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By Matthew McCormick, Scott Freifeld, and Lynne Kiesling
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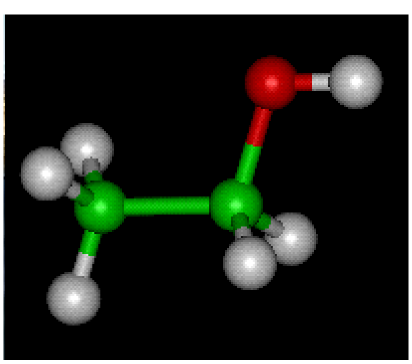

POLICY SUMMARY
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Policy Study No. 315

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Executive Summary

The Clean Air Act Amendments of 1990 require that gasoline used in the United States has additives that oxygenate the fuel. The most common oxygenate was MTBE, which is being phased out due to harmful effects on human health. Both the House and Senate energy bill proposals in 2003 contain a mandate making ethanol the only legal oxygenate for meeting the federal fuel oxygenate requirement. But both versions of the energy bill also abolish the federal oxygenate requirement, but add a requirement to use ethanol as a renewable energy source. Navigating these political waters has been challenging for both politicians and the interests on all sides of the oxygenate debate.

The Environmental Protection Agency formed a Blue Ribbon Panel in 1999 to study the health benefits of fuel oxygenates. The Blue Ribbon Panel report highlighted the fact that the air quality benefits of oxygenated fuel are unclear. The environmental problems caused by MTBE reinforce that concern, but little analysis has addressed the combined air, water and soil effects of ethanol.

The Blue Ribbon Panel recommendation was to eliminate the oxygenate requirement altogether. In this study we perform a benefit-cost analysis of the ethanol mandate as an oxygenate; our findings support the recommendations of the Blue Ribbon Panel. We also analyze the political economy dimensions underlying the success of federal ethanol mandate provisions in both the House and Senate proposals. That success rests on the uncoupling of ethanol as a renewable energy source from ethanol as an oxygenate, a subtle piece of political rhetoric. We conclude that ethanol is not actually a renewable energy source, given the fossil fuel use required to produce ethanol.

We find that whether or not ethanol use generates net positive energy or net negative energy, ethanol-oxygenated reformulated gasoline uses more resources overall and does not pass an

economic or environmental benefit-cost analysis. The fossil fuel energy used in producing and transporting ethanol imposes environmental costs, and whether or not ethanol produces negative net energy, its consumption also leads to costs. These costs outweigh the health benefits of ethanol use. Adding the cost of environmental detriment from agricultural runoff from growing crops for ethanol reinforces this conclusion.

Examining the political dynamics of the success of the ethanol provisions reveals that separating the fuel oxygenate issue from the renewable fuels issue has enabled Congress to satisfy both the strong farm and oil interests in the debate, even when ethanol does not make economic or environmental sense.

Thus although Congress is following the recommendations of the EPA's Blue Ribbon Panel and eliminating the fuel oxygenate requirement, the bait-and-switch of ethanol from oxygenate to renewable fuel has created the opportunity for the ethanol industry to succeed politically, at a cost that is spread across all taxpayers, drivers, and natural resources.

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Part 1

Introduction

The Clean Air Act Amendments of 1990 require that gasoline used in the United States have additives that oxygenate the fuel. The most common oxygenate was MTBE, which is being phased out due to harmful effects on human health. Both the House and Senate energy bill proposals in 2003 contain a mandate making ethanol the only legal oxygenate for meeting the federal fuel oxygenate requirement. But both versions of the energy bill also abolish the federal oxygenate requirement, but add a requirement to use ethanol as a renewable energy source. Navigating these political waters has been challenging for both politicians and the interests on all sides of the oxygenate debate.

The Clean Air Act Amendments of 1990 (CAAA), among other things, established standards for reformulated gasoline in an attempt to address three types of pollutants. The legislation was successful in reducing the levels of all three pollutants. However, in the process, a provision of the bill requiring a minimum oxygen content in reformulated gasoline encouraged the widespread use of methyl tertiary-butyl ether (MTBE), a petroleum-based compound that makes water unpalatable if present even in very small quantities in water supplies.

As a result of health and water potability concerns raised by MTBE leaks, the EPA formed a Blue Ribbon Panel in 1999 to study the health benefits of fuel oxygenates. The Blue Ribbon Panel report highlighted the fact that the air quality benefits of oxygenated fuel are unclear. The environmental problems caused by MTBE reinforce that concern, but little analysis has addressed the combined air, water and soil effects of ethanol.

The Blue Ribbon Panel recommendation was to eliminate the oxygenate requirement altogether. In this study we perform a benefit-cost analysis of the ethanol mandate; our findings support the recommendations of the Blue Ribbon Panel. We also analyze the political economy dimensions underlying the success of federal ethanol mandate provisions in both the House and Senate proposals. That success rests on the uncoupling of ethanol as a renewable energy source from ethanol as an oxygenate, a subtle piece of political rhetoric. We conclude that ethanol is not actually a renewable energy source, given the fossil fuel use required to produce ethanol.

Part 2

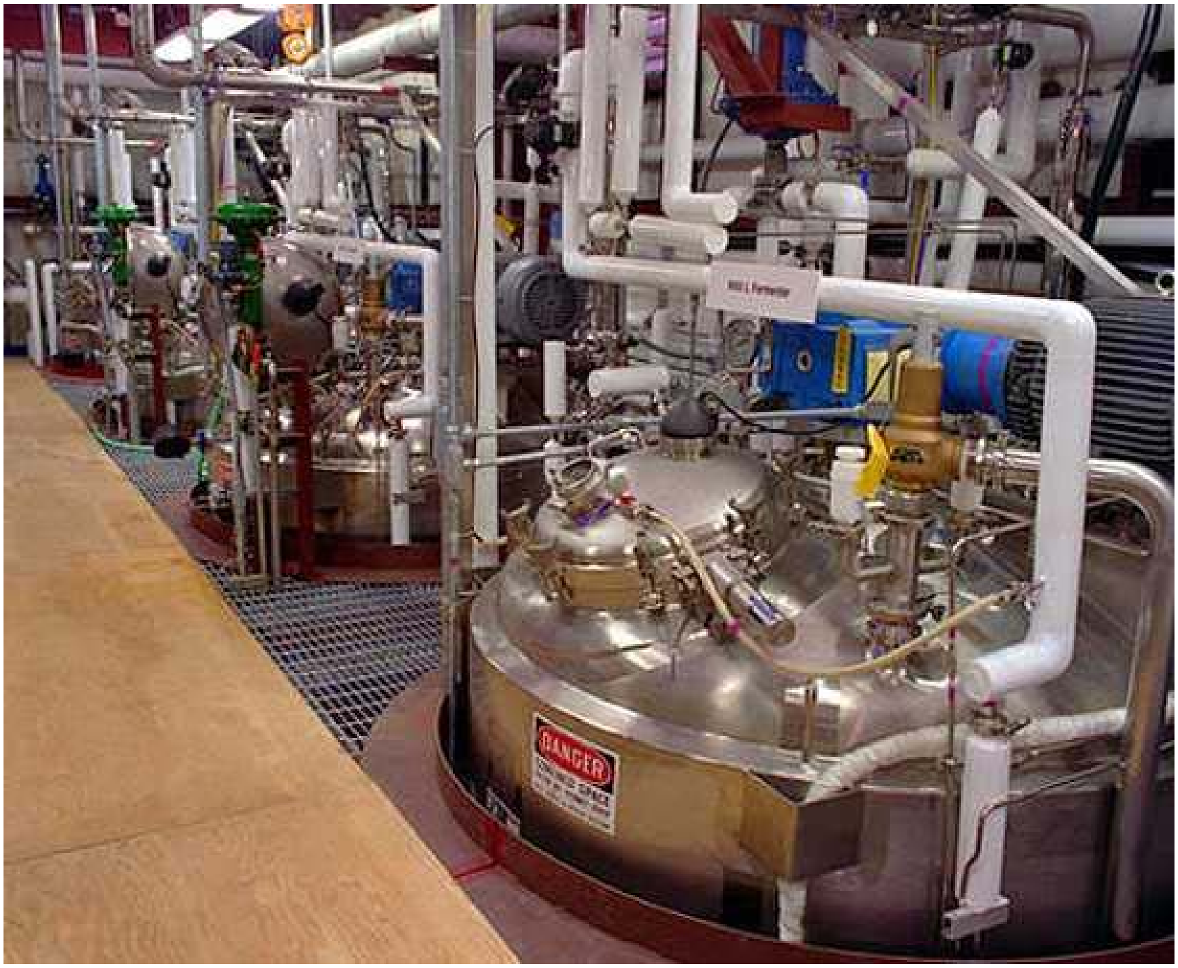
The Federal Fuel Oxygenate Requirement

The reformulated gasoline (RFG) provisions are contained in Section 219 of the Clean Air Act Amendments of 1990, which amends Section 211(k) of the Clean Air Act. Section 219 was crafted to address three major categories of pollutants: carbon monoxide, smog-forming compounds, and mobile-source air toxics. The CAAA include several measures to address these pollutants, with three broad policy moves comprising the measures: the oxygenate provision, the Reid Vapor Pressure (RVP) requirements, and the measures designed to reduce air toxics.

Oxygenates are chemicals added to reformulated gasoline (and to state-level fuel formulations) to increase the gasoline's oxygen content. Under the CAAA, air basins that do not meet air quality standards for levels of ozone and carbon monoxide (making them "nonattainment" areas) are usually required to use reformulated gasoline containing at least 2 percent oxygen by weight. The added oxygen content of the gasoline allows for more complete combustion of hydrocarbons, reducing the emission of carbon monoxide and volatile organic compounds (VOCs, which react in the atmosphere to form ozone). The two most common oxygenates used during the 1990s were MTBE, itself a petroleum product, and ethanol, manufactured from corn or other biomass. Section 219 required that refiners produce oxygenated gasoline by November, 1992, low-sulfur diesel by October, 1993, Phase I RFG by January, 1995, Phase II RFG by January, 2000, and low-sulfur gasoline by January, 2004.

Reid Vapor Pressure, a measure of the volatility of a liquid, determines how quickly the liquid will evaporate into the air. The CAAA include provisions for lower maximum RVPs for reformulated gasoline, which provides two major benefits. First, at the site of fueling, aromatic hydrocarbon release is reduced; the largest effect of this regulation is the reduction in benzene exposure. Second, lower maximum RVPs reduce exhaust emissions. Section 219 of the CAAA provided for an initial reduction of RVP to 8.7 psi (pounds per square inch).

Simultaneously, Section 219 provided for individual states and localities to set additional standards for nonattainment areas, creating a set of formulations known as "boutique" fuels. These boutique formulations have expanded rapidly in the past decade, with 15 different formulations (with at least regular and premium, and sometimes midgrade, subdivisions) in existence. In total, over 40 different types of boutique gasoline can be found throughout the country, with many of these boutique fuel mixtures providing for even lower RVPs than the CAAA required reduction to 8.7 psi.



A. Pollutants Addressed by the 1990 CAAA

The first type of pollutant addressed is carbon monoxide, a byproduct of the incomplete combustion of hydrocarbons. In normal combustion, compounds containing carbon and hydrogen atoms react with oxygen, releasing significant amounts of energy and forming water vapor and carbon dioxide as byproducts. Hydrocarbon combustion gives off a great deal of energy, making hydrocarbons such an ideal energy source—the energy density of hydrocarbons is as much as 15 times as high as that of typical batteries that can store energy. However, especially at low temperatures, the reaction between hydrocarbons and oxygen can occur only partially, resulting in the release of carbon monoxide (CO) instead of carbon dioxide (CO_2), as well as unburned hydrocarbons. Catalytic converters in cars help alleviate this problem; unfortunately, they must heat up to be effective, causing large amounts of CO to be released during the winter months, mostly within a short time after a vehicle is started.

The health effects of carbon monoxide are significant but short-lived, with about half the excess levels of CO remaining in the bloodstream three to four hours after exposure. CO acts by interfering with the body's ability to absorb oxygen. It combines with hemoglobin at a rate about 200 times faster than oxygen, forming carboxyhemoglobin as opposed to the beneficial oxyhemoglobin. As a result, the body is starved of oxygen.

> *It affects the central nervous system at relatively low concentrations; it weakens heart contractions, lowering the volume of blood distributed to various parts of the body; it significantly reduces a healthy person's ability to perform manual tasks, such as working, jogging and walking; it causes healthy people to feel tired and drowsy from short-term exposure to concentrations greater than 30 parts per million (ppm); it causes shortness of breath and chest pain in people with heart disease at exposures as low as 10 ppm; and it induces irritability, headaches, rapid breathing, blurred vision, lack of coordination, nausea, dizziness, confusion and impaired judgment in healthy people at levels greater than 35 ppm.*[1]

In higher concentrations, CO exposure leads to death. Especially susceptible to these effects are children, the elderly, and those with compromised cardiovascular systems, especially those who smoke or suffer from angina pectoris.

The second category of pollutants addressed is precursors to smog: volatile organic compounds (VOCs) and nitrous oxides (NOx). VOCs are unburned hydrocarbons, formed by the same incomplete or inefficient combustion that forms CO. NOx are formed when nitrogen combines with oxygen during high-temperature combustion to form NO, which can then combine with oxygen again to form NO_2. NOx then reacts in sunlight with VOCs to form ozone (O_3), the primary component of smog. Due to their temperate climates, most areas in the United States consider ground-level ozone a summertime pollutant. Stratospheric ozone, though, is beneficial and helps protect humans and other animals from dangerous levels of exposure to ultraviolet radiation.

The health effects of ozone are significant in both the short and long run.

> *Ozone can irritate lung airways and cause inflammation much like a sunburn. Other symptoms include wheezing, coughing, pain when taking a deep breath, and breathing difficulties during exercise or outdoor activities. People with respiratory problems are*

most vulnerable, but even healthy people that are active outdoors can be affected when ozone levels are high. Repeated exposure to ozone pollution for several months may cause permanent lung damage. Anyone who spends time outdoors in the summer is at risk, particularly children and other people who are active outdoors. Even at very low levels, ground-level ozone triggers a variety of health problems including aggravated asthma, reduced lung capacity, and increased susceptibility to respiratory illnesses like pneumonia and bronchitis.[2]

Because of these dangers, ground-level ozone is a more significant concern in many areas than carbon monoxide. According to data from 1998, the use of oxygenates in gasoline has reduced ambient levels of hydrocarbons by 17 percent, NO_Xs by 11 percent, CO by 11 percent, and sulfur dioxide (SO2) by 80 percent.[3]

The third category of pollutants addressed by Section 219 of the CAAA is "air toxics." Air toxic reduction in the CAAA takes several forms. All heavy metals are banned from reformulated gasoline, with exceptions allowed at the discretion of the EPA administrator. In addition, benzene is limited to 1.0 percent by volume. A further restriction divides RFG into two phases: Phase I requires an annual 15 percent reduction in air toxics relative to a baseline of vehicles using conventional gasoline, and Phase II requires an additional 25 percent reduction in air toxics, with exceptions allowed at the discretion of the EPA administrator. In all cases, the strictest of all applicable standards applies.

The EPA controls 188 chemicals considered to be air toxics, two groups of which are targeted for reduction under Section 219. The first group addressed is that of heavy metals, lead in particular. The toxicity of lead is well-known and severe; according to the EPA:

Lead is a very toxic element, causing a variety of effects at low dose levels. Brain damage, kidney damage, and gastrointestinal distress are seen from acute (short-term) exposure to high levels of lead in humans. Chronic (long-term) exposure to lead in *humans results in effects on the blood, central nervous system (CNS), blood pressure, kidneys, and Vitamin D metabolism. Children are particularly sensitive to the chronic effects of lead, with slowed cognitive development, reduced growth and other effects reported. Reproductive effects, such as decreased sperm count in men and spontaneous abortions in women, have been associated with high lead exposure. The developing fetus is at particular risk from maternal lead exposure, with low birth weight and slowed postnatal neurobehavioral development noted."*[4]

Lead and all heavy metals are highly persistent, creating a very high potential for long-term harm to humans.

The other targeted air toxic, benzene, is a hydrocarbon found in gasoline. Benzene's effects are local and short-lived, however, they can also be severe:

Acute (short-term) inhalation exposure of humans to benzene may cause drowsiness, dizziness, headaches, as well as eye, skin, and respiratory tract irritation, and, at high levels, unconsciousness. Chronic (long-term) inhalation exposure has caused various disorders in the blood, including reduced numbers of red blood cells and aplastic anemia, in occupational settings. Reproductive effects have been reported for women exposed by inhalation to high levels, and adverse effects on the developing fetus have been observed in animal tests. Increased incidence of leukemia (cancer of the tissues that form white blood cells) have been observed in humans occupationally exposed to benzene. EPA has classified benzene as a Group A, human carcinogen.[5]

Most of the air toxics reductions from reformulated gasoline have come from reductions in benzene.

B. Meeting the Federal Fuel Oxygenate Requirement

The CAAA mandated that reformulated gasoline (RFG) must have at least 2 percent oxygen by weight.[6] Adding 11-15 percent MTBE or up to 10 percent ethanol by volume satisfies the requirement. There are debates as to which one of these additives is more efficient. The addition of ethanol increases the Reid Vapor Pressure (RVP), meaning that it evaporates faster than regular gasoline. Higher RVP increases evaporative emissions that can create smog-forming volatile organic compounds (VOCs) in the atmosphere. However, some people claim the addition of ethanol substantially decreases the ambient emission of compounds that could react with elements in the atmosphere to create smog. MTBE's proponents claim that it has a much lower RVP, but lowers ambient emission just as much as the addition of ethanol to RFG. MTBE is also easy to produce, easy to transport, does not increase RVP, and was the oxygenate of choice for most petroleum companies before new regulations began to phase MTBE out.

Recent findings have increased the demand for oxygenates other than MTBE to use in reformulated gasoline: "Legislation that would ban or restrict the use of MTBE in gasoline has already been passed in 16 States: California, Colorado, Connecticut, Illinois, Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Missouri, Nebraska, New York, Ohio, South Dakota, and Washington."[7] California originally intended to ban MTBE from all RFG by 2003, but the deadline has been pushed back until January 1, 2004 because of the difficulties that refineries encountered in switching their production processes. As of January 2003, only ConocoPhillips had removed all MTBE from its gasoline. Companies such as Shell Oil, ExxonMobil, Tesoro, and BP will be MTBE-free by January 2004.

One key factor of the removal of MTBE from gasoline is the high supply of ethanol. Ethanol can substitute MTBE and satisfies the 2 percent oxygenate requirement. It is commonly called 'gasohol' because it can be used as 100 percent ethanol or an 85 percent blend with only 15 percent being gasoline.[8] Most service stations provide E85 (85 percent ethanol, 15 percent gasoline), but E10 (10 percent ethanol and 90 percent gasoline) is also available in some states.[9]

Ethanol is highly soluble in water, has an octane rating of 115, and has an RVP of 18, higher than both conventional gasoline and MTBE-oxygenated RFG. Ethanol also contains almost 34.8 percent oxygen by weight; almost double that of MTBE and other ethers. This high oxygen content means that to meet the federal regulations reformulated gasoline requires half as much ethanol by weight as MTBE.[10]

The two basic drawbacks to ethanol, however, are its complete solubility in water and its high Reid Vapor Pressure. Ethanol has a high affinity for water, and if it were shipped through a pipeline that had water in it, the ethanol would separate out of the gasoline and combine with the water. This would create an RFG that has less ethanol by volume and may not conform to the oxygenate requirement. Because of this affinity, ethanol cannot be shipped through pipelines and must be blended into RFG at the gasoline terminals, not at the refinery where most gasoline is blended. Additionally, most ethanol is produced in the Midwest from corn, which increases the transportation and shipping costs dramatically for ethanol's use outside of the Midwest.

Ethanol-blended RFG also has trouble satisfying all of the federal RFG requirements for RVP. The RVP of ethanol is higher than that of MTBE, and RFG blended with ethanol also has a higher RVP than MTBE-oxygenated RFG or conventional gasoline. Without a special RVP allowance, ethanol does not always meet all of the federal RFG requirements. Also, vehicle exhaust emissions data have shown that acetaldehyde emissions can increase by up to 100 percent with just a 2 percent level of ethanol in RFG. Much of the emitted acetaldehyde goes into the atmosphere and has a chemical reaction similar to that of VOCs. According to the EPA, the use of ethanol greatly decreases the amount of ambient emissions except for evaporative ethanol and acetaldehyde. These reductions include a 15 percent reduction of VOCs, a 40 percent reduction in carbon monoxide, a 10 percent reduction of NOx, and an 80 percent reduction of sulfates.[11]

California is at the head of the industry for finding new standards of RFGs. As of January 2004, gasoline cannot contain MTBE, but all of the gasoline must still burn at levels determined by the CAAA. In California Phase 3 RFG, ethanol will replace MTBE. The main proponents of the ethanol requirement are the corn-growing states of the Midwest. Currently, the corn growers are receiving an extremely large government subsidy, approximately 54 cents per gallon, to produce large amounts of ethanol from corn.[12] Although ethanol may be a better alternative to MTBE due to water and soil contamination, we must understand the costs of switching to ethanol in RFGs.

C. Existing Analyses of Ethanol as an Oxygenate

Ethanol's value as an oxygenate remains controversial. A UC Berkeley study argues that ethanol is not the correct oxygenate needed for reformulated gasoline.[13] According to the study, not only does ethanol increase the RVP of gasoline, but is also highly corrosive and has a 34 percent lower heating level compared to regular gasoline. Additionally, more energy is needed to create ethanol than burning it afterwards creates. The report concludes that 1.5 gallons of ethanol are needed to replace 1 gallon of gasoline in a car engine.[14] It takes an incredible amount of energy to yield a relatively small amount of ethanol: "…in the process of converting industrial corn grain into ethanol, we have lost 65 percent of the energy inputs. More ominously, we have burned at least as much fossil fuel energy to obtain ethanol, as we may gain by burning it."[15] The report also claims that the production of ethanol from corn leads to degradation of the environment by the emission of global warming gases, fertilizer and herbicidal runoff, and wastewater.[16] "It does reduce carbon monoxide emissions, but increases nitrogen oxides (NOx) and aldehydes. Finally, all energy in ethanol comes from fossil fuels, with their own emissions." [17] This last point reminds us that the energy to produce/manufacture ethanol comes from fossil fuels, and more energy is burned to produce ethanol than created from the combustion of the ethanol.

In addition to the emissions from the combustion of fuel in the ethanol production process, fertilizer runoff from the production of high levels of corn has environmental costs such as high levels of fertilizer and herbicidal runoff into water sources. Such agricultural runoff is the likely source of nutrient deposition and increased harm to fish populations in the Mississippi River watershed and in the Gulf of Mexico.

Once produced, ethanol must be transported from the Midwest to the rest of the nation. Shipping by truck is too costly, and due to ethanol's affinity for water, it cannot be safely distributed in pipelines without putting water resources at risk, leaving rail the only viable transportation method. This burns yet more fossil fuel and contributes to air pollution.

The Berkeley study argues that although ethanol decreases carbon monoxide emissions and may lead to the cleaner burning of gasoline, ethanol does not have the overall effects that are expected. As an oxygenate, ethanol does not lead to lower ambient air emissions. The emissions of NOx and aldehydes that are released from ethanol combustion combined with the burning of fossil fuels to create ethanol do not promote a cleaner environment. In sum, we have negative net benefits of energy from the production of ethanol.

Another study claims that the use of ethanol as an oxygenate creates negative net energy, finding that an acre of land that produces 7,110 pounds of corn yields 328 gallons of ethanol.[18] Producing this amount of corn would use approximately 1,000 gallons of fossil fuels. [19] Including the production of ethanol and the price it costs to produce the corn, the total cost per gallon of ethanol is approximately $1.74 per gallon. The Cornell study calculates that it takes 131,000 BTUs of energy to produce the ethanol, when taking into account the fossil fuel used to produce the ethanol and to produce fertilizer, while only 77,000 BTUs are created from the burning of the ethanol. It concludes that the energy produced from a gallon of gasoline is equivalent to 1.5 gallons of ethanol, the same result as the more recent Berkeley study.

However, there are many who believe that the use of ethanol creates positive net energy production. Michael Wang and Dan Santini of the Argonne National Laboratory dispute the claims of these two studies that the production and combustion of ethanol has negative net benefits. Wang and Santini have concluded that technological advancement over the past decade has

significantly reduced the cost of production of ethanol. In their study, Wang and Santini conclude that corn productivity has increased by 30 percent from the early 70s through the mid-90s. [20] In addition, they also claim to have found that the amount of energy needed to produce ethanol has decreased by 40 percent since the mid-1980s. According to the UC Berkeley and Cornell studies, the total energy inputs to create a gallon of ethanol were 131,000 BTUs. Wang and Santini claim that the real energy inputs are only 55,600 BTUs. Given that Wang and Santini claim that one gallon of ethanol nets 77,000 BTUs of energy, they claim a positive net energy balance of 21,400 BTUs, in stark contrast to the net balance of negative 54,000 BTUs found by UC Berkeley and Cornell. Also in their analysis, they claim that ethanol-blended RFG does modestly decrease greenhouse gas emissions.

So, should we believe that it takes 131,000 BTUs of energy to create one gallon of ethanol that when burned only produces 77,000 BTUs of energy per gallon, so that there are negative net benefits of 54,000 BTUs of energy from producing ethanol? Or should we believe that improvements in ethanol production technology give us a positive net energy output of 21,400 BTUs per gallon of ethanol? The fact remains that fossil fuels such as coal and natural gas must be burned in processing the corn into the ethanol, and the second estimate does not incorporate the costs associated with the burning of energy in the ethanol production process. The first estimate, that using a gallon of ethanol wastes 54,000 BTUs of energy, comes from a more complete analysis of the costs along the entire supply chain.

Part 3

A Benefit-Cost Analysis of an Ethanol Mandate

Benefit-cost analysis allows us to quantify the effects of the ethanol mandate. Using numbers from a variety of sources, we can quantify particular costs and benefits across a large group of people allowing us to see the effects of the mandate in the form of distinct dollar amounts.

As an oxygenate, ethanol can decrease pollution emissions into the environment. However, the production and consumption of ethanol create both costs and benefits across the entire population. There are costs and benefits to the government, producers, and the consumers of ethanol-based reformulated gasoline, as well as the population at large.

A. Existing Ethanol Subsidies Increase Corn Production

Currently, there is a large federal subsidy that grants 54 cents per gallon of ethanol produced to the producers.[21] According to research, last year alone over 130 billion gallons of gasoline were used.[22] If we use a conservative blend of ethanol at 10 percent, E10, then every year approximately 13 billion gallons of ethanol will be needed to blend into gasoline at current levels of fuel consumption. Therefore, a 54-cent subsidy per gallon of ethanol produced will lead to a total federal subsidy of approximately $7 billion dollars per year. [23] Since most RFG sold is E85 or 85 percent ethanol, the financial implications are staggering.

B. Costs: Ethanol Consumption

Recent legislation, however, is calling for five billion gallons of ethanol to be used per year in the United States by 2012. The question remains then, does the production of such a high amount of ethanol decrease emissions enough to create benefits that not only outweigh these costs to the government, but also to the producers who pay for the extra transportation costs?

The ethanol requirement creates positive net benefits for those farmers who are growing corn and who are receiving payments from the government. These corn farmers are being paid to produce more corn than if there were no ethanol requirement. As of 2002, nearly 714 million bushels of corn were fermented into ethanol, all of which were subsidized by the federal government.[24] One bushel of corn can yield up to 2.5 gallons of ethanol. Approximately 1.77 billion gallons of ethanol were produced in 2002. This has led to more than a $956 million subsidy being paid to farmers in 2002 alone. However, finding the actual benefit received by producers is more difficult.

The main benefit of the ethanol requirement to producers is that it greatly increases the demand for corn. Corn farmers across the country would have to increase substantially the amount of corn produced per year. As of last year, 714 million bushels of corn were used for ethanol production. Besides the approximate subsidy of $956 million, the increased corn demand will increase income for corn farmers. This could lead to billions of extra dollars in income for America's farmers. As recently as July 21, 2003, the average market price of corn was approximately $1.86 per bushel.[25] Therefore, the average value of the total corn demanded in one year due to existing ethanol demand is roughly $1.328 billion.

Estimates put costs of corn production at $3 per bushel.[26] In this case, it would cost almost $2.1 billion per year to grow the extra 714 million bushels of corn required to meet the ethanol mandate. By selling the corn at $1.86 per bushel the farmers receive $1.328 billion. Therefore, we estimate costs to farmers at approximately $772 million. The only reason why the farmers produce this much corn is because of the subsidy, but because it is funded by taxpayers, it is not considered a benefit, but is instead a transfer from taxpayers to farmers.

Using 2002 data, we can project the benefits in 2012 from using ethanol in RFG. Projections are that we would be using five billion gallons of ethanol by 2012, which are produced from 2 billion bushels of corn, given that a bushel of corn can generate 2.5 gallons of ethanol. If a bushel of corn costs $3 to produce, farmers incur $6 billion in corn production costs. Selling the corn at $1.86/bushel generates $3.72 billion in sales. The federal subsidy of ethanol production at 54 cents/gallon would be $2.7 billion. Adding the $2.7 billion subsidy to the revenues from corn sales yields $6.42 billion in revenues for farmers from production, a 420 million dollar profit. However, overall net benefits remain negative at $2.28 billion. Thus, notwithstanding the explicit positive benefits to farmers due to the subsidy, the net benefit to the nation would be negative. Thus the high cost of ethanol is not reflected in its market price, but is borne by the taxpayer through federal subsidy.

Now that we have calculated the costs of ethanol, we need to know the net energy received from burning gasoline vs RFG based on ethanol. A gallon of gasoline creates 123,240 BTUs of energy; ethanol has a much lower amount of energy per gallon at 77,000 BTUs. When we mix ethanol into gasoline to create an RFG, such as E10, gasoline with 10 percent ethanol by volume, the energy output generated is 118,616 BTUs per gallon, yielding a net loss of 4,624 BTUs of energy lost from burning one gallon of E10 gasoline rather than burning one gallon of conventional gasoline. At today's level of demand for fuel, the addition of ethanol results in an energy loss of 601 trillion BTUs per year. That means we would need to burn over five billion more gallons of RFG to generate the same amount of energy we would get if we stuck with ordinary gasoline.[27] Burning an extra five billion gallons of fuel would cost consumers approximately $9.25 billion per year (at $1.85 per gallon retail).[28] This is the most conservative estimate, being based on E10 RFG and not the more commonly used E85 RFG (an 85 percent ethanol mixture).

Meanwhile, using five billion gallons of ethanol calls for 50 billion gallons of reformulated E10 gasoline, which costs 20 cents more per gallon than conventional gasoline, adding another cost to consumers of $10 billion per year to pay for the more expensive fuel.

Adding up, so far we have $21.53 billion net costs per year of the proposed ethanol mandate:

- $2.28 billion in net costs to produce the extra corn needed to create ethanol for the proposed mandates;
- $10 billion in costs to purchase the extra fuel needed to get the same amount of energy from E10 as we would from conventional gasoline; and
- $10 billion in costs to consumers due to the higher price of RFG relative to conventional gasoline.

C. Costs: Ethanol Production and Transportation

In Minnesota, where approximately 17 percent of the nation's ethanol is produced, ethanol plants are generating emissions that run afoul of air quality regulations. Manufacturing ethanol is a difficult process, and VOCs and CO are frequently emitted into the atmosphere. Currently,

> *The Minnesota ethanol plants agreed to install air pollution control equipment that will reduce emissions of volatile organic compounds (VOC) by 2,400 to 4,000 tons per year and carbon monoxide (CO) emissions by 2,000 tons per year. The settlement will also reduce nitrogen oxides (NOx) emissions by 180 tons per year, particulate matter (PM) by 450 tons and other hazardous air pollutants by 250 tons.*[29]

We have to consider the negative impact these emissions are having, counteracting the benefits created from burning ethanol-based RFG. In addition, ethanol plants incur substantial costs at each plant to reduce their emissions; these costs can be nearly two million dollars per plant, plus an average civil fee of thirty five thousand dollars.[30] If each U.S. ethanol plant incurs costs of two million dollars to slash emission, plus the added civil fee, there is a total fixed cost of approximately $144 million for emission reductions.[31]

Another major cost to the ethanol industry is transportation. Because ethanol is completely soluble in water, it cannot be sent through pipelines. It must be transported via truck, rail, or barge. Due to special handling, truck shipping is not cost efficient and therefore ethanol will only be shipped via rail or barge.[32] Current rail infrastructure is deficient, and delays on shipments and higher pump prices are likely. Members of the California Energy Commission claim that pump prices in California may rise to almost $4 per gallon for ethanol-based RFG.[33] A 2002 study by the Department of Energy published the costs of shipping ethanol, assuming 5.1 billion gallons per year are shipped in total. According to the study, an additional 2.987 billion gallons of ethanol will be shipped by 2012. The costs of infrastructure to accommodate this expansion are extremely large. The costs of tank conversion, new tanks, and other costs to expanding and improving the terminal system alone are fixed at $153 million.[34] Also, the total freight costs for shipping 5.1 billion gallons of ethanol are variable and will accumulate every year, reaching approximately $391 million. Therefore, by 2012, the total costs of shipping 5.1 billion gallons of ethanol across the country will reach approximately $544 million.

D. Benefits from Emissions Reduction

The primary benefits from reduced pollution from vehicles are reduced health risks from poor air quality. According to the World Resources Institute,

> *Many of air pollution's health effects, such as bronchitis, tightness in the chest, and wheezing, are acute, or short term, and can be reversed if air pollution exposures decline. Other effects appear to be chronic, such as lung cancer and cardiopulmonary disease. In fact, in the United States, two long-term epidemiological studies representing some of the most significant recent research on air pollution effects documented an increase in the death rate of those chronically exposed to dirty air. These studies, which compared death rates among many U.S. cities with widely varying pollution levels, found that mortality rates were 17 to 26 percent higher in cities with the dirtiest air compared with those with the cleanest air, and those with the dirtiest air had significantly higher rates of lung cancer and cardiopulmonary disease . . . These increased risks translate roughly to a 1- to 2-year shorter life span for residents of the most polluted cities . . . Higher infant mortality rates have also been associated with high particulate levels . . .*[35]

The pollutants that are most associated with health problems are particulate matter, sulfur dioxide, and ozone, although nitrous oxides and volatile organic compounds also have been associated with respiratory illness in epidemiological studies. Gathering data on the cost of the health effects of particulate matter and ozone is difficult, so in our calculation of the benefits of reduced emissions we omit the benefits from their reduction. We estimate the benefit per person per ton of emission reduction of nitrous oxides, sulfur dioxide, and volatile organic compounds, and multiply that number by the expected reduction in emissions to calculate the estimated total benefit from emission reduction attributable to ethanol. In the course of this analysis, when we have to make assumptions we overstate the potential benefit, so that any bias inherent in our estimates will bias us toward finding net benefits.

In 2001 approximately 1.77 billion gallons of ethanol were produced. Thus meeting the five billion gallon ethanol production target by 2005 that is included in the federal energy bill proposal will require the additional production of 3.23 billion gallons of ethanol.

If we assume that fuel energy demand (measured in BTUs) is unchanged, and assume further that ethanol replaces gasoline with exact BTU production (i.e., using the Wang and Santini assumptions of no net energy loss from the production and consumption of ethanol), then ethanol would replace 3.23 billion gallons of gasoline. In 2001, 130 billion gallons of gasoline were consumed.

As of 2001, nearly 8.2 million tons of nitrous oxides are emitted into the atmosphere from on-road vehicles annually.[36] Considering previous data indicating that 130 billion gallons of gasoline are burned every year, we can conclude that one ton of nitrous oxides is emitted into the air for every 15,759 gallons of burned gasoline (0.064 tons of NOx per gallon of gasoline). Also, we know that nitrous oxide permits trade for an average of $3,095 per ton emitted.[37] Permit prices indicate the market value of the right to emit, which provides a measure of the value of nitrous oxides emissions. In this case, with 8.2 million tons emitted from moving vehicles, we get a total price of $2,553,065,500 in permits per year. Dividing this aggregate permit value by the total population of the United States (260 million), we estimate NOx emission reduction benefits at $9.80 per person, per ton of reduction, per year.

Studies suggest that people would likely be willing to pay $22.26 annually for a 10 percent decrease in sulfur dioxide, SO_2.[38] However, this value is not expressed in value per ton per person of emissions reduction, so while this analysis gives us some context, we instead use a method of estimation that parallels our NOx estimate—emission permit prices.

In 2001, on-road mobile sources emitted 261,000 tons of SO_2. Comparing that emission level with the 130 billion gallons of gasoline burned annually suggests an average emission rate of 0.002 tons of SO_2 per gallon of gasoline. The average SO_2 permit price in 2001 was $185 per ton.[39] With 261,000 tons of SO_2 emitted from on-road mobile sources, the total value of those emissions is $48.285 million per year. Dividing this aggregate permit value by the U.S. population of 260 million, we estimate the value of SO_2 reduction at $0.19 (19 cents) per person, per ton, per year.

In 2001, on-road mobile sources emitted 4.87 million tons of VOCs. Comparing that emission level with the 130 billion gallons of gasoline burned annually suggests an average emission rate of 0.037 tons of VOCs per gallon of gasoline. Similar permit estimates are not available for VOCs, so we assume benefits of VOC reductions are in a similar range to NOx reductions at a benefit of $10 per ton per person.

Adding together these three benefits yields total benefits of $19.99 per person, per ton of aggregate emissions reductions, per year.

If this decrease in emissions is worth $19.99 per year for each person, then we can multiply this amount by the total population (260 million) to estimate the total benefits of the decreased health risks due to reduced vehicle emissions. In our calculation we attribute all of these benefits to ethanol-based RFG, biasing our analysis toward finding positive net benefits by overstating the ethanol-specific benefits.

Increasing ethanol use by 3.23 billion gallons and thereby reducing gasoline use by the same amount, we assume a reduction of our three primary pollutants according to the averages calculated above. Thus we approximate the reduction in NOx as 206 million tons (3.23 billion gallons x 0.064 tons/gallon), the reduction in SO_2 as 6.46 million gallons (3.23 billion gallons x 0.002 tons/gallon), and the reduction in VOCs as 119.5 million gallons (3.23 billion gallons x 0.037 tons/gallon). Multiplying each pollutant's value per ton per person of reduction yields a total benefit from this additional ethanol production and use of $3.125 billion, as shown in the Table shown.

We also calculated total benefits under the assumptions that increased ethanol use would require increased gasoline use (assuming constant fuel energy demand) because of the net negative energy production found in the entire ethanol production and consumption process. Under these assumptions, producing and burning an additional 3.23 billion gallons of ethanol in the form of E10 RFG would mean a reduction of 3.23 billion gallons of gasoline consumption, but it would also require an increase of gasoline consumption to compensate for the lost BTUs from the burning of ethanol. In our analysis of costs, we found that we would need to burn an additional five billion gallons of E10 to generate the same number of BTUs created through burning conventional gasoline. Burning those five billion additional gallons of E10 RFG implies burning 4.5 billion additional gallons of conventional gasoline. Netting that out against the 3.23 billion gallons replaced by ethanol means that if demand stays the same an additional 1.27 billion gallons of conventional gasoline will be consumed by increasing ethanol to five billion gallons. The table reflects the result of this calculation, a total benefit that is negative, at -$1.264 billion.

Using the benefits and costs described above yields a total net loss of approximately $23.34 billion. This calculation relies on the UC Berkeley and Cornell findings on the net negative energy production of ethanol's use. However, even if we assume that Wang and Santini are correct and that there is a positive net energy production from using ethanol-based RFG, then we still conclude that E10 would have negative net benefits, this time of $18 billion.

Table: Costs, Benefits, and Net Benefits of Ethanol Production and Consumption, in Dollars			
Costs of increased ethanol			
▪ Ethanol consumption			21,540,000,000
▪ Ethanol production and transportation			540,000,000
Total cost			22,080,000,000
Benefits of increased ethanol under optimistic assumptions	*Benefit/ton/ person*	*Tons reduction*	*Total benefit*
▪ Sulfur Dioxide (SO2)	0.19	3.23 bil * 0.002 = 6.46 million	1,227,400
▪ Nitrous Oxides (NOx)	9.80	3.23 bil * 0.064 = 206 million	2,018,800,000
▪ Volatile Organic Compounds (VOCs)	10.00	3.23 bil * 0.037 = 119.5 million	1,195,000,000
Total benefit, under optimistic assumptions			3,215,027,400
Net benefit, under optimistic assumptions (negative)			**(18,864,972,600)**
Benefits of increased ethanol under pessimistic assumptions	*Benefit/ton/ person*	*Tons reduction*	*Total benefit*
▪ Sulfur Dioxide (SO2)	0.19	-1.27 bil * 0.002 = -2.54 million	(482,600)
▪ Nitrous Oxides (NOx)	9.80	-1.27 bil * 0.064 = -81 million	(793,800,000)
▪ Volatile Organic Compounds (VOCs)	10.00	-1.27 bil * 0.037 = -47 million	(470,000,000)
Total benefit, under pessimistic assumptions			(1,264,282,600)
Net benefit, under pessimistic assumptions (negative)			**(23,344,282,600)**

There are two different schools of thought. If one agrees the UC Berkeley and Cornell studies, then the use of ethanol creates negative net benefits of almost $24 billion. If one agrees with Wang and Santini, then the use of ethanol creates negative net benefits, but they are much smaller.

Finally, we must compare the prices of reformulated gasoline to conventional gasoline. Using this, we can compare the relative costs and benefits and see if the benefits of using reformulated gasoline outweigh the costs of using it. Knowing that conventional gasoline costs on average $1.65, we find that consumers would save $10 billion per year if only conventional gasoline were used. We would also save $688 million in infrastructure and shipping costs for ethanol. However, returning to conventional gasoline would lead to zero health benefits and zero benefits toward ethanol producers. $10.935 billion in health benefits would be lost. Producers also do not bear the high costs of growing the extra corn, which is $2.28 billion. Therefore, we have net losses of benefits of $10.68 billion but gain approximately $13 billion in averted costs. This creates net benefits of $2.32 billion. However, there are great costs associated with increased emissions and this will create much larger costs on healthcare. If costs of healthcare are greater than $2.32 billion due to increased emissions, then we have negative net benefits from using conventional gasoline. If healthcare costs are less than $2.32 billion, we have positive net benefits from using conventional gasoline.

While disagreement exists on the energy and environmental costs of producing and burning ethanol, our analysis indicates that UC Berkeley and Cornell studies incorporate actual costs in their analyses that Wang and Santini omit. UC Berkeley and Cornell studies provide a fuller estimate of the costs incurred along the entire ethanol supply chain. Thus we find that the net economic loss from producing and burning five billion gallons of ethanol is almost $24 billion per year.

Part 4

Political Economy of the Current House and Senate Proposals

The political challenge facing Congress in crafting the fuels portion of the energy bill is to address the problems raised by the fuel oxygenate requirement without harming either the farm or oil constituencies. The current bills achieve this objective primarily through uncoupling the provisions encouraging ethanol use from the fuel oxygenate requirement, discarding the fuel oxygenate requirement, and providing transition assistance for producers of MTBE, a semantic dance-step that assures the interests of farm and oil companies to the detriment of taxpayers and the environment.

Both House and Senate motor fuels provisions consist of several components: a "renewable content" requirement, a safe harbor clause, findings regarding the use of MTBE, the removal of the oxygen content requirement for RFG, MTBE transition assistance, a loan guarantee program for commercial attempts to derive fuel from municipal solid waste, and funding for a number of studies regarding the fuel supply system. The bills differ most significantly in their treatment of MTBE, their "safe harbor" clauses, and their schedules for renewable content phase-in. By examining each of the individual components, the interests served become clear, as does the nature of the agreement reached between the farm and oil lobbies.

The "renewable fuels" provisions of both the House and Senate energy bills are little more than expansions of the subsidies established under the 1990 Clean Air Act Amendments. The original subsidies, in the form of an oxygen content requirement for federal RFG, were billed as a way of reducing smog, decreasing the nation's dependence on foreign oil, reducing farm program outlays, and reducing emissions of carbon dioxide. All of these arguments were controversial at the time. The body of evidence regarding ethanol's effects on smog was inconclusive at best. Ethanol, it was argued, was also a "net energy loser," requiring more energy to produce than it provided. Further, while farm program outlays were reduced, the excise tax exemption already provided to ethanol as a motor fuel meant a loss to the highway trust fund as the increased volume of ethanol used in motor gasoline displaced taxed components. The one claim to go unchallenged was that ethanol use would reduce carbon dioxide emissions, most likely due to the absence of any focus on global warming at the time; the questions surrounding the energy used in ethanol production and distribution placed this claim in doubt, however.

The new provisions carry the same promises, and have received much of the same criticism. The largest opponent of the 1990 provisions was the oil industry, in particular the American Petroleum Institute. Although the renewable fuels component remains detrimental to the oil industry, other components of the bills more than offset the losses, making the package acceptable as a whole. Furthermore, if ethanol does indeed produce net negative energy, increased demand for fuels over time (from forecast increased vehicle miles travelled) will translate to an even larger increase in the demand for gasoline than in the absence of an ethanol mandate.

Additionally, the renewable fuels provisions do represent an expansion of the subsidies, not merely the maintenance of them in the absence of the oxygenate requirement. In fact, according to the EPA, "ethanol production capacity and use would still increase over today's levels even in the absence of either the federal RFG oxygen mandate or a renewable fuel mandate" as a result of the federal subsidies granted for ethanol production and distorting the price signals in fuel markets.[40] However, the EPA supports the inclusion of a renewable fuels provision, due to the fact that a number of the boutique fuels have been mandated not to satisfy clean air requirements, but rather to encourage the use of certain oxygenates. The most notable case of this is Minnesota, which has an ethanol mandate but no other clean fuel requirements. The EPA's stance is that the elimination of the oxygenate requirement in the absence of a renewable fuels requirement would encourage further boutique proliferation driven by parties wishing to push ethanol or MTBE use.[41] However, such legislation at the state level would not be required to protect current ethanol production; as previously noted, the EPA holds that the use of ethanol would increase in the absence of any mandate. Further, if the federal government were to mandate the use of one or two fuels to the exclusion of boutiques, the concern regarding boutique proliferation in the wake of the elimination of the oxygenate requirement would be a moot point.

The "safe harbor" clause, which limits the liability of renewable fuel producers (most notably, refiners and ethanol producers), is clearly a winner for both major lobbying groups. However, the House version protects both renewable fuels and MTBE, whereas the Senate version protects only renewable fuels. Several oil companies have already settled one lawsuit due to MTBE water supply contamination for $69 million,[42] and will be keen to see that the House provision is adopted in conference. The ethanol component, included in both versions, will likely be important in the future due to the fact that ethanol mixes perfectly with water and can travel great distances if it leaks from a storage tank. Making this problem worse is the fact that benzene can essentially piggyback on ethanol, increasing the size of carcinogenic benzene plumes in the event of a leak.[43] Such events are not uncommon; one study found that in areas using MTBE to meet RFG or

oxygenate requirements, 21 percent of wells showed some level (greater than 0.2 ppb) of MTBE in the water supply.[44]

The findings contained in both bills appeal to the same interests. By establishing a legal basis upon which one could argue that the use of MTBE was necessary to meet the requirements established by the 1990 CAAA, Congress will be allowing defendants in MTBE cases to argue that they cannot be held liable for a product that they had been compelled to use.

The removal of the oxygen content requirement while still requiring a renewable fuel source for reformulated gasoline is the core of this portion of the energy bill. By following the EPA Blue Ribbon Panel's recommendations and eliminating the oxygen requirement—which has offered no significant health benefits, has led to the widespread use of MTBE and the associated costs of MTBE contamination, and has served only to subsidize ethanol producers—Congress will be seen as acting in the public interest. Refiners will not protest, either, given that the "renewable fuels" provision provides them greater flexibility than the per-gallon oxygenate requirement, and that small refineries will be eligible for "hardship" exemptions.

The only question raised by this removal of the oxygenate requirement is the fact that Congress has included the previously discussed "renewable fuels" provision, which will consist largely of ethanol use. This ethanol use will not be targeted in any way at high-pollution areas, so it is disingenuous to claim that the renewable fuels provision will accomplish any public health goals. Given that studies indicate that ethanol is a net energy loser, we can also conclude that increased ethanol use may have no or even a negative effect on energy independence. Further, a number of questions exist regarding the effects of widespread ethanol use on the environment due to its complete solubility in water, and its formation of aldehydes, including formaldehyde, in biological processes. Finally, the ethanol advantages that are explicitly included in this package make it clear that ethanol is the overwhelming favorite to meet the "renewable fuels" requirement. These factors indicate that the new "renewable fuels" provision is merely a politically expedient way of eliminating a particularly destructive subsidy by creating further subsidies, and that no significant benefits will accrue to the public at large as a result of this legislation.

The issue of MTBE use is handled similarly in the House and Senate versions of this bill, through pieces of legislation that are perfect inverses of one another. The Senate version more closely follows the Blue Ribbon Panel recommendations, banning the use of MTBE in motor gasoline as of at most four years from the date the Act becomes law, excepting MTBE use in states that opt-out of the ban by notifying the EPA administrator. The House version does not ban MTBE, however, it notes that individual states can enact MTBE bans through their own legislatures. The provisions allowing individual states to select whether or not they wish to be party to an MTBE ban greatly ease the battle over the issue of MTBE use. Since California moved to ban MTBE, several other states have enacted restrictions of their own, bringing to 16 the total number of states restricting MTBE use. Additionally, Maine has passed legislation expressing the goal of eliminating MTBE use.[45] The tension between these states and states with significant MTBE production facilities makes either banning MTBE outright or disallowing restrictions on its use politically infeasible. Thus, both current proposals amount to little more than codifying the current state of affairs: each state will do as it pleases. Unfortunately, this means that both versions miss the entire point of passing a federal law, and do nothing to simplify the patchwork of fuels regulations responsible for many of the price spikes in recent years. Instead, as the MTBE bans take effect over the next several years, the supply chain will likely become even more inflexible.

With respect to the proliferation of boutique fuels following the 1990 Clean Air Act Amendments and the resulting supply disruptions, the House and Senate versions differ significantly. The Senate bill takes two actions to ease the supply chain inflexibility: allowing commingling between gasoline containing ethanol and that which does not contain ethanol, and consolidating VOC Control Regions 1 and 2. By allowing limited commingling, the Senate bill will eliminate the need to completely empty storage tanks before accepting fuel blends different from those already in the tanks while still maintaining RFG performance standards. This running-down of tanks will still have to take place during the transition between Winter and Summer ethanol mixes however, which has been a larger contributor to price spikes than transitions between ethanol and ether blends. The House bill simply requires that the EPA administrator give a preference to cleaner-burning or low-RVP fuels when considering whether to approve implementation plans. Clearly, neither bill goes far enough in reducing the proliferation of boutique fuels, especially compared to the options studied by the EPA, which favors the use of only two or three fuels (California CBG, Federal CBG, and potentially Federal low-RVP) across the nation.

The mandated study of concentration in the ethanol production industry appears to be nothing more than a response to concerns that the "renewable fuels" provision will give enormous power to a small number of very large producers, namely Archer Daniels Midland (ADM) and, to a much lesser extent, Cargill. According to Senator Feinstein's figures, the Hirschman-Herfindahl Index (HHI) of industry concentration for the ethanol production industry is over 2,227. The DOJ considers an index of over 1,800 to be concentrated. Thus by current antitrust guidelines, the ethanol industry is extremely concentrated. Further, as Feinstein notes, ADM admitted to price-fixing as recently as 1996. Both bills mandate an annual study of concentration in the ethanol industry, but nothing more. Clearly, the effects of market concentration in the ethanol industry have diffuse negative consequences for consumers, as opposed to the concentrated benefits to ADM and other industry players. Given the enormous power of farm lobbyists in central states and the nature of the cost/benefit distribution, a provision such as this that can be used to deflect criticism but spells out no further action is exactly what one would expect.

Part 5

Conclusion

Our benefit-cost analysis indicates that the ethanol mandate included in both House and Senate versions of the energy bill is not worth it. The fossil fuel energy used in producing ethanol imposes environmental costs, and whether or not ethanol produces negative net energy, its consumption also leads to costs. These costs outweigh the health benefits of ethanol use. Quantifying the cost of the environmental detriment from agricultural runoff would only reinforce this conclusion.

Our analysis of the political dynamics in the success of the ethanol provisions reveals how they can succeed politically, even though they fail our economic and environmental benefit-cost analysis. Uncoupling the fuel oxygenate issue from the renewable fuels issue has enabled Congress to satisfy both the strong farm and oil interests in the debate.

Thus although Congress is following the recommendations of the EPA's Blue Ribbon Panel and eliminating the fuel oxygenate requirement, the bait-and-switch transaction from oxygenate to renewables has created the opportunity for the ethanol industry to succeed politically.

Part 6

About the Authors

Lynne Kiesling is Director of the Applied Energy Research Program in the Interdisciplinary Center for Economic Science at George Mason University, and a Senior Fellow at the Reason Foundation. Dr. Kiesling's research focuses on regulation and technological change, and other issues in regulation and privatization. Dr. Kiesling taught economics and public policy at the College of William and Mary in Virginia, during which time she published extensively in academic journals. She has also worked as an international economic consultant for PricewaterhouseCoopers LLP. Dr. Kiesling holds a Ph.D. in Economics from Northwestern University, specializing in industrial organization, information theory, public finance and economic history. She also holds a B.S. in Economics from Miami University, Oxford, Ohio. Dr. Kiesling is also Senior Lecturer of Economics at Northwestern University.

Matthew McCormick is a student at Northwestern University, with a background in economics, political science, and engineering. His experience includes environmental economics and environmental politics, and he also serves on the executive board of Students for Ecological and Environmental Development at Northwestern University.

Scott Freifeld is an economics student at Northwestern University, with a background in environmental economics and corporate finance.

Part 7

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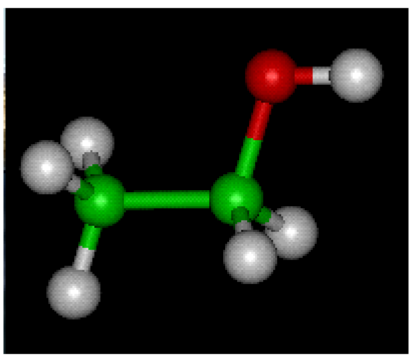

Reason Public Policy Institute
3415 S. Sepulveda Blvd., Suite 400
Los Angeles, CA 90034
310/391-2245
310/391-4395 (fax)
www.rppi.org