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Ethanol Energy Balances

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The energy balance calculation for corn ethanol has been a controversial and often distorted subject in the political arena. Congress is now in the process of crafting a comprehensive energy bill, and the ongoing debate over policies to increase fuel ethanol use has raised the public's awareness of the energy balance issue. The Senate version of the energy bill includes a Renewable Fuels Standard (RFS) provision for motor fuels that would increase the amount of fuel derived from biomass sources from 2.3 billion gallons in 2004 to 5 billion gallons by 2012. Last year (2001), the U.S. produced 1.77 billion gallons of ethanol from biomass sources. It is expected that most of the RFS requirement will be met by ethanol, with biodiesel making up the remainder. Almost all the fuel ethanol used in the U.S. today is derived from corn, but a small amount is also produced from other grains such as wheat and sorghum.

Corn Ethanol Energy Balances

In the early eighties, some studies concluded that the energy inputs for producing corn ethanol were greater than or about equal to the energy contained in the ethanol product. In the last twenty years, significant advances in farming techniques and improvements in ethanol production have occurred, and recent studies have concluded that the energy balances are now positive.

The net energy gain is defined as the difference between the energy in the fuel product (output energy) and the energy needed to produce the product (input energy). The net energy gain is often expressed as a percent of the input energy. The input energies are life-cycle energies, e.g., for gasoline, they include the energy needed for extracting and refining crude oil. Using the latest energy data for agricultural requirements and ethanol plant use, several studies released in 2002 estimated that the net energy gain for corn ethanol is between 21 and 34 percent today (Table 1). Wang (2002) estimates that with further improvements in agricultural practices and improvements made to ethanol plants, the net energy gain will increase to 47 percent in the near future. Graboski (2002) estimates a similar net energy gain by 2010. For comparison, the net energy losses are between 19 and 20 percent for gasoline, and about 33 percent for methyl tertiary butyl ether (MTBE).

The Wang and Shapouri (Shapouri 2002) results include the total energy inputs, while the Graboski results were limited to the fossil energy inputs. A small amount of non fossil energy, primarily nuclear and hydro, is used to generate electricity that is supplied to the ethanol plant. The Argonne National Laboratory (ANL) Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model estimates that the contribution of the non fossil energy inputs for corn ethanol are less than 0.5 percent of the fossil energy inputs. The petroleum energy balances are also an important measure for alternative fuels, since developing non petroleum transportation fuels is a strategic priority for the United States. The petroleum energy inputs for ethanol production are small, about 0.09 BTUs of petroleum energy for every BTU of ethanol produced (GREET V1.6). That is, the production of ethanol uses abundant domestic supplies of coal and natural gas in lieu of petroleum.

Table 1. Energy Balance Ratios

	Ratio of Energy Input to Energy Output	Net Energy Gain/Loss (percent)
Current Ethanol Energy Balances		
Wang (2002)	0.76	31
Shapouri (2002)	0.75	34
Graboski (2002)	0.82	21
Future Corn Ethanol Energy Balances		
Wang (2002)	0.68	47
Gasoline Energy Balances (GREET V1.6)		
Conventional Gasoline	1.24	-19
Reformulated Gasoline (RFG)	1.26	-20
MTBE	1.48	-33

Because ethanol competes with gasoline and MTBE, comparing their energy balances is the most meaningful way of assessing the impact of substituting ethanol for gasoline or MTBE. The energy requirements for ethanol are between 33 and 44 percent less than those of gasoline, and between 44 and 50 percent less than those of MTBE (Table 2). Wang estimates these savings will increase to 45 percent for gasoline and 54 percent for MTBE in the near future.

Table 2. Reduction in Energy Inputs for Ethanol Compared to Gasoline and MTBE

	Percent Reduction Relative to Conventional Gasoline	Percent Reduction Relative to MTBE
Current Corn Ethanol Energy Balances		
Wang (2002)	-39%	-49%
Shapouri (2002)	-40%	-50%
Graboski (2002)	-33%	-44%
Future Corn Ethanol Energy Balances		
Wang (2002)	-45%	-54%

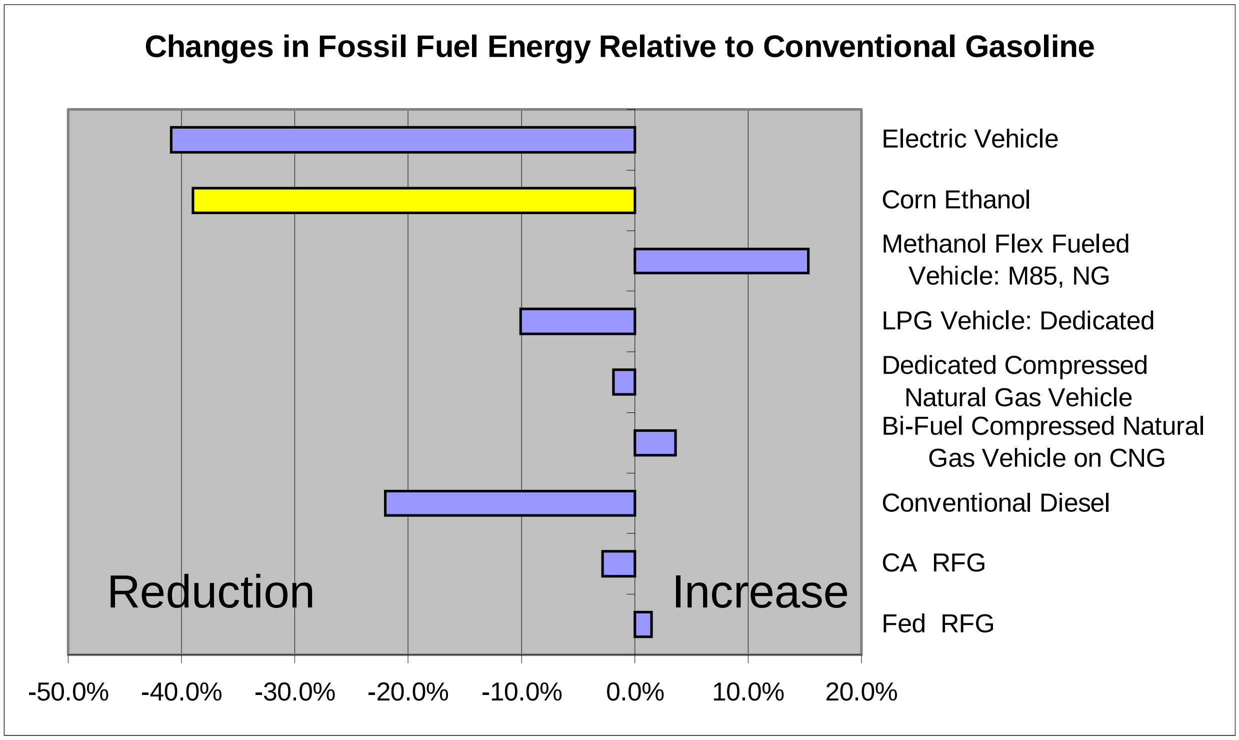

Figure 1 Changes in Fossil Fuel Energy Requirements for Alternatives Fuels / Vehicles Compared to Gasoline for Near-Term Technologies (Source: GREET V1.6)

The GREET model calculates fossil fuel energy requirements on a per-mile basis for the major alternative fuels and vehicle systems. Figure 1 shows these changes relative to using conventional gasoline for the near-term alternative fuel choices. The fossil energy savings for corn ethanol are comparable to those of electric vehicles (about 40 percent), and considerably greater than those of LPG and compressed natural gas (CNG). Fossil energy savings for LPG are only about 10 percent, while fossil energy requirements for CNG vehicles are about 4 percent greater than those of conventional gasoline. Fossil energy savings for corn ethanol are almost twice as much as those of conventional diesel. While diesel fuels are more efficient than gasoline fuels, pollution from today's diesel engines is much greater than from gasoline engines. The energy requirement for reformulated gasoline (RFG) designed to reduce emissions of air pollutants is a little greater than that of conventional gasoline, primarily due to the fact that most RFG now contains an 11 percent MTBE concentration.

Figure 2 compares the changes in petroleum energy requirements for the near-term transportation alternatives. The non petroleum-based alternative fuels – corn ethanol, LPG, and CNG – all provide a reduction of more than 90 percent in petroleum energy, as do electric vehicles.

Out of all the alternative fuels, only corn ethanol and electric vehicles provide substantial savings in both fossil energy and petroleum energy. However, the number of electric vehicles on the road today is very small and without significant advances in battery storage technologies, electric vehicles will remain a niche technology. The advantage of ethanol is that gasoline containing up to10 percent ethanol can be used in all cars in the U.S. today without any modifications, and ethanol blends are routinely used in the existing gasoline distribution infrastructure.

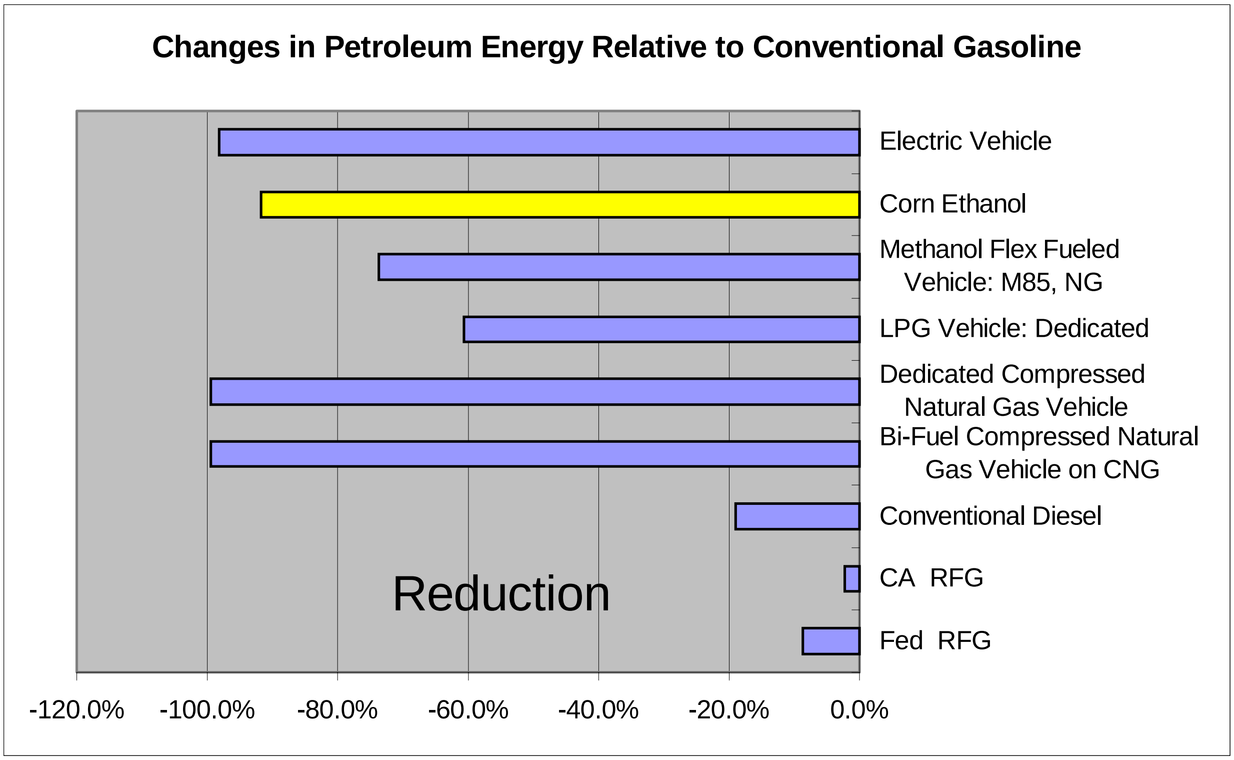

Figure 2 Petroleum Energy Reductions for Alternatives Fuels / Vehicles Compared to Gasoline for Near-Term Technologies (Source: GREET V1.6)

Cellulosic Ethanol

Fuel ethanol in the United States is currently produced from starch-based crops like corn, but scientists are working on ways to develop more efficient and economical methods for converting cellulosic matter to ethanol. As this technology matures, the nation’s vast reservoir of agricultural residues, and eventually energy crops, will serve as the feedstocks to significantly expand ethanol production. The corn ethanol industry can easily meet an RFS requirement of 5 billion gallons of ethanol. However, expanding ethanol production past 6 to 8 billion gallons per year will require a transition to cellulosic ethanol.

A major difference between cellulosic and corn ethanol plants is their source of power. Corn ethanol plants use purchased fossil fuel sources, while cellulosic ethanol plants incorporate an integrated power plant that uses the lignin in the feedstock to generate electricity and heat for process energy. Because most of the energy requirements associated with cellulosic ethanol production are derived from renewable sources, the conversion process uses virtually no fossil fuels. A 1999 ANL report (Wang 1999) estimated that cellulosic ethanol can reduce fossil energy consumption relative to gasoline by 88 to more than 100 percent, depending on the type of feedstock. Reductions of fossil energy by more than100 percent come from a co-product credit for the sale of excess electricity from cellulosic ethanol plants. The cellulosic ethanol fuel cycle has an added benefit of emitting virtually no net greenhouse gases.

According to the GREET Model's estimates for future technologies, fuel cells using fossil fuels can reduce fossil energy requirements relative to RFG significantly. The reductions range from 28 percent when methanol is used to 43 percent when CNG or LPG is used. When gasoline is used in fuel cells, the reductions are between 35 and 38 percent. For electric vehicles, fossil energy reductions are about 50 percent. Reductions for future corn ethanol used in conventional gasoline vehicles (Table 1) are estimated at 45 percent (relative to conventional gasoline, a little greater relative to RFG), and compare favorably with those of fuel cells using fossil fuels and electric vehicles. However, when ethanol is used in fuel cells, the fossil fuel reductions relative to RFG are 71 percent for corn ethanol and 99 percent for cellulosic ethanol. Cellulosic ethanol is the only transportation fuel option on the drawing board that can reduce fossil fuel energy by about 90 percent or more, whether used in conventional vehicles or fuel cells.

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