol blends. Pipelines are possible for the alcohols but will require tighter controls on water content and materials compatibility. For these reasons, pipeline shipment of either methanol or ethanol will not be done until the volumes justify either pipeline upgrades or pipelines dedicated to methanol or ethanol.

Table 7. Distribution of Methanol and Ethanol Blends—the value chain and stakeholders

Value Chain	Methanol Gasoline Blend	Stakeholder	E85 Blend	Stakeholder
Energy source	Natural gas	Energy companies and gas producers	Corn	Farmers
Production	Methanol	Chemical producers e.g. Methanex, Celanese, etc.	Ethanol	Ethanol marketers, ADM, CHS, Murex, Western Ethanol Co, etc.
Bulk Shipping	Rail car	Class 1 railroads, UP, BNSF, CSX, NS	Rail Car	Class 1 railroads, UP, BNSF, CSX, NS
Rail to Terminal shipping	Tank Truck	Local haulers, oil companies, distributors	Tank Truck	Local haulers, oil companies, distributors
Storage and blending	Gasoline Terminals	Energy, Pipeline, Jobber, and private/partnerships Companies, etc	Gasoline Terminals	Energy, Pipeline, Jobber, and private/partnerships Companies, etc
Local distribution to stations	Tank Truck	Local haulers, oil companies, distributors	Tank Truck	Local haulers, oil companies, distributors
Fuel Dispensing	Local Service Station Branded (owned and jobber) and independent public stations; private fleet stations	Energy/oil companies, independents, Big box stores, mini markets Local, state, Federal governments Private Companies	Local Service Station Branded (owned and jobber) and independent public stations; private fleet stations	Energy/oil companies, independents, Big box stores, mini markets Local, state, Federal governments Private Companies

Figure 10 illustrates the current distribution system for low-level ethanol blends or E85 and shows the importance of terminals as the blend point in the fuel distribution system. The role of rail and trucking shipments are also shown.



Source: http://www.afdc.energy.gov/fuels/images/rail_dist_map.jpg

Figure 10. Distribution of Ethanol Blends

For methanol gasoline blends to enter the market, changes in the current gasoline and ethanol infrastructure are required. As indicated in the value chain table and above ethanol distribution schematic, investments in the following areas are needed:

- Fuel station/retail outlet—require changes to underground tanks, piping, pump, and dispenser as discussed in Section 3.
- Bulk and local transport—require the purchase of dedicated methanol railcars or use of ethanol railcars if logistics of dual use can be achieved; requires the use of tanker trucks. Could use gasoline trucks but most likely will need dedicated fleet from rail off loading to terminal and perhaps from terminal to retail outlet to accommodate the larger volumes of alcohol gasoline blends.

4.2 Fueling Station

Details regarding the changes needed to dispense methanol gasoline blends were discussed in Section 3. Here we itemize our assumptions regarding the costs of modifying an existing gasoline station to have at least one storage tank and dispensers capable of providing methanol gasoline blends. We have assumed that an average gasoline station dispenses 124,000 gallon of gasoline per month and services 277 customers.[60] We also assumed that an average station has 6 dispensers and adequate storage. Our assumption regarding the retailing of methanol gasoline blends is that one half of an average station would sell methanol gasoline blends and one half would sell gasoline. So, in this scenario, three dispensers would be dedicated to methanol gasoline blends and three dedicated to gasoline. Table 8 shows our estimate for the capital and installation costs of adding three new dispensers and a new 15,000 gallon underground storage tank to an existing station. These costs are comparable to those published by EPA as part of the Renewable Fuel Standard[61] for costs of E85 stations.

Table 8. Estimated Retail Outlet Equipment and Installation Costs—15,000 gallon storage with 3 dispensers

Number	Item	Costs
3	Dispenser	69,000
1	Tank 15k gallons	102,000
	construction and misc matls	
	plans, permits, etc	
	subtotal	171,000
20%	markup + contingency	34,200
	subtotal	205,200
10%	profit	20,520
	Total	225,720

Our assumptions regarding owning and operating costs are detailed in Table 9. Again we have assumed that half of the station would sell gasoline and the other half would sell methanol gasoline blends. We have adjusted for the lower energy content of the methanol gasoline blends by increasing the average fill up from 15 gallons per customer to 21 gallons (a more likely scenario is that consumers will fill more often and have the same average fill per gallon as gasoline). The O&M costs per dispenser are $1,485 per month. Normalized by methanol gasoline blend throughput per month (see Table 10) gives a cost of 1.7 cents per month per gallon.

Table 10 shows our assumptions for the methanol gasoline blend retailing. We have assumed half of the vehicles will be filling with these blends and that the average fill per vehicle is 20.8 gallons. Again, we have assumed three methanol gasoline blend dispensers and the total installed capital costs are $225,720 as shown in Table 8. With a 15-year life, 8 percent discount rate, and a salvage value of $22,572 the monthly capital costs are $2,222 or 3 cents per methanol gasoline gallon dispensed.

[60] National Association of Convenience Stores (NACS), "2012 NACS Retail Fuels Report," February 2012 http://www.nacsonline.com/NACS/Resources/campaigns/GasPrices_2012/Pages/default.aspx

[61] U.S. EPA, "Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis," Assessment and Standards Division, Office of Transportation and Air Quality, EPA-420-R-10-006, February 2010

Table 9. Estimate of Monthly Owning and Operating Costs for Average Retail Station

	277	vehicles/day
	6	dispensers
	15	gal/fill
Labor Costs		
	18	Labor, hr/day
	15	Labor Rate, $/hr
O&M Monthly Cost		
	$8,019	Labor
	$9,000	Rent, Credit/Debt Swipe Fees, Insurance
	$800	Utilities
	$17,819	Monthly Cost
	$1,485	Cost per dispenser per month
	$0.0172	Cost per dispenser per month per gal

Note: Labor, rent, and utilities are highly variable depending on location. These estimates are meant to be representative only.

Table 10. Estimated Monthly Capital Costs for Dispensing Methanol Gasoline Blends

Vehicles/day	138
gal/fill	20.8
# dispensers	3.0
Daily Throughput (gal/day)	2,885
Stream Days	360
Annual Throughput (gal)	1,038,750
Monthly Throughput (gal)	86,563
Facility Finance Life	15
Discount rate (%)	8%
Total Capital Cost Input	$225,720
Salvage Value	22,572
Payment Periods	180
Monthly Payment	($2,222)
Capital cost/unit fuel	($0.03)
Capital Recovery Factor	12%

Total monthly retail station costs for the methanol gasoline blend side of the business are:

	Monthly Costs	Costs per Gallon
• Local transportation		$0.05
• Capital costs	$2,222	$0.03
• O&M costs	$8,910	$0.10
• Profit		$0.04
Total		$0.22

According to NACS on average it costs a fuel retailer about 13 cents to sell a gallon of gasoline. In 2011, the average national retail markup was 18.5 cents per gallon delivering an average profit of 3 to 5 cents per gallon[62]

4.3 Bulk Transport and Storage Costs

Bulk Transportation and storage costs were assumed to the same as those for ethanol. As indicated in Table 8 we do not expect that methanol transportation modes and storage will differ significantly from those that are currently used for distributing ethanol. EPA, in their analysis for the RFS2 Regulatory Impact Analysis,[63] estimated the costs of distributing cellulosic ethanol from the ethanol plant to the gasoline terminal. They assumed that ethanol would be shipped mostly by 30,000 gallon rail cars with some marine shipping in barges. Accounting for capital and owning and operating costs, EPA estimated on average a bulk ethanol distribution costs of $0.13 per gallon. This costs includes the capital for rail cars or barges and the off loading facilities near or at the gasoline terminal.

Storage costs at the gasoline terminal for ethanol were estimated by EPA to be $0.02 per gallon. We assumed that the total costs of bulk distribution of ethanol or methanol from production facility to a gasoline terminal would be on average $0.13. Storage costs at the gasoline terminal are $0.02, which gives total costs of transport and storage of $0.15 per gallon.

4.4 Methanol Gasoline Blend Pricing

Using the costs of the retail station and the costs of distributing methanol and ethanol, we estimated the price of a methanol gasoline blend with 56% methanol, current gasoline with 10% ethanol (E10), and ethanol with 15% gasoline (E85). These estimates were based on wholesale prices in October 2012 for methanol[64] FOB Medicine Hat Canada, ethanol[65] FOB Omaha, and RBOB FOB Salt Lake City, Utah. Table 11 shows a comparison of the estimated pump prices for these various fuels on a volume basis—retail fuel pump price—or on an energy basis—energy equivalent pump price.

At the October 2012 wholesale prices, neither M56 nor E85 competes with gasoline (E10). M56 is more competitive on an energy basis (2 percent higher than gasoline) than E85 (21 percent higher than gasoline). Gasoline has an advantage over M56 and E85 since all costs are based on gallons and not energy content. Bulk and local transportation and storage costs are on a per gallon basis. This makes sense since the costs are based on moving or storing a volume of fuel. Taxes are also based on gallon sold, meaning M56 and E85 are paying higher taxes—on a tax per energy or mile basis. Station costs are also based on a volume of fuel dispensed, but in our analysis we have corrected for the increased throughput of M56 or E85. This slightly reduces

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[62] NACS, "What Influences Gas Prices—2012 NACS Retail Fuels Report," February 2012. http://www.nacsonline.com/NACS/Resources/campaigns/GasPrices_2012/Documents/NACSFuelsReport2012__WhatInfluencesGasolinePrices_Purple.pdf

[63] U.S. EPA, "Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis," EPA-420-R-10-006, February 2010

[64] Methanex methanol prices October 2012. http://www.methanex.com/products/documents/MxAvgPrice_Oct312012.pdf

[65] Ethanol price from Nebraska's Unleaded Gasoline and Ethanol Average Rack Prices at http//:www.neo.ne.gov/statshtml/66.htlm downloaded 10/15/12

the operating and capital costs. We held station owner profit the same for gasoline and the alternatives.

Table 11. Comparison of the Retail Price of a Methanol Gasoline Blend (M56) Compared to Gasoline (E10) and Ethanol (E85) in Utah

Cost Element	M56	E10	E85
Meoh or Etoh Wholesale price	$1.34	$2.52	$2.52
Meoh or Etoh transport & storage at terminals	$0.14	$0.15	$0.15
Cost of Methanol at terminals	$1.48	$2.67	$2.67
Gasoline Wholesale price	$3.13	$3.13	$3.13
M56 wholesale price	$2.21	$3.08	$2.74
Truck Transport	$0.05	$0.05	$0.05
Fed Excise tax	$0.18	$0.18	$0.18
UT Excise tax + undergrd tank	$0.25	$0.25	$0.25
Station Operating Cost	$0.10	$0.12	$0.10
Capital Recovery	$0.03	$0.04	$0.03
Operator Profit	$0.04	$0.04	$0.04
UT Sales Tax	$-	$-	$-
Retail Fuel Pump Price	$2.85	$3.76	$3.39
Energy Equivalent Pump Price	$3.84	$3.76	$4.56

Clearly methanol offers an opportunity to provide a lower price option to consumers compared to E85. The question, however, is: What is the value proposition to the consumer? As we stated in the introduction, for an alternative fuel to be successful it either must compete with gasoline or become be an additive to gasoline (and thus have no competition).

What discounting is needed in order to make M56 a value proposition? EPA in their RFS2[66] presented two discounting arguments. First, it is not likely that all retail outlets would offer E85 for sale. So the convenience of fueling is reduced due to lower E85 station density. Second, consumers have to fuel their vehicles more often with E85 due to the lower energy density and this is also less convenient. Both of these arguments also apply to M56.

Researchers at Oak Ridge National Laboratory (ORNL) have quantified the level of discounting needed by consumers to offset less fueling station density and more frequent fueling. Figure 11 shows the incentive or discount needed based on fuel availability and the frequency of purchasing the alternative fuel. EPA suggested that only a quarter of the retail stations would offer E85 or 25 percent availability on Figure 11. Further, their analysis of the amount of ethanol available and sold, as E85 would limit the fueling frequency to 58 percent. This results in a discount of $0.11 per gallon ($1997). Adjusting for current dollars ($2012) gives a discount of $0.157 per gallon. This means that about half the time consumers would choose E85 or M56 and they would expect the fuel to be 15.7 cents cheaper than a gallon of gasoline.

Similarly, consumers value their time and will want to discount alternative fuels if they have to spend more time at the local retail station. ORNL also estimated the value of this for E85 for which consumers will take more time refueling than gasoline. Using a U.S. value of time of $30 per hour (in $2005) and adjusting for today gives $34.91 per hour. Based on our estimate of

66 U.S. EPA RFS2

heating values, we estimate that consumers refueling time will 28 percent more than gasoline. Assuming, like EPA, that the average fill is 15 gallons, which takes about 6 minutes, then E85 or M56 needs to be priced at 7 cents less than gasoline.

Combining these estimated discounts, we suggest that M56 or E85 should be 22.7 cents cheaper than gasoline to be a value proposition to the consumer. Referring back to Table 11, M56 or E85 to be competitive would have to have an energy equivalent price of $3.53 per gallon ($3.76-$0.227). On a gallon basis, M56 would have to be priced at $2.55 per M56 gallon. Working this backward to determine the needed wholesale price for methanol results in $0.778 per methanol gallon or 58% of the October 2012 non discounted price quoted by Methanex.

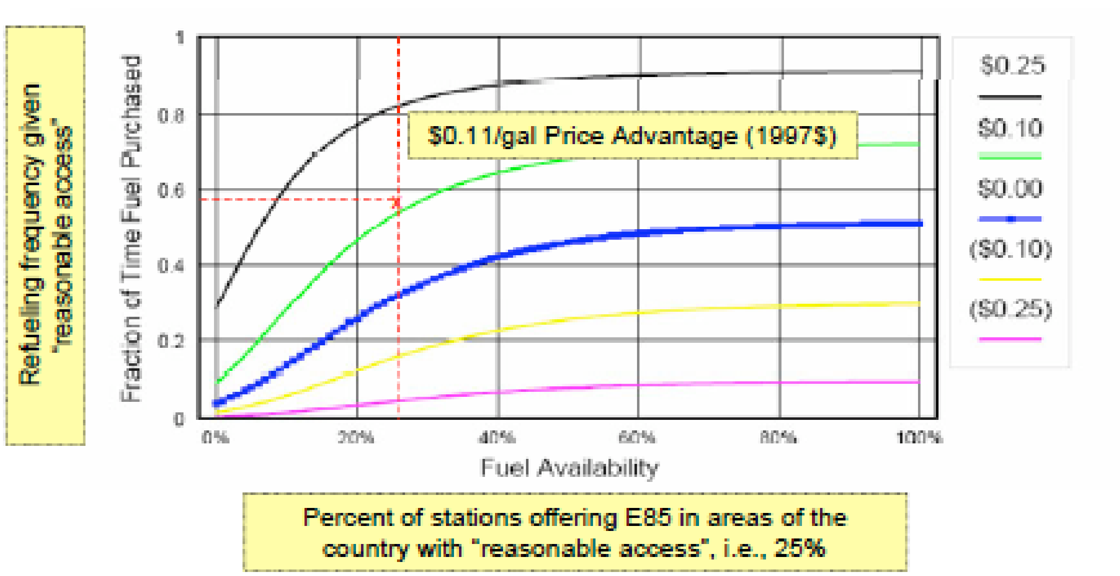

Figure 11. ORNL Estimate of the Required Price Incentive for Alternative Fuels with Limited Availability (Source: EPA RFS2 Regulatory Impact Analysis)

In order to explore the M56 price sensitivity further we varied the wholesale price of gasoline, held the wholesale price of ethanol constant at October 2012 prices, and solved for the wholesale price of methanol. The results of this analysis are shown in Figure 12. This figure shows the result that at Utah's gasoline price of $3.76 per gallon the wholesale methanol price needs to be 78 cents per gallon—quite a bit lower than the published market price. Even at the highest gasoline prices in Salt Lake of $4.17 per gallon, wholesale methanol price needs to be about $1 per gallon—still lower than current pricing.

This suggests at today's prices methanol is not competitive in the transportation market. This most likely will change in the future as the price spread between oil and natural gas prices widens. We looked at historical and projected prices of oil, natural gas, and methanol to get an idea of what is possible in the future and whether changing world demands for oil will change the competitiveness of methanol vis–à–vis gasoline.

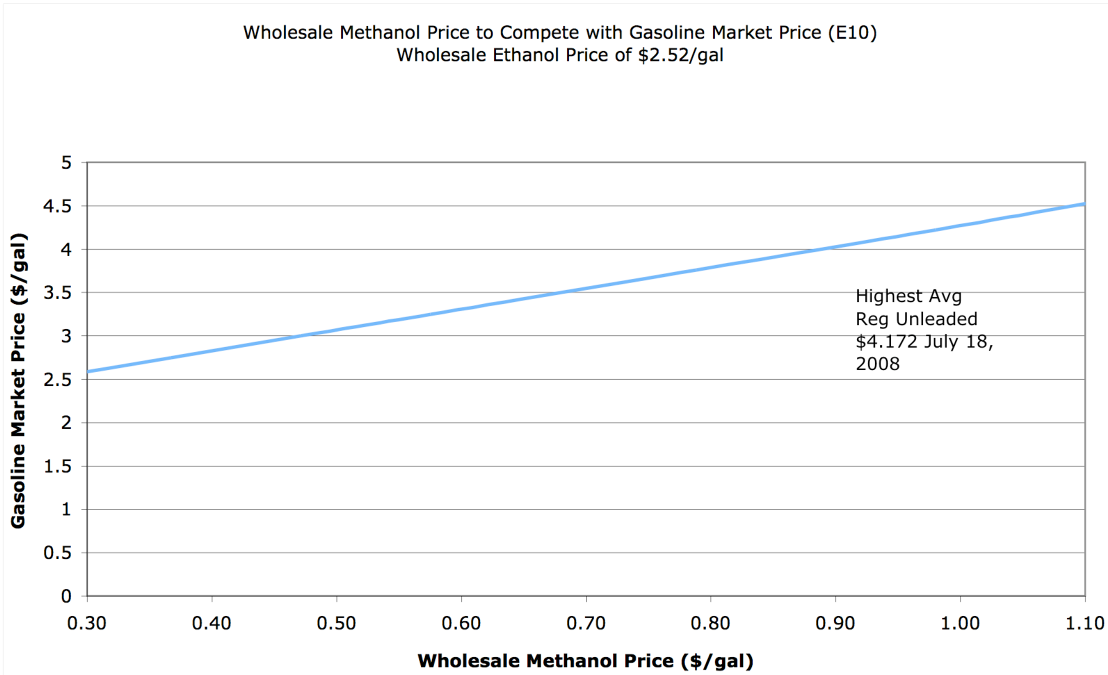

Figure 12. Required Wholesale Methanol Price to Compete with Gasoline Market Price for Utah Market

Figure 13 shows a comparison of prices for crude oil, gasoline, and methanol. Not surprisingly, gasoline price mirrors that of crude oil, as does methanol at least in the 2008-2009 time frame. We would expect that methanol's price would decrease as the price differential widens between natural gas and crude oil. As shown by Figure 2 in Section 1, the widening of the price differential started in 2009. However, as indicated in Figure 13 methanol's price has increased from a low in 2009 to a high in November 2012. This indicates that supplies of methanol must currently be tight, since the price of natural gas has remained relatively constant over this period and has even decreased in 2012 as shown in Figure 14. From 2001 through 2006 methanol averaged about three times the price of natural gas. In November 2012 methanol was 10 times the price of natural gas. At three times the price of natural gas methanol's price would be 43 cents per gallon today, which is well within the price needed to compete with gasoline at $3.76 per gallon.

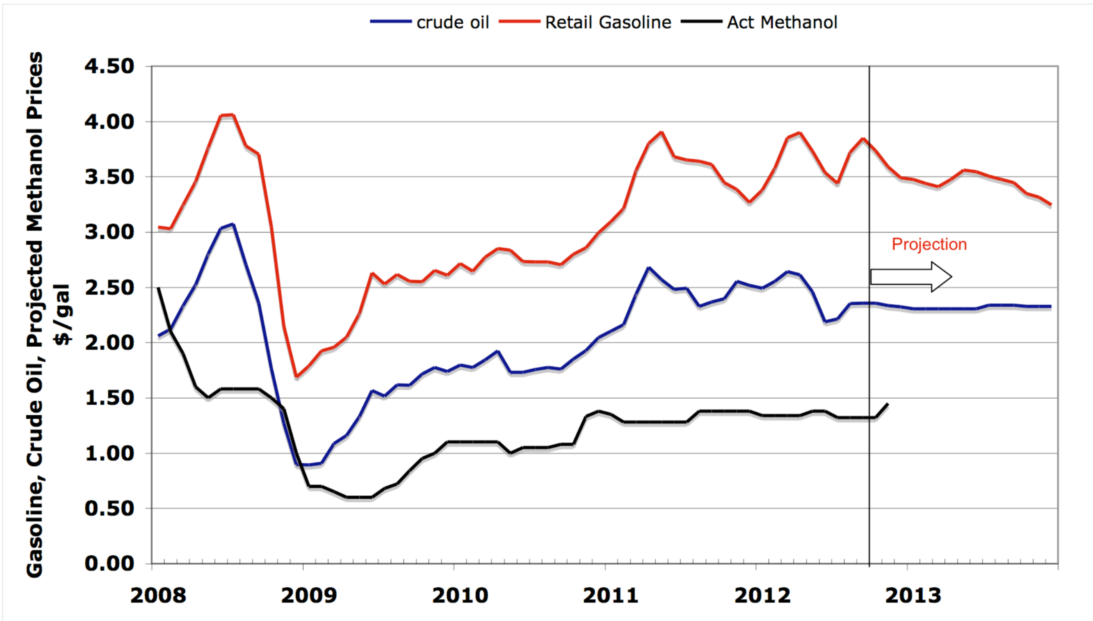

Figure 13. Price comparison of Crude Oil, Gasoline, and Methanol in $ per Gallon (Source: EIA data for Retail Gasoline, refiner costs of crude, and Methanex's website for methanol)

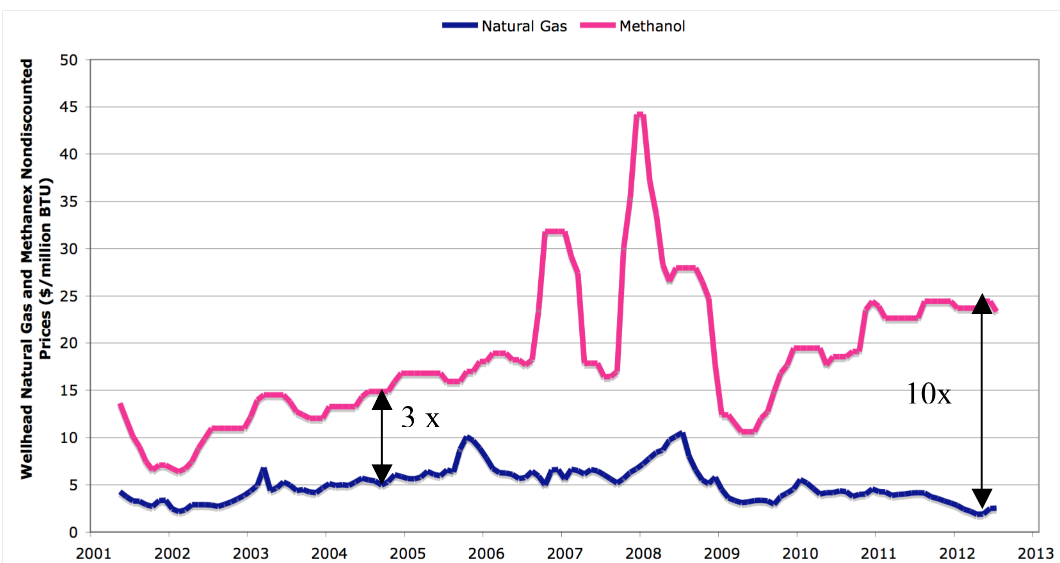

Figure 14. Comparison of Natural Gas and Methanol Prices over the Last Decade (Source: EIA natural gas wellhead data, Methanex's methanol price history non-discounted price)

5. Blue Print Demonstration Plan

Although methanol gasoline blends look promising, the previous sections have indicated there are a number of technical and economic issues that need resolution before these blends can enter the marketplace. The purpose of this section is to outline the components of a plan that will work through these issues and to demonstrate the viability of methanol gasoline blends. One of the key elements of this plan is stakeholder involvement. Cooperation and participation of fuel suppliers and automakers are required for success but also needed is participation from government/regulatory agencies. Stakeholder involvement is discussed in this section as well as preliminary selection of demonstration location, and what we believe are the technical elements necessary for this demonstration. This section is meant to be an outline of the demonstration plan and not the plan itself. A next step is to develop this demonstration plan.

5.1 Demo Project Stakeholders

The planning and creation of a methanol gasoline blend demonstration in Fuel Flexible Vehicles (FFVs) involves participation and support from a wide array of diverse stakeholders with a common interest. These stakeholders bring knowledge, intellectual and financial resources, and political will to test and demonstrate this timely and strategic alternative fuel option to dramatically reduce petroleum use in the United States. Assembling and engaging a stakeholder group that spans not only technical expertise but includes environmental and political interest is essential to the success of the demonstration itself. This group will be able to work together to solve issues that will arise in the demonstration and will be able to report on the results of the demonstration to regulatory agencies and to a broader audience. Forming this stakeholder group is a critical important step, and it will be the lynch-pin to achieving success of all aspects of the demonstration.

In past examples of alternative fuels demonstrations, many of the key participants are either not identified or included, or their contributions are not adequately sought, maximized or valued—to the detriment of the project and its potential for success. Some of the entities essential for this Pilot Demonstration and their roles are briefly described below.

Political leaders at the federal, state and local levels—Inclusion of federal representatives from the Departments of Energy, Transportation, General Services Administration and the Environmental Protection Agency; the State of Utah's Governor and many executive departments (Department of Environmental Quality, Fleet Services, others), the Utah Legislature- state, and cities of Salt Lake City, Orem, Provo, Logan and others-local.

Initial contact and discussions have begun at the Governor's level, as well as with the state fleet and Department of Environmental Quality, and the Utah state Clean Cities Coalition. Reaching out to Utah Senator Orin Hatch and members of the Utah Congressional delegation, and establishing points of contact and engaging with General Services Administration (GSA-fleet), the US Environmental Protection Agency (USEPA), the Department of Energy (DOE), and the Department of Transportation (DOT) can be very important strategically.

Public and private fleet operators —Involvement of the federal, state and local fleet operators, and private fleet operators motivated to try the methanol gasoline blend in their FFVs, and participate in this important demonstration.

Engaging with GSA and Utah state fleet, as well as city, county and other municipal fleets is essential to form the varied 'vehicle fleet' for the Pilot Demonstration.

Fuel producers, refiners, distributors and fueling station owner/operators—Invitation should be made to methanol producers, petroleum fuel refiners and distributors, operators of today's efficient transportation fuel distribution system, and the network of fuel dispensing station operators and marketers, interested in providing the methanol gasoline blend to their clients and customers. These entities represent the fuel delivery system now, and will be for decades to come, and so their participation is absolutely critical.

Contacts have been started with Methanex Corporation, and other methanol suppliers, along with preliminary contacts with the local fuel industry, including Cardwell Distributing, Inc., Christensen Oil Co., Commercial Petroleum Equipment Co- all of which could be critical for program success.

Business leaders at all levels—Seek investment and leadership from the state's business community can show the positive economic attributes of reducing petroleum with alternative fuels, and lend support and a positive public profile to the effort.

Specific business interests in the fuel distribution supply chain, the automakers, and their local dealerships, and the Chambers of Commerce for Utah and Salt Lake City, can be very strategic allies for the methanol gasoline blend Pilot Demonstration.

Automobile manufacturers, dealers and service technicians—Initiate constructive engagement with the automobile manufacturers and dealers and their service technicians, to find constructive solutions to technical problems or needed 'fixes' to the existing FFV population demonstrating the use of methanol gasoline blends.

Formal outreach to Ford, General Motors, and Chrysler, at a minimum should be continued with urgency.

Interested non-governmental organizations and academia—Engage these parties to better quantify the positive attributes of using methanol gasoline blend for the environment, for our energy security needs, and for our economic health, now and for the future. These parties are well positioned to assure that the results of this demonstration can be emphasized and publicized for the general public to be better informed on this and other possible fuel choices.

Several entities in this section can comprise an effective "Coalition of the Assertive", including the Fuel Freedom Foundation, the Natural Resources Defense Council (NRDC), Resources for the Future, Utah Clean Cities Coalition, TIAX and (potentially) the University of California, Riverside.

An independent, dedicated, informed and resolute Project Team—Integrating various stakeholder interests into a cohesive, dedicated and disciplined Pilot Demonstration for the use of methanol gasoline blends will require a wide array of political, leadership and persuasion skills. Incorporating the lessons of the past, with the developments of the present and the future, will properly inform this effort for its best chance of achieving technical, logistical and eventually, commercial success.

With a dynamic Project Team, led by Fuel Freedom Foundation (FFF), and potentially including RFF, NRDC, TIAX, Alternative Fuels Advocates (AFA), mdj Research, the methanol gasoline blend Pilot Demonstration can be successful in the first actual 'field test' of methanol gasoline blend as a strategically significant, capital-efficient potential lower-carbon alternative fuels option with serious market potential.

5.2 Location for the Methanol Gasoline Blend Pilot Demonstration

Utah has been selected for the location of the methanol gasoline blend Pilot Demonstration, and it seems entirely appropriate that the state with the motto of "Industry"[67] be the host for this demonstration. The trial and demonstration of this fuel—and the commercial introduction if successful——will not be easy or simple, but will require cooperation, collaboration and asserted effort by the 'pioneering' group enlisted for this effort.

Utah is a state that holds vast energy resources in the forms of coal, natural gas, oil and oil shale, along with its continuing development of renewable energy resources in the forms of solar, wind, geothermal, biomass, and hydroelectric for electricity generation. There is a large number of Utahans employed in the energy sector, over 23,000, and the promise of abundant natural gas reserves and expanding development of both conventional and renewable resources, this number will undoubtedly grow in the coming years.

Utah, like all states, is subject to the insecure and unstable aspects of petroleum fuels use, and has dedicated itself, from the Governor down, to reducing this vulnerability with active alternative fuels development efforts. The Governor has assembled an alternative fuels task force to seek actions and efforts to reduce petroleum use in the state, in general, and in the State Fleet, specifically. The state has shown it is quite interested in stabilizing and reducing long-term energy costs and minimizing environmental impacts. This methanol gasoline blend project is a very credible and strategic play, and for its large potential and lower cost as an option, could be just the right fit for Utah, and the rest of the United States.

Salt Lake City, the capital of the state, is centrally located among many of the state's main cities and transportation infrastructure, and therefore can serve as a main part of the methanol gasoline blend demonstration project. The surrounding cities of Orem, Provo, Logan, and others may also be considered as host cities for the project, depending upon the location of existing fuel dispensing infrastructure, or where new methanol gasoline blend fueling facilities would be established.

[67] "Industry" officially became the State Motto on March 4, I959. "Industry is associated with the symbol of the beehive. The early pioneers had few material resources at their disposal and therefore had to rely on their own "industry" to survive.

Because Salt Lake City and the other cities are surrounded by the Wasatch Mountains, the air quality in the basin needs improvement even as the population increases. The use of a methanol gasoline blend can have positive environmental benefits such as the reduction of NOx, particulate matter (PM), reduced GHG emissions, and reduced air toxics from gasoline evaporation and combustion. In addition, methanol can be less hazardous (spills and fires) than gasoline fuels in common use today.

Establishing the methanol gasoline blend project in Utah, and in and around the capital of Salt Lake City, with its short distances to other cities and a very good highway system linking all the cities, is therefore an excellent choice, and quite suitable for the effort.

5.3 Elements for the Methanol Gasoline Pilot Demonstration Project

The elements for planning of the methanol gasoline blend Pilot Demonstration are those aspects that will require particular focus and effort, and that are critical to its success. Each will have to be addressed and planned individually and in depth, and then integrated into a cohesive Pilot Demonstration Plan. Those elements are listed below as a sort of 'checklist', and are followed by a description of each one. It may be that the best approach involves a phased strategy in each of these elements, and these possible phases are also described.

- Selecting which vehicles to demonstrate, and recruitment of public and private fleets
- Defining the methanol gasoline blend to be demonstrated, and securing ample supply
- Determining the number and locations of fueling stations to be established
- Seek necessary permission from regulatory agencies with jurisdiction

5.3.1 Selecting Vehicles and Recruitment of Fleets

Phase 1: Prior to establishing the methanol gasoline Pilot Demonstration, initial testing needs to be performed on several existing/new FFVs. We would suggest that at least one if not two FFVs from each domestic automaker be selected. Selection would be based on technical conversions with the automakers. This first phase is necessary to determine any emissions or driveability issues with methanol gasoline blends. Testing to determine the vehicle's compatibility with the fuel, and its operability on the fuel will be necessary prior to advancing to Phase 2—the methanol gasoline blend Pilot Demonstration.

Phase 2: The methanol gasoline blend Pilot Demonstration in existing FFVs will require the participation of fleets or individuals with FFVs of varying manufacturer and model years, for adequate breadth and depth of the demonstration, and to determine if the fuel is useful and acceptable across a range of FFVs in the existing fleet. Due to the requirements of the Energy Policy Act of 1992 (EPACT), federal and state government fleets have been required to purchase alternative fuel vehicles (AFVs) for up to 90% of all new vehicles purchased in each budget year. Therefore, it is likely that a large number of FFVs currently exist in the federal and state fleets in Utah, and estimates of state FFVs ranging from 600-800, bears this out. While the exact number of federal FFVs in the Utah and Salt Lake City are unknown at this time, it is reasonable to assume that several hundred are located in this region. FFVs are likely to exist in city, county and municipality fleets as well, though they are not subject to the requirements of EPACT.

Lastly, there are no doubt FFVs in private fleets, and some operated by private citizens, but these vehicles may not be as likely candidates for recruitment to the methanol gasoline blend demonstration, if past experience is a good indicator.

Recruiting the federal and state fleets for such a demonstration is likely to have positive results, as federal and state governments have energy and environmental policies that are consistent with the need to reduce petroleum, criteria emissions, GHG emissions—all potential benefits from the use of methanol gasoline blend. Additionally, the FFVs in those fleets are currently more likely to use gasoline in those vehicles than E85, mostly due to the few number of E85 stations in the area, and the higher cost of E85 even as compared to high gasoline prices, on an energy equivalent (cents-per-mile) cost basis.

In this phase the key objective is to demonstrate the viability of methanol gasoline blends and, therefore, we suggest the fleet size be increased from the 6 to 10 vehicles in Phase 1 to at least 100 FFVs. This scale is needed to get a cross section of vehicle manufacturers and model years and to demonstrate blend production and distribution. It is important that these vehicles remain in normal service to the fleets, continue to accumulate high mileage, and have the capability to be monitored and/or tested throughout the demonstration term. Ideally, the vehicle maintenance and service personnel of these operating fleets have had the certified warranty service training to be dealer or OEM—approved warranty service providers—to support the FFVs with remaining warranty coverage.

Once recruited for the demonstration, all the participating fleet operators (and if possible the drivers) should be provided a standard orientation training including safety, fueling and maintenance recordkeeping, how to respond to a vehicle or equipment malfunction, provision of an 800# hotline for questions and reporting, and attendance at regularly scheduled Demonstration Status Meetings throughout the project term. It is quite likely that various fleets—federal, state, and local—will be willing to participate in the demonstration if the benefits of using methanol gasoline blend (energy, economic and environmental) in their fleet are properly represented.

5.3.2 Defining the methanol gasoline blend, and securing supply

As previously described, methanol's RVP increases to unacceptable levels when added to typical gasoline, and so the gasoline blend stock must have a lower RVP than gasoline used to blend ethanol. Also, methanol gasoline phase separation is a potential issue that needs to be investigated especially for wintertime temperatures in Utah.

Phase 1: Laboratory testing of fuel methanol with varying types of gasoline mixtures and additives is necessary to be sure that the RVP of the methanol gasoline blend is within required limits for winter- and summertime conditions. Initially this can be accomplished with small, drum volumes of methanol blended with samples of low RVP gasoline components. Any co-solvents also need to be investigated for mitigating corrosion and phase separation. The output of this work will be a fuel specification for the Phase 1 vehicle testing. Fuel supplies will be procured based on this specification.

Phase 2: For the methanol gasoline blend Pilot Demonstration, ample supplies of fuel methanol and the selected low-RVP gasoline blend stock must be secured, blended and stored to the fuel specification developed in Phase 1. This fuel then can be distributed to fueling stations established for the Pilot Demonstration.

There appear to be several companies in the Salt Lake City area that can store and distribute fuel methanol, the requisite gasoline blend stock, and the finished methanol gasoline blend to established or retrofitted methanol gasoline blend fueling stations. Once these facilities are secured, ample supplies can be blended and distributed to the fuel stations for the Pilot Demonstration.

5.3.3 Fuel Storage and Dispensing Stations

Phase 1: During the initial stage of defining and testing the appropriate methanol gasoline blend, the use of drummed methanol and gasoline supplies can be readily procured. Once this blend is determined, the location and number of necessary fueling stations can be planned and permitted in anticipation of commencing the Pilot Demonstration.

Phase 2: Prior to starting the larger vehicle demonstration, fueling stations must be secured (if existing E85 stations, for example) or designed, permitted and constructed. The fueling stations necessary to support the demonstration of FFVs using methanol gasoline blend will require methanol compatible materials and components (as detailed in Section 3) to assure that the methanol gasoline blend provided to the vehicles is ‘on spec’, and that the fuel is readily available in accordance with the expected range and intended use of the fleet FFVs.

As of this writing, it is not clear whether the state of Utah’s fleet-operated fueling facilities include systems to dispense E85. If there are such E85 facilities in the total count of over 100 state-operated fueling facilities, it is possible that some of those stations could be utilized for the demonstration, after inspection and audit of the equipment and components manifest is performed.

The number of fueling stations needed for this demonstration is highly dependent on the number of vehicles in the demonstration; however, we would like to see at least one public retail outlet and perhaps two, depending on fleet participants’ current fueling practices. The vehicle operators, the vehicle and station locations, existing fueling capability, are all factors to be considered that will determine the necessary fuel coverage for the planned demonstration region.

5.3.4 Seek necessary permission from regulatory agencies with jurisdiction

Phase 1: Utah state DEQ and EPA should be informed of the Phase 1 limited vehicle demonstration. Local fire officials should also be consulted regarding planned fueling for this phase of the project. Although Phase 1 will mostly involve vehicle testing at various facilities road testing will also be performed, so it is important to inform appropriate regulatory agencies.

Phase 2: For the larger scale vehicle demonstration, the project team will need to get EPA approval to perform the demonstration. In the past this has been done with an experimental permit. EPA may limit the number of vehicles under this permit and this will need to be discussed. Ultimately, it will be necessary to request a fuel waiver from EPA to sell methanol gasoline blends. This will require various data on vehicle operation as well as on station performance. EPA will require material compatibility and long-term hardware durability. Both phases of the demonstration project will provide much of these data.

5.4 Cost Estimates

Costs to perform Phase 1 and Phase 2 of the methanol gasoline blend Pilot Demonstration include the following major elements:

- Cost of vehicle procurement and, if needed, cost to retrofit for vehicles, if any;
- Cost of producing the methanol gasoline blend fuel
- Cost of fuel transport, terminal storage, fuel loading and transportation to retail and/or fleet fueling stations;
- Cost of existing station upgrades for methanol gasoline blends utilization;
- Cost of design, permitting, construction and start-up of new methanol gasoline blend stations;
- Cost of vehicle, fuel, and station testing;
- Cost of Pilot Demonstration Project Management and Reporting.

The cost ranges for these items are difficult to determine without knowing the ultimate size of the Pilot Demonstration itself, and that is hard to determine without knowing what entities will participate, and what resources they may contribute for this effort. Therefore, the cost ranges cited below are only estimates at this time and many of these costs may be shared or defrayed by project partners. These estimates can provide a ‘rule of thumb’ for performing Phase 1 and Phase 2 of this demonstration project.

- Needed cost to use and monitor vehicles, if any. We assumed not to exceed amount of \$200 per vehicle per year X 100 FFVs= \$20,000 per year (a stipend to defray extra costs for participating fleets).

- Emissions testing per vehicle are in the range of \$20,000 and upwards of \$50,000 depending on the sophistication of the testing. In Phase 1 at least three vehicles needed to be tested and probably at least two times. Additional testing may be required if recalibration is required or evaporative systems development is needed. All total this would require upwards of ten test or \$500,000 at \$50,000 per test.

- Driveability and fuel economy testing will also be needed. These efforts for both phases of the demonstration are estimated to cost between \$100,000 and \$200,000.

- Cost of fuel, transport, terminal storage, fuel loading and transportation to methanol gasoline blend station locations could be as high as \$10 per gallon in limited quantities. For Phase 1 with six vehicles the fuel requirements for 1 year are about 5,000 gallons ((12000 miles at 15 mpg for 6 vehicles). At \$10 per gallon, the fuel costs are \$50,000. For Phase 2, the costs could be needed to provide fuel incentives to encourage FFVs users to purchase the methanol gasoline blend. This incentive could be as high as 50%

of the price of gasoline or $1.90 per gallon if the costs of the blend are comparable to gasoline (which will depend on methanol and RBOB prices). If this is the case and the demonstration runs for 2 years then the incentive required is $300,000 for 100 vehicles.

- Cost of existing station upgrades for methanol gasoline blend utilization is $20,000-$30,000 per station (assumes minor changes)

- Cost of design, permitting, construction and start-up of new methanol gasoline blend stations is $185,000-$265,000 per station for UST system; $65,000-$85,000 for AST system.

- Cost of Pilot Demonstration Project Management and Reporting at least $200,000 per year.

The cost of such a methanol gasoline blend Pilot Demonstration for both phases, using the minimum of 100 FFVs, and establishing two methanol gasoline blend stations, is estimated to be more than $2.5 million. In addition, there remains the possibility of project participants either defraying some of the expected costs outright, cost-sharing or mitigating some costs by contributing services, equipment, fuel, testing and analysis, and management and reporting services to the Pilot Demonstration. Due to the market potential of this methanol gasoline blend Pilot Demonstration, public agency (federal, state and local) funding and cost sharing, and private financing or cost sharing, should be actively sought. The value of public-private partnerships necessary for this methanol gasoline blend Pilot Demonstration cannot be over-stated. While both public and private funding and resources are essential for the effort, it is the combination of skills, wills, and abilities of the committed team participants that will achieve expected results, and best assure success of the demonstration.

6. Longer Term Policy Options

This section discusses policy options that would encourage the use of methanol gasoline blends to reduce petroleum consumption and to lower the impact of vehicle emissions. Currently several policies reduce petroleum consumption including CAFE and EPA's RFS program and both these programs are very effective for new vehicles. However, most of the fuel consumption comes from the existing fleet, which is made up of a small portion of new vehicles and a larger portion of older vehicles. To significantly reduce petroleum use over the entire fleet, new and existing vehicles need to be included. Methanol gasoline blends could work well in the fleet of existing FFVs, estimated to be 12 million, and could potentially also be feasible with gasoline technology vehicles with modifications.

This section reviews policy options used in the past and discuss how applicable these options may be for methanol gasoline blends.

6.1 Policy Options

The Congressional Research Service (CRS) recently published a report that summarized Federal programs to incentivize alternative fuels and advanced vehicle technologies.[68] In this report, Cummingham et. al. categorized alternative fuel programs into six categories:

1. Expand ethanol production
2. Establishing other new alternative fuels
3. Encourage the purchase of non-petroleum vehicles
4. Reducing fuel consumption and GHG emissions
5. Supporting U.S. vehicle manufacturing
6. Funding U.S. highways

Ethanol, which is a "homegrown" fuel, has been promoted as an alternative to imported oil and as a strategy to also reduced GHG emissions from the transportation sector. Congress authorized a volumetric ethanol excise tax credit (VEETC) that was implemented by the IRS. VEETC was very successful at moving ethanol from a local farm product to a commodity used in transportation fuels. Small ethanol producers can still get credit under VEETC. R&D funding, as well as vehicle and infrastructure incentives, have supported other alternatives such as compressed natural gas, electric, and hydrogen vehicles.

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[68] Cummingham, Lynn J., Beth A. Roberts, Bill Canis, and Brent D. Yacobucci, "Alternative Fuel and Advanced Vehicle Technology Incentives: A Summary of Federal Programs," Congressional Research Service, R42566, June 12, 2012.

The purchase of non-petroleum vehicles has been supported by incentives to the vehicle manufactures (CAFE credits) and through tax incentives to consumers. Tax credits and rebates are used to encourage particularly early technology adopters to purchase advanced vehicles including CNG, hybrids, plug in hybrids, battery electric, and hydrogen vehicles. Congress also made available tax credits to encourage fueling stations to support these vehicles.

Reducing fuel consumption, and most recently GHG emissions, falls within the jurisdiction of the Department of Transportation (DOT) and the U.S. EPA. DOT through its National Highway Traffic Safety Administration (NHTSA), sets CAFE standards for light, medium and now heavy-duty vehicles. These standards are coordinated with EPA, which set corresponding standards for GHG emissions from these vehicles. These standards mandate that the auto- and truck makers achieve levels of standards that will substantially reduce the use of petroleum and GHG emissions. Other programs include EPA's Diesel Emissions Reduction Program (DERP), which provides incentives to reduce particulate matter emissions by modernizing technology either by newer vehicles or retrofitting vehicles. A somewhat similar program is administered by DOT to implement programs that reduce congestion and air quality—Congestion Mitigation and Air Quality (CMAQ) program. Recently, the Transportation Bill—MAP-21—was passed allocating new funding for this and similar programs.

The Department of Energy has supported R&D for light and heavy-duty vehicles for many years. More recently DOE has included grants to build lithium-ion battery manufacturing plants. DOE has also developed the Advanced Technology Vehicles Manufacturing (ATVM) loan program to support manufacturing plant investments that will enable developing technologies to reduce fuel consumption.

Federal excise taxes on fuels are used to support the nation's highway network. At times, federal excise taxes were determined base on energy content of the alternative fuel as an incentive to promoting these fuels. Today most alternative fuels pay the same excise tax as the conventional petroleum fuels. With the exception of electricity, which is currently not taxed, most alternative fuels are taxed more on an energy basis than petroleum, and this is a disincentive for the alternatives.

Table 12 summarizes the various programs implemented by the Internal Revenue Service to promote the purchase of alternative fuel vehicles and the production and distribution of alternative fuels. As shown tax credits of varying amounts were used in these programs to incentivize consumers to purchase vehicles. There are several on-going programs including incentives for plug-in hybrid electric vehicles (PHEVs) and for fuel cell vehicles (FCVs). Similarly, tax credits for offering for sale ethanol, biodiesel, and renewable diesel have all expired (these incentives were re-instituted in late December 2012; retroactively to 1/1/12 through 12/31/13). Of these the volumetric ethanol excise tax credit (VEETC) was by far the largest of all the programs with over $6 billion in foregone tax receipts. Cellulosic biodiesel credits are set to expire at the end of this year (extended as above).. Tax credits to encourage industry to build fueling stations were also implemented by the IRS. These programs included credits for homeowners to install alternative fueling for natural gas or electricity as well as for industry to install stations for CNG, LPG, hydrogen, electricity, E85, and biodiesel blends (20%). These too have expired (except for hydrogen), as have most of the producer credits. Here again, cellulosic credits remain but these are set to expire at the end of 2012 (also extended).

Table 12. IRS Programs to Promote the Use of Alternative Fuels (source: CRS R42566, June 2012)

Expiration Date	Program	Brief Description	Alternative Fuels
NA	Motor Fuels Excise Taxes	Tax on the volume sale of motor fuels. Funding to Highway Trust Account	All fuels pay except electricity
12/31/11	Credit for Blending	Credit for blending ethanol and biodiesel in conventional gasoline and diesel fuels	Ethanol in gasoline; biodiesel in diesel
12/31/10 & 12/31/14 FCVs only	Alt Motor Vehicle Credit	Credit for fuel cell, advanced lean burn, qualified hybrid, or qualified alternative fuels technologies	CNG, LNG, LPG, hydrogen, 85% methanol
Vol, previous 12/31/11	Plug-in EVs Credit	Tax credit of up to $7,500 depending on battery capacity; was previously $2,500	Up to 200,000 PHEVs
12/31/11	Conversion Kits	Credit up to $4,000 for converting to PHEV	PHEV
12/31/11 & 12/31/14 H2 only	Alt Fuel Refueling Property Credit	Covers home refueling as well as retail station development for alternative fuels including higher credits for hydrogen	CNG, LNG, LPG, hydrogen, electricity, E85, 20% biodiesel blends
12/31/11	Volumetric Ethanol Excise Tax Credit	Provided gasoline suppliers a tax credit for blending in ethanol of $0.45 per gallon of ethanol	Gasoline ethanol blends
12/31/11	Small Ethanol Producer Credit	Provides credit of up to $0.10 per gallon of ethanol on first 15 million gallons for producers producing less than 60 million gallons per year	Ethanol
12/31/11	Biodiesel Tax Credit	Provided tax credit of $1.00 per gallon for biodiesel fuels	Biodiesel
12/31/11	Small Agri-Biodiesel Producer Credit	An Agri biodiesel producer tax credit of $0.10 per gallon of biodiesel up to 15 million gallons for producers producing less than 60 million gallons per year	Biodiesel
12/31/11	Renewable Diesel Tax Credit	Tax credit of $1.00 per gallon of renewable diesel	Renewable diesel
12/31/12	Cellulosic Biofuel Credit	Tax credit of $1.01 per gallon of cellulosic biofuels to producers. Credit reduced by VEETC or small producer credits	Cellulosic Biofuels
12/31/12	Special Depreciation Allowance Cellulosic Plants	Cellulosic plants can take 50% depreciation in first year	Cellulosic Biofuels

The IRS tax incentive programs were needed to move the various alternative fuels into the market place. Some incentives worked by getting early adopters to purchase the technology, and as volume increased and prices dropped, incentives where no longer needed. A good example of this is the market acceptance of hybrid electric vehicles. Experience with other alternatives has been less successful. Biodiesel for example was competitive with conventional diesel provided the tax credit was in place, but once the credit was removed most producers were not in a position to compete with diesel prices, even at high diesel prices.

Other federal agencies have used both incentives and mandates to get industry to provide alternative fuels or more advanced technology vehicles. DOT has, since the first energy policy act, had the authority to regulate the fuel economy of light duty passenger vehicles and trucks. The Corporate Average Fuel Economy (CAFE) was first implemented in 1975 and continues today. This program mandates or regulates auto manufacturers to meet fuel economy standards for the entire fleet of vehicles they sell. Congress further authorized DOT to set fuel economy standards for medium and heavy-duty trucks. These regulations were implemented in 2011 for MY 2014 to 2017 trucks.

To encourage the use of alternative fuels the light duty CAFE regulations included an incentive for electric vehicles originally that determined an equivalent mpg with electricity use. Other alternatives were later added with the Alternative Fuel Motor Vehicle Act (AMFA) of 1989. This legislation created credits for fuel flexible vehicles in part due the California Methanol Program and the desire of automakers to provide these vehicles to California. When California's interest in methanol waned, the automakers continued to make FFVs but focused on E85 vehicles only instead of both M85 and E85 FFVs. The CAFE credits have been very successful with over 12 million FFVs currently operating in the U.S.

The Open Fuel Standard Act (HR1687, 2011) is a variation the AFMA credits that would require the automakers to make 95% of their vehicles alternative-fueled by 2017. Alternative fuel includes dedicated vehicles operating on natural gas, hydrogen, or biodiesel or FFVs operating on gasoline, E85, or M85, and fuel cell vehicles. Hearings on this act where held in July 2012. The Alliance of Automobile Manufacturers testified at this hearing, as did others.[69] The Alliance testified that FFVs would be the low costs option to meet the regulations, but that the costs of producing a trifuel FFV that includes M85 would be too expensive. In short, the Alliance does not agree that vehicle mandates will achieve the goal of reducing our dependence on petroleum. Even thought they have produced millions of E85 FFVs, the average amount of E85 used in these vehicles is only10 gallons per year.

Other examples of mandates are those developed by the U.S. EPA and CARB to regulate motor vehicle emissions. Regulations from these agencies control vehicle emissions and also regulate fuels. Vehicle emission regulations include criteria pollutants—HC, CO, NOx and PM, but also toxic emissions like formaldehyde. Fuel regulations for gasoline include RVP, and benzene and sulfur content. EPA and CARB have also set GHG regulations for vehicles. EPA's Renewable Fuel Standard (RFS) is another example of mandating the use of renewable alternative fuels with some flexibility given to fuel suppliers for compliance. The last light-duty fuel economy and GHG regulation development was a cooperative effort between EPA, DOT, and CARB.

Local air quality agencies also have authority to regulate stationary emission sources and government fleets. DOE also developed alternative fuel vehicle regulations as part of the Energy Policy Act of 1992. Fuel suppliers and government fleets (federal, state, and local) were required to purchase alternative fuel vehicles at increasing percentages over time.

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[69] Energy and Commerce Committee, U.S. House of Representatives, "The American Energy Initiative: A Focus on Alternative Fuels and Vehicles, Both Challenges and the Opportunities," Preliminary Hearing Transcript, HIF192.030, July 10, 2012

Table 13 summarizes various policy options discussed. Market based incentives, coupled with performance based regulations, have been the most successful at moving more advanced technology into the market place. Mandates picking a "winner" technology have not always provided a technology that had success in the market place. Providing industry with performance standards to meet but not mandating the technologies to meet these standards, gives industry a chance to use their expertise to bring the most cost effective alternatives to the market place. This works well if the regulated industry is the only stakeholder affected, but gets more difficult if the regulation requires the cooperation of many stakeholders—from fuel producers to vehicle manufacturers. Unfortunately, this cooperation is what is needed to meet the combined goals of lowering criteria and GHG emissions and decreasing petroleum use.

Table 13. Summary of Policy Instruments Use to Encourage Alternative Fuels

Policy Instrument	Regulation Examples	Comment
Mandates	RFS requires blending of ethanol in gasoline	Poor past performance by government in picking the most efficient technology pathways
Mandates-performance based	Tailpipe criteria emissions Cap and trade SO_2 regulation	Extremely effective in reducing emissions. Health-based standards help to justify reductions.
Pricing controls	Vehicle and fuel taxes	May be the most effective market signals
Market-based incentives	AFV tax credits and alternative fuel tax credits	Have helped to move alternative fuels into marketplace but do not directly address either lowering emissions or foreign oil consumption
Combinations of above	SCAQMD fleet rules, coupled with incentives	Requires AFVs but helps with added cost of technology

6.2 Policies for Methanol Gasoline Blends

Methanol gasoline blends already have the vehicle incentives in place with credits for FFVs. This assumes that the blends are limited to matching the combustion properties of E85, little or no material changes are required, and emissions systems do not need to be modified. Phase 1 of the demonstration project will determine the needed vehicle changes that will be required for methanol gasoline blends. However, the costs of these changes are not expected to be overwhelming. Nevertheless, if costs increase then it is reasonable to suggest that additional incentives will be needed either for the automakers or for the consumers. Lower fuel prices (on an energy basis) may be sufficient to get consumers to retrofit their FFVs or to pay more for a newer FFV capable of using methanol gasoline blends.

The situation regarding the production and distribution of the methanol gasoline blends is more complicated. At least initially, gasoline suppliers will have to purchase methanol from chemical companies and the chemical market and not the transportation fuels market will, therefore, influence methanol's price. If methanol gasoline blends are successful, then those energy companies with large domestic sources of natural gas may supply methanol. This would decouple the chemical and fuels market (the fuel specification may also be different for the fuels market). It would seem logical to think that this market would develop if oil supplies in the U.S. were short or constrained. However, current projections are that petroleum supplies in the U.S. will increase and not be constrained. The question then arises: Why would gasoline suppliers want to displace petroleum with methanol?

One reason might be the market, which demands a lower cost liquid transportation fuel. However, it is difficult to see any of the current gasoline producers motivated to displace gasoline, especially when faced with newer fuel economy standards, which will actually decrease demand for gasoline in the near future.

That being the case, and if the U.S. is serious about further reducing the demand for petroleum fuels in the transportation market, then we believe there will need to be some regulation to accomplish this. This was similar to the debate that occurred with methanol in the California Program where it was determined that there was an air quality benefit of using methanol but the fuels industry had no incentive to displace gasoline with methanol. The consensus then was to provide incentives to the automakers to produce vehicles capable of using methanol and then to develop a regulation to encourage fuel suppliers to provide methanol. This later regulation was never implemented, although CARB had a provision to require the fuels industry to provide methanol for sale if the number of vehicles in California exceed 20,000 – this was referred to as the Clean Fuels Outlets— "fuel trigger." This fuel regulation was not needed due the improvements made in gasoline and vehicle emission equipment, but remains in place.

A similar regulation could be developed for reducing petroleum use in the transportation market. EPA could expand the current RFS program to include any fuels (not just ethanol or other renewables) that displace petroleum. EPA could set a performance standard that the fuels industry would have to meet. Presumably industry would develop the most cost effective way of achieving this standard while not compromising progress on ever increasing vehicle efficiency. In California, this concept was called "fuel pool averaging" where fuel suppliers would have to include ever-increasing amounts of methanol or other alternative fuels into their overall California fuel sales.

More research is needed to explore the need and possible structure of policies to encourage petroleum reduction, and to integrate the needs for displacing petroleum with the needs of reducing criteria and GHG emission for the complete fuel cycle from production to end use.

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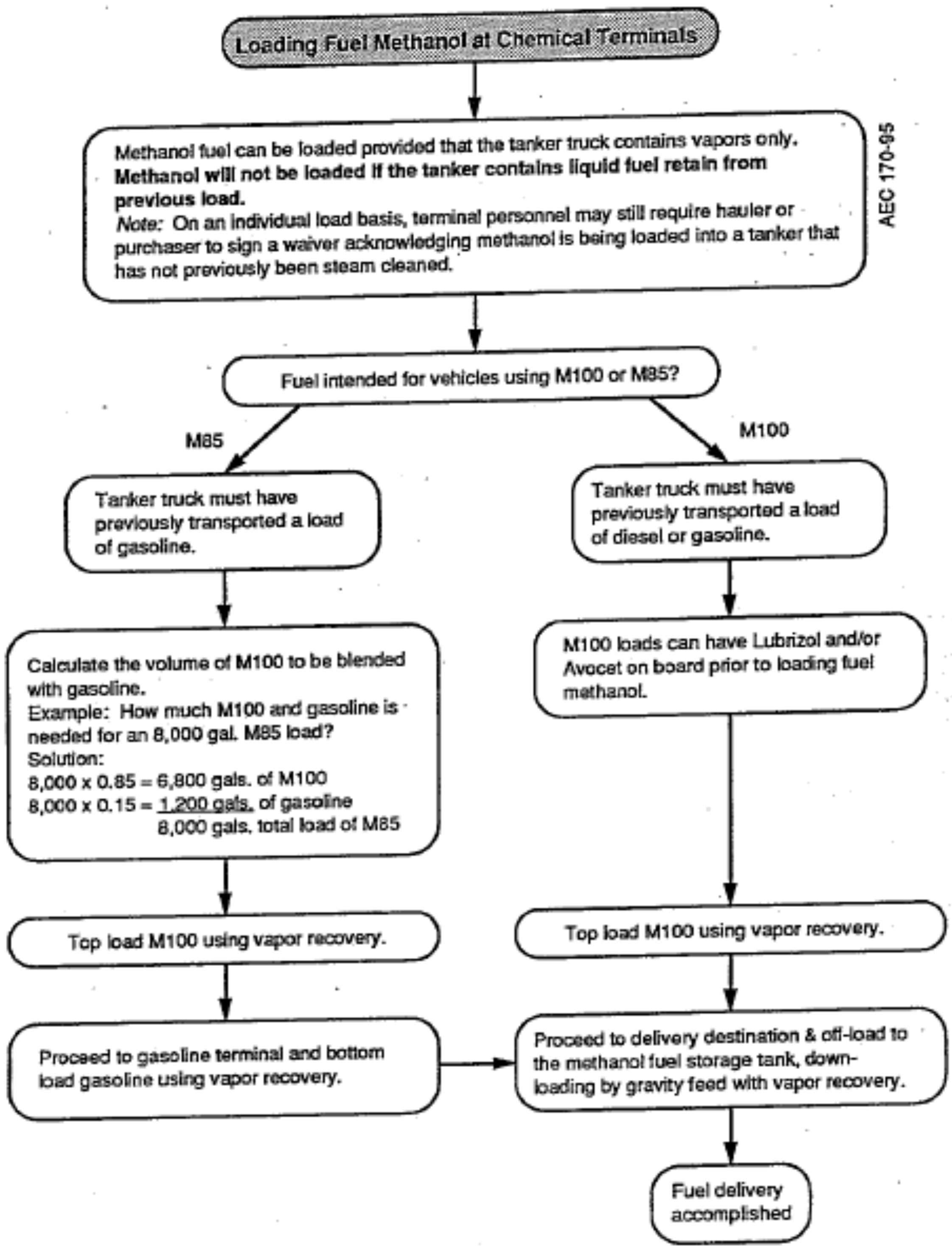
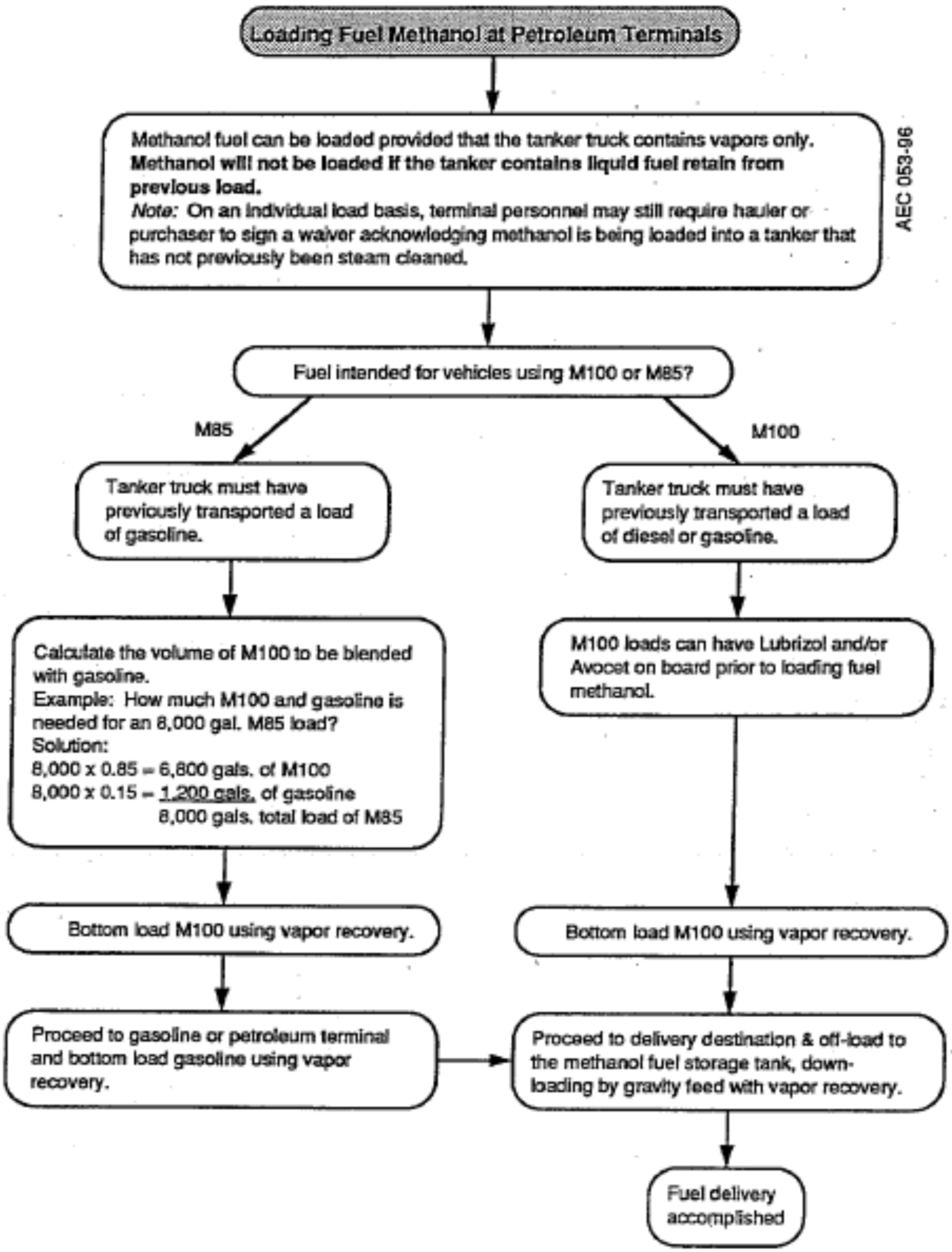
Appendices

Appendix 1-A: Methanol Loading at Chemical Terminals



Appendix 1-B: Methanol Loading at Petroleum Terminals



Appendix 2-A: Equipment List for M85 Dispensing Systems

I. Recommended Parts List for M85 Dispensing Systems with Aboveground Tank (Revised 11-15-95):

General Features:
M85 Aboveground Storage Tank
Stage II Vapor Recovery
Suction or Submersible Pump

1. Tank Construction:
   Aboveground storage tank and piping
   Inner wall - Low carbon cold finish steel
   Butt welded and ground smooth
   suction pump for 2,000 gallon tanks
   Optional Submersible turbine pump for tanks 4,000 gallons and up

   Manufacturers: Convault
   Envirovault
   Hallmark
   Trusco
   Modern Welding
   Hoover (Lube Cube)

2. Dispenser:
   - Tokheim Model No. 7552 electro-mechanical suction pump dispenser (modified for methanol) with No. 898 piston meter for commercial applications
   - Gasboy Model No. 9152 electro-mechanical dispenser (modified for methanol) with 1/2-hp intermittent suction pump for commercial applications
   - Gasboy Model No. 9153 electro-mechanical dispenser (modified for methanol) with 3/4-hp continuous suction pump for commercial applications
   - Tokheim Model No. 8753E electro-mechanical dispenser (modified for methanol) for retail applications. (This replaces the Tokheim 1250 ASRCAPCM
   - Tokheim Model No. 262-A-1-RC electronic dispenser modified for methanol for retail applications. Note: Tokheim coaxial adapter must be nickel plated
   - Gasboy Model No. 9122 electro-mechanical dispenser (modified for methanol) with 1/2-hp intermittent suction pump for commercial applications
   - Gasboy Model No. 9822 electro-mechanical dispenser (modified for methanol) with 1/2-hp intermittent suction pump for commercial applications

3. Dispenser Leak Detector:
   - Red Jacket XLP Piston Leak Detector Model 116-035
   - Red Jacket Model FX1 Leak Detector
   - Tokheim Model 585A-PM

4. Interconnect/Control Box:
   - Red Jacket Model No. 880-029
   - Tokheim Model 67-8
   - Tokheim Model 168-1

5. <u>Suction Pipe:</u>
   - Black Iron

6. <u>Splitter Fitting:</u>
   - OPW 38C-0492 or 38CS-0492 electroless nickel plated coaxial splitter
   - Emco Wheaton A4041-003 electroless nickel plated coaxial splitter for vertical vapor piping
   - Emco Wheaton A4041-004 electroless nickel plated coaxial splitter for horizontal vapor piping

7. <u>Dispenser Hose:</u>
   Goodyear premier coaxial Nylon 11 M85 vapor recovery hose (Blue outer with nylon veneer inner hose)

   Note: This hose is being utilized by the Energy Commission Retail Network, and presently is not commercially available.

8. <u>Nozzle:</u>
   OPW 11VF-0492 electroless nickel plated coaxial nozzle with Stage II vapor recovery
   Emco Wheaton A4005-135 electroless nickel plated coaxial nozzle with Stage II vapor recovery

9. <u>Breakaway:</u>
   OPW 66CL-0492 electroless nickel plated breakaway

10. <u>Dispenser Filter Adapter:</u>
    Cim-tek Model No. 50017 electroless nickel plated filter adapter

11. <u>Dispenser Filter:</u>
    Cim-tek Model No. 70025 one micron microglass spin-on filter

12. <u>Top Seal Adapter:</u>
    OPW 633TT-8076 made of bronze

13. <u>Top Seal Cap:</u>
    OPW 634TT-7085

14. <u>Overfill Prevention Valve and Fill Drop Tube:</u>
    - OPW 61FSTOP-100M modified to include 0.002-in thickness and a methanol-compatible float. Float must retain 90-100% of original density and integrity after soaking in M85/M100.

    - Clay & Bailey Model F30 prevention valve, and Model 01228-03-5048 4-in fill drop tube.
      Note: Must specify nickel plating for M85.

15. Vapor Vent:
OPW 523 or 523S pressure vacuum vent

16. Emergency Vapor Vent:
OPW Model No. 202

17. Coaxial Hose Return Line:
Black Iron Pipe

18: Interstitial Leak Detection Tube:
Supplied with Tank

19. Environmental Monitoring System:
Red Jacket Environmental Monitoring System
- PPM 2000-232- 4 Channel Probe Monitor with RS232 Communications Port
- RE400-180-5 Liquid Refraction Sensor to monitor interstitial areas and sumps
- PPM3100 Relay Cabinet for pump control, Model No. RE400-007-5. Shuts off pump if a leak is detected.

API/Ronan Environmental Monitoring System
- X76S Leak Detection System
- LS-3 Vertical Level Sensor
- HVA Vertical Liquid Sensor for Riser Applications
- LS-7 Annulus Sensor
- JT-2 Tank Leak Sensor

20. Spill Containment Pan with Lid & Drain:
Normally supplied integral with tank. If added, use EBW 706-400-01.

21. Level Monitoring Gauge:
- Steil safety gauge, Model No. E92, UL listed for M85
- Morrision Model 818 or 918

22. Solenoid Valve:
Morrison 710 1 1/2-in viton solenoid valve

23. Pressure Regulating Valve:
Tokheim Model 52

Note: Tokheim Model 52 pressure regulating valve to be used with both full size and compact suction pump dispensers. If the compact dispenser is placed on top of the aboveground tank, the 52 pressure regulating valve is not required.

When ordering the Tokheim Model 52 pressure regulating valve, it is imperative that the diaphragm, Part No. 227696, be constructed of GFLT Compound #DE60161 Polyester Fabric, not Dupont Hytrel #5556.

II. Recommended Parts List for M85 Dispensing Stations with Underground Tanks (Revised 11-15-95):

General Features:
M85 Underground Storage Tank
Stage II Vapor Recovery
Submersible Pump

1. Tank Construction:
   - Double-wall, low carbon cold finish steel, butt welded and ground smooth
   - Double-wall composite steel with fiberglass reinforced plastic secondary containment
   - Double-wall methanol-compatible fiberglass

2. Piping:
   - Primary piping: Schedule 40 black iron piping
   - Secondary piping: Total containment made of polyethylene with clamp seals which use flat gaskets
   - Ameron or AO Smith Red Thread IIA primary and/or secondary non metallic fiberglass underground piping

3. Pipe Sealant/Adhesives:
   - Ameron pipe adhesive kit, Model No. 820LT, and Model No. RP48A, UL listed for alcohol blend use
   - AO Smith 8000 series pipe adhesive kit

4. Flex Connectors:
   - Stainless steel flex connectors w/swiveling end fittings for product lines
   - Corrosion protected flex connectors w/swiveling end for vent and stage II vapor return line.

5. Fill Adapter:
   - OPW 633T-8076 4-in bronze fill adapter

6. Spill Container:
   - Fairfield Industries SCM-5 4-in diameter stainless steel threaded onto fill pipe

7. Fill Tube with Overfill Protection:
   - OPW 61SOM-4BYT

     Note: The bottom portion of the fill tube should be supplied by the installation contractor, and constructed of methanol-compatible fiberglass.
   - EBW polyethylene dura tube 782-207-02

8. Vapor Recovery Adapter:
   - OPW 1611AVB made of bronze

9. Top Seal Cap:
   - OPW 634TT-7085 made of duratuff

10. Tank Manhole:
    - Standard petroleum manhole is acceptable

11. Vapor Vent:
    - OPW 523, or 523S

12. Vapor Cap:
    - OPW 1711T

13. Pressure/Vacuum Vent:
    - OPW 523LPS-2253 2-in vacuum vent

13. Extractor Fitting:
    - OPW 233VM-4422

14. Ball Float Valve:
    - OPW 53VML-0180

15. Submersible Turbine Pumps:
    - Marley Red Jacket 3/4-hp or 1 1/2-hp submersible turbine pumps, Models AGP75S1 and AGP150S1
    - FE Petro Model No. 585-13 1/3-hp submersible turbine pump modified for methanol

16. Emergency Shut Off Valve:
    - OPW10 RUPM-0492 for Tokheim Model 7552 dispensers

17. Dispenser:
    - Tokheim Model No. 8753 EX electro-mechanical dispenser modified for methanol (Retail applications); this replaces the Tokheim 1250 ASRCAPCM
    - Tokheim Model No. 262-A-1-RC electronic dispenser modified for methanol (Retail applications)
    - Tokheim Model No. 7552 electro-mechanical dispenser modified for methanol (Commercial applications)
    - Gasboy Model No. 9152X electro-mechanical dispenser modified for methanol (Commercial Applications)
    - Gasboy Model No. 9153X electro-mechanical dispenser modified for methanol (Commercial applications)
    - Wayne-Dresser Vista Duo Model AL/V387D1 electronic single product dispenser modified for methanol (Retail applications)

    Note: All listed dispensers are remote and use submerged turbine pumps.

18. Dispenser Leak Detector:
    - Red Jacket leak detector, Model FX-1
    - Red Jacket leak detector Model FX-2 with snap tap connection (Site does not require down time to complete leak detection test)
    - Tokheim Model No.585A-PM leak detector

19. Interconnect/Control Box:
    - Marley/Red Jacket Model No. 880-029
    - Tokheim Model No. 67-8 Interconnect box
    - Tokheim Model No. 168-1 Relay box

20. Dispenser Filter:
    - Cim-tek one micron microglass spin-on filter, Model No. 70025

21. Dispenser Adapter:
    - Cim-tek nickel plated filter adapter, Model No. 50017

22. Hose Breakaway:
    - OPW 66CL-0492 (electroless nickel plated)

23. Dispenser Hose:
    - Goodyear premier coaxial Nylon 11 M85 hose. (Blue outer hose with nylon veneer inner hose)

24. Swivel:
    - OPW 45M-0492

25. Nozzle:
    - Emco Wheaton A4005-135 electroless nickel plated coaxial vapor recovery nozzle
    - OPW 11VF-4092 electroless nickel plated coaxial vapor recovery nozzle

26. Jumper Hose:
    - Goodyear cross link polyethylene ¾-in XLPE fabchem hose with MxM stainless steel roster fittings

27. Splitter Fitting:
    - OPW 38CS-0492 nickel plated coaxial splitter
    - Emco Wheaton A4041-003 electroless nickel plated coaxial splitter with vertical vapor piping
    - Emco Wheaton A4041-004 electroless nickel plated coaxial splitter for horizontal vapor piping
    - Emco Wheaton A4042-001 electroless nickel plated coaxial splitter for high hose mount

28. Flame Arresters:
    - Protectoseal in-line flame arrester, ductile housing, Model No. CF4951F, 316 stainl steel internal grids, 1-in 150# flanged connections
    - Protectoseal in-line flame arrester, ductile housing, Model No. CF4952F, 316 stainl steel internal grids, 2-1n 150# ANSI flanged connections

29. Manhole Covers:
    - Manhole covers do not contact fuel. Standard petroleum manhole covers are acceptabl

30. Tank Level Gauges:
    - Steil safety gauge, Model No. C89-LCT-M85, UL listed for M85

31. Environmental Monitoring Systems:

    Ronan Engineering
    - Leak Detection System, Model No. X76LVC
    - Electronic tank monitor, Model No. X76ETM
    - Vertical liquid sensor, Model No. LS-3 (SS)
    - Horizontal liquid sensor, Model No. LS-7
    - Relay Module, Model No. KV-700
    - Pipe pressure sensor, Model No. JT-H2
    - Stainless steel level monitoring probe, Model No. 951-402B (SS)

    Marley/Red Jacket
    - RLM 9000 monitoring system
    - Tank inventory/leak detection monitor
    - Line pressure monitor
    - 4100 relay cabinet for pump control
    - RS232 Communication ports and built-in printer
    - Line pressure kit, Model No. 400-012
    - 8-ft inventory sensor with 4-in float kit, Model No. RE400-098-5

Appendix 2-B: Methanol Blend Compatible Equipment Listing

Appendix 2-B: Methanol Blend Compatible Equipment Listing

(Changes noted from E85 'Proxy' system)*

QTY	DESCRIPTION	PART NO.
1	MODERN WELDING 10M GAL GLASTEEL II DOUBLE WALL JACKETED UST, TANK MOUNTED FITTINGS AND (2143" DOUBLE WALL AC COLLARS PER CURRENT A52481 REGULATIONS	OLASTEELSOW
2	Bravo Systems HYDROSTATIC TANK SUMP SYSTEM	BR0.13420x32.38T OBAAW
	42' X 34" MUST *Meet* AB2481- Includes Brine and Blinding Kits	
	UST ACCESSORIES & MANHOLES	
1	RED JACKET *AG* 3/4 HP STP *NEW AGEISS/R12	410140020
1	RED JACKET ISOTROL CONTROL BOX W/RELAY	II600471
1	RED JACKET MECHANICAL LEAK DETECTOR-GASOL.	Likosas
1	RED JACKET VAC.GENISYPHDN SYST.CART.W/CV 6	410151D01
1	RED JACKET SIPHON CHECK VALVE	1082415
1	OPW 37' MULTIPORT EVR SYSTEM W/SEALAEILE COVERS	6571.11219a02751052
1	OPW vapor swivel adapter, bronze-bronze	0155.445*
1	OPW fuel swivel adapter low profile, bronze-bronze	61SALP-MA*
1	OPW fuel. top seal cap	63417.7086
1	OPW vapor, top sea{ cap	177111085
2	OPW face seal adaptor	F34-400S
1	*DPW jack* screw *assembly* ***Cast Iron Base***	71EK44MA
I	OPW 2" thread-on Pressure/Vacuum vent	*6231.220
1	4"x 8" nipple (vapor bucket)	3
1	4' x 10' nipple (fill bucket)	415271M
		H12806M
1	OPW x 15' fill drop tube for E-85	6ISOM*
1	OPW 4' x 3" x Extractor fitting	233-4430
1	OPW 3' x12" ball float valve	53VML3120
1	OPW 39" CONQU/STADOR MANHOLE W/ROTO LOKS	39CDTLKL
1	OPW KEY LIFT Stick	SON*LS
2	Flex-log 3' x 18" MxM flex connector	FLYMJLID018L.7[31*
1	EMCO T FULL PORT VALVE	A075-200
1	Gilbarco ENCORE SODS 1-grade 2-hose 2-side MPG dispenser with BuyPass Spec CRIND 5.7" monochrome screen, totalizer per meter. canopy, speaker kit and E-85 product ID panels	CILBARCO ENCORE 5003 DISPENSERS*
1	GILBARCO Universal Distribution Box	PA02610000022
	OISPENSER ACCESSORIES	
2	Goodyear 3/4' x I3'6" Future hose, MXMS	o/Y532327x.O3UBX*
2	Goodyear 3/4' x 12' Future hose. MXMS	6/Y53232M=0304 *
2	OPW 3/4' SWIVEL FOR E-85 AND 510-DIESEL	2417PS-0492
2	OPW 3/4" BREAKAWAY FOR E-85 AND BIO DIESEL	6010492
2	OPW ALTERNATIVE FUEL NOZZLES	110P-0492*
	ISLAND ACCESSOREES	
1	POMECO DOGBCNE 4' x 8' x 13" ISLAND FORM	60134GE30 RaN4L8
ı	Bravo Single product double wall deep fiberglass dispenser sump for Brine	08800000-riL-PO-aa*
2	Bravo frame upgrade for **electrical** offsets	BRAEO.FRM*
1	OPW 11/2' DOUBLE POPPET SHUT OFF VALVE	106.0152-Eas*
2	Flex-log 1-1/2' x 18' MSM flex connector	FLXFF15XI8HMAM*
1	Bravo single product double well vent line containment sump	BRA8500FIS-D-9S*
	Diversified Products Entry fittings-Electrical Conduit	
9	DIVERSIFIED PRODS, 1"-3/4" Dual Side Monitored UL listed	L4MI 4
8	DIVERSIFIED PRODS. Bulkhead Polysulfide J.TW **1002.**	DBF II
2	DIVERSIFIED PRODS. Bulkhead Bonder UL usted 16oz.	mall!
1	DIVERSIFIED PRODS. Methyl Methacrylate	DWAC600
1	DIVERSIFIED PRODS. Gun Rental per day	DWAC600R
	Smith Fittercast Product/Vapor Entry fittings	
4	SMITH FIBERCAST 3" Double Wall Sump Entry w/port	120306260
4	SMITH FIBERCAST x 3' Concentric Reducer	120402363
6	SMITH FIBERCAST Adhesive 7014	26900000*
6	SMITH FIBERCAST Filler	0299-033C
1	TLS 350 SOFTWARE UPGRADE-EXCHANGE	331500306
4	PIPING LIQUID SUMP SENSOR	794360323*
4	SUMP MINI-HYDROSTATIC SENSOR AB2481	794380304
1	INTERSTITIAL SENSOR STEEL TANK 16' CABLE	794366430*
2	&INPUT LIQUID/ANNULAR INTERFACE MODULE	329358001
1	4-INPUT MAGI INTERFACE MODULE	atuses-oo
1	MAO PLUS PROBE	8415391-0.%*
1	MAO INSTALLATION KITS 5'	846391,4=*
1	MORRISON 4" **CAP &** ADAPTER W/CABLE GRIP-BRASS EVR	an sx pAiloaAK
1	MORRISON 2" CAP & ADAPTER W/CABLE GRIP-BRASS EVR	305XPA2200AK
	A62481	
1	4 VACUUM SENSOR KIT FOR STEEL TANK	338020467
1	SMART SENSOR W/EMBEDED PRES.SENSOR MODULE	332250001
I	VACUUM HOSE 26'	332312001
1	4-INPUT PUMP SENSE INTERFACE MODULE	329696001

Appendix 3-A: Cim-Tek Filters

P R E S S R E L E A S E

DATE: JUNE 2008

CONTACT: TODD OBERG
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CIMTEK'S 5 MICRON HIGH ALCOHOL FILTERS FOR E85 EXCLUSIVELY MEET NREL & UL STANDARDS

According to the NREL (National Renewable Energy Laboratory) and Underwriters Laboratories (UL®), Central Illinois Manufacturing Company's (CIM-TEK®) high alcohol filters (Bio-tek®BHA series) meet current requirements for dispenser pumps using Ethanol-blended gasoline up to and including 85%. The NREL encourages all fuel dispenser owners with an interest in establishing E85 fueling systems to engage professional support during installation to ensure fuel integrity and system compatibilty by using a 5 micron filter. Now, station owners will be able to complete their systems with a NREL recomended 5 micron specified fuel filter that currently, is the only UL® recognized (Bio-tek®) filter designed for blends up to E85.

For literature and technical information, call 888.898.7187.
www.cim-tek.com