DRAFT Memorandum

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TO: Climate Change Steering Committee

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Subject: Ethanol as an Alternative Fuel: The Implications

Purpose

At its June meeting, the Climate Change Steering Committee raised the issue concerning the cost effectiveness and environmental benefits of producing ethanol as alternative transportation fuel source to gasoline. The purpose of this memorandum is to provide background information on the relative performance characteristics ethanol.

Policy Framework

Researchers and policy makers have raised questions regarding the overall energy balance and the potential climate change implications of ethanol. In this regard, this report focuses on two main questions:

1. Does corn-based ethanol provide a net energy benefit as a transportation fuel compared to gasoline?

    ANSWER: The amount of energy needed to produce corn-based ethanol is roughly equal to the amount of energy obtained from its combustion. Overall, most studies show there is a slight positive energy balance from producing corn-based ethanol. The benefit may range from 24-35 percent.

- Compared to gasoline, does corn-based ethanol use reduce greenhouse gas emissions?

    ANSWER: Yes, but only marginally, on the order of 2- 30 percent. Greenhouse gas benefits are substantially higher from cellulosic ethanol (up to 85%).

Ethanol: The Basics

According to the American Coalition for Ethanol (ACE), ethanol is a clean-burning, high-octane fuel that is produced from renewable sources. It is a grain alcohol, produced from crops such as corn or sugarcane. It is domestically produced and therefore helps to reduce America's dependency on foreign energy sources.

The use of ethanol has increased worldwide. It is reported that the U.S. ethanol industry is one of the fastest growing energy industries in the world. The Energy Justice Network reports that as of August 2007 there are 124 full scale grain ethanol plants in operation, 7 are being expanded and 76 under construction. According to the U.S. Department of Agriculture current U.S. ethanol production capacity of 5 billion gallons per year can reduce gasoline imports by more than one-third.

As a transportation fuel, a percentage of ethanol is combined with unleaded gasoline. When ethanol is combined with gasoline it decreases the fuel's cost, increases the octane rating, and decreases harmful gasoline emissions. There are a number of different ethanol blends. Pure 100% ethanol is not commonly used as a motor fuel. The most commonly known ethanol blends are E10 and E85. E10 is 10% ethanol and 90% unleaded gasoline. It is approved for use in any make or model of vehicle sold in the U.S., with no modifications to the engine. Automakers recommend its use because of its high performance, clean-burning characteristics. The ACE reports that 46 percent of America's gasoline contains some ethanol, most at the E10 blend level.

E85 is 85% ethanol and 15% unleaded gasoline. It is an alternative transportation fuel for use in flexible fuel vehicles (FFVs). There are currently more than 6 million FFVs on the road in the U.S. Subsequently, the E85 infrastructure industry has increased, albeit at a slower rate, to support the boom in E85 vehicles. When ethanol is unavailable, these vehicles can operate on gasoline or any ethanol blend up to 85%. There are technical efforts underway for blends above 10%, such as E20, E30, or E40 to be used in standard U.S. automobiles.

Net Energy Balance of Ethanol

The amount of energy used to produce ethanol depends on a number of factors including the type of feedstock (corn-based or cellulosic) used, the type of fertilizer, co-product credit, etc. Approximately 95 percent of ethanol production capacity in the United States relies on corn feedstock. Commercial production of ethanol from cellulosic feedstocks such as agricultural wastes, perennial grasses and wood chips is not yet available.

The debate over the energy benefits of using corn-based ethanol is on-going. Some research shows there is a net energy benefit; however experts are questioning the long term potential of its use. A summary of the key energy analyses include:

USDA ERS 1995, Wang 2005:

- There are net energy benefits from use of corn-based ethanol. *The energy contained in the fuel (ethanol) is higher than the energy used to produce the fuel.* For corn-based ethanol, the net energy benefit ranges from 24 to 35 percent, or from 20,000 to 30,000 Btu per gallon.

CRS Report for Congress. Updated October 19, 2006:

- In analyzing the net energy consumption of corn-based ethanol, the entire energy cycle must be considered. These inputs include energy needed to produce fertilizers, operation of farm equipment, transportation, conversion from corn to ethanol and distribution of the final product. *The amount of energy needed to produce corn-based ethanol is approximately equal to the amount of energy obtained in combustion.*

Chesapeake Bay Commission, September 2007:

- Corn-based ethanol only provides a limited net energy benefit over the energy required to produce it, as compared to the likely net energy benefit from cellulosic ethanol.

MIT Study, Groode 2006

- Gasoline has a higher energy content than ethanol. Higher ethanol blends have lower heating values; therefore having higher fuel consumption. Table 1 shows the heating values and fuel consumption for different ethanol blends compared to gasoline. Considering the energy content, one gallon of ethanol displaces 0.67 gallons of gasoline.

TABLE 1

	Energy Content *(MJ/L)* *megajoules per liter*	**Fuel Consumption** *(L/100-km)* *liters per 100 kilometers*
Gasoline	33	8.6
E10	32	8.8
E85	25	11.5
E100	23	12.2

Source: Groode 2006

Greenhouse Gas Benefits of Ethanol

Questions have been raised about the net greenhouse gas benefit of ethanol compared to gasoline. Specifically, researchers and policymakers have asked whether using corn-based ethanol as an alternative to gasoline results in reduced emissions of greenhouse gases. The key factors to consider in answering this question are relative CO_2 emissions from production and consumption of the fuel.

Combustion of gasoline releases more CO_2 to the atmosphere than corn-based ethanol. CO_2 is removed from the atmosphere to produce the ethanol feedstock, therefore the net CO_2 emissions from *combustion* of ethanol is zero. Corn-based ethanol *production* however releases more greenhouse gases than gasoline *production*. Therefore, corn-based ethanol provides only marginal reductions in greenhouse gases compared to gasoline because of the emissions associates with producing and transporting the corn feedstock, and the emissions associated with energy use during ethanol production. The extent of any greenhouse gas benefits is also affected by whether ethanol is blended with gasoline.

A summary of the key studies evaluating the greenhouse gas benefits of ethanol are summarized below:

Argonne National Laboratory. Wang 2005:

- Corn-based ethanol reduces greenhouse gases by 18 to 29 percent. Greenhouse gas benefits from cellulosic ethanol are greater (up to 85 percent reduction) because less energy is needed to produce the cellulosic feedstock.

Farrell et al. 2006:

- Use of corn-based ethanol results in a 13 percent reduction in greenhouse gases compared to gasoline.

MIT Study Groode 2006:

- Study found that there are no net greenhouse gas benefits when comparing ethanol to gasoline without consideration of co-benefits associated with ethanol production. Ethanol production generates non-fuel co-products (e.g., corn sweetener, commercial grade CO_2, and corn gluten as animal feed[1]) that should be considered when assessing net energy and CO_2 emissions. Use of ethanol was found to reduce greenhouse gas emissions compared to gasoline only when the greenhouse gas impact of ethanol co-products was factored into the analysis. This finding was based on an assumed 20-40 percent co-benefit, and that the "co-product is displacing a good that is already in the market and therefore is displacing the amount of fossil fuel consumed and greenhouse gas released during its production." Greenhouse gas reductions ranged from 2 to 30 percent when co-products were considered.

Table 2 compares the GHG emissions based on fuel production and fuel consumption of ethanol and gasoline.

[1] When corn is converted into ethanol, one material that remains is a high valuable feedstock. The ACE lists two types of co-products, distiller grain and carbon dioxide (CO2). Dried distillers grain with solubles is a high quality feedstuff ration for dairy cattle, beef cattle, swine, poultry, and aquaculture. The feed is an economical partial replacement for corn, soybean meal, and dicalcium phosphate in livestock and poultry feeds. CO_2 is produced during the fermentation stage of ethanol production. It is processed then sold to other industries, used to carbonate beverages, to manufacture dry ice, and to flash freeze meat. CO_2 is also used by paper mills and other food processors.

TABLE 2

	Fuel Production (gCO2-equ/L) gramsCarbon Dioxide equivalent per liter	Fuel Use (gCO2-equ/L) gramsCarbon Dioxide equivalent per liter	Total (gCO2-equ/L) gramsCarbon Dioxide equivalent per liter
Ethanol	2,430 (+/-) 330	0	2,430 (+/-) 330
Gasoline	660(3)	2400	3,060

Source: Groode 2006.

Table 3 compares the GHG emissions of corn-based ethanol blends for no co-product credit to 20% and 40% co-product credit.

TABLE 3

Corn-based Ethanol GHG Emissions (gCO2/km-traveled) gramsCarbon Dioxide per kilometers traveled			
	No Co-Product Credits	20% Co-Product Credits	40% Co-Product Credits
E10	+2%	0%	-2%
E85	+20%	-4%	-23%
E100	+23%	-4.5%	-30%

Source: Groode 2006.

Studies suggest that cellulosic ethanol provides significantly higher greenhouse gas benefits than corn-based ethanol because less energy is required to produce the feedstock. Ethanol from cellulosic sources such as switchgrass, corn stover (stalks and leaves) and wood chips is not yet commercially viable. The production and availability depends upon innovative technology. The U.S. Department of Energy awarded a grant to offset the cost of constructing six cellulosic ethanol plants. The goal is to have the cost of cellulosic ethanol competitive with gasoline be 2012.[2]

Other Environmental Impacts of Ethanol

The growth of ethanol fueled cars has grown tremendously, as evidenced by the increased number of ethanol vehicles that are now available on the market. One of the main reasons is its environmental benefits. Ethanol proponents such as the Department of Energy and the National Ethanol Vehicle Coalition assert the following overall environmental benefits:

[2] The U.S. House of Representatives recently passed its version of the Energy Bill, (H.R.3221), making concessions for the biofuels industry. One of the provisions calls for programs to increase energy efficiency in the operation of biorefineries and to enable biorefineries that exclusively use corn grain or corn starch as a feedstock to produce ethanol, to be retrofitted to accept a range of biomass, including cellulosic feedstocks.

- Ethanol blends are likely to reduce carbon monoxide emissions in vehicles by between 10% - 30%, depending upon the combustion technology.
- Ethanol contains 35% oxygen, making it burn more cleanly and completely than gasoline.
- E85 contains 80% fewer gum-forming compounds than gasoline.
- Ethanol is highly biodegradable, making it safer for the environment.
- Oxides of nitrogen (NOx) emissions are about the same for ethanol and gasoline vehicles.
- E85 has fewer highly volatile components than gasoline and so has less evaporative emissions.
- Ethanol has a high octane rating, which is beneficial for engines that are designed to operate on higher octane fuels.

In September 2007, the Chesapeake Bay Commission published a study called "Biofuels And the Bay" which details the impacts of biofuels on the Chesapeake Bay watershed. The report discusses the forestry and agricultural concerns related to reductions in nitrogen, phosphorus and sediment loads to the Bay. Forests cover close to 60 percent of the watershed and agricultural lands comprise 22 percent of the watershed. There are substantial efforts underway to reduce the nutrient overloading to tributaries and the Bay. The growing demand for biofuels development, with provisions introduced in the Energy Bill, has the potential to change the Bay's ecological profile. The most immediate concern is as the demands for corn-based ethanol increases so will the acreage planted to corn grown as feedstock. This potential increase in local crops will make it difficult for the Bay to achieve nutrient reduction loads.

Implications/Conclusion

Based on current information, existing production of ethanol is from corn-based sources. Producing corn-based ethanol does provide a net energy benefit, but there are only marginal reductions in greenhouse gases when used as an alternative to gasoline. It is possible that cellulosic ethanol technologies can be commercialized which would provide higher net energy benefits and greater greenhouse gas reductions.

Information Sources

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