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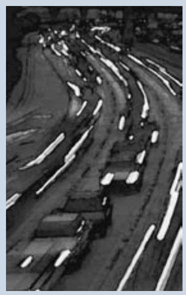

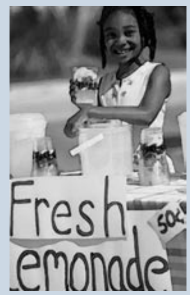

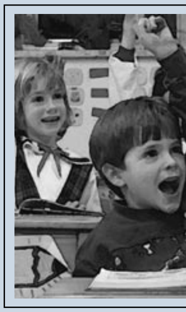

Corn Ethanol: Right Problem, Poor Solution

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Executive Summary

The corporate welfare program for corn ethanol is inefficient and environmentally harmful. Energy independence is a genuine problem, but subsidizing corn ethanol is a bad solution:

- Burning corn ethanol instead of gasoline releases 1.7 times more carbon dioxide for every vehicle mile traveled.
- Corn ethanol is so inefficient that the energy contained in a gallon of ethanol is about 7 percent less than the total amount of energy from coal, oil, and natural gas that is required to produce the ethanol.
- The taxpayer subsidies for making ethanol from corn are equivalent to more than a dollar a gallon for gasoline.
- Subsidizing the use of corn for fuel significantly raises food prices.
- The United States has too little cropland available to come close to replacing gasoline through ethanol production.
- The best ethanol policy would be to repeal the laws which artificially raise the price of cane sugar. Corn ethanol is economically viable only with massive subsidies. In contrast, ethanol from cane sugar could be a legitimate part of the U.S. energy supply—if the feedstock sugar were available at world market prices.

I. Why Ethanol Is So Inefficient:

In the 2006 State of the Union Address, President Bush announced an initiative to expand the production of ethanol. He promised even more subsidies in the 2007 State of the Union. Unfortunately, the increasing emphasis on corn ethanol is a distraction from workable energy solutions.

A careful analysis requires starting with the elementary physics principle that it takes energy to move automobiles. The automobile engine uses chemical energy in the fuel to produce mechanical energy and thereby move the vehicle. Liquid hydrocarbon fuels are preferred for autos because they are easy to distribute, easy to convert into mechanical energy, and after a century of consumer and business experience, safer to handle relative to other sources.

Gasoline and ethanol are both hydrocarbons; they are made up mostly of hydrogen and carbon atoms. Ethanol has an oxygen atom already attached within the molecule; that is why it is called an oxygenated fuel. Gasoline is a soup of many hydrocarbon chemicals, most of which have many hydrogen atoms and relatively few carbon atoms. Hydrogen releases more energy pound for pound than any other fuel, which is why pure hydrogen powers the Space Shuttle.

Because it has relatively many hydrogen atoms, burning gasoline releases a great deal of energy. A gallon of gasoline weighs a little less than six pounds, and produces 120,750 British Thermal Units (BTUs)[1] of energy. For comparison, that is as much energy as the average home furnace can produce in an hour.

Mechanical energy created in an automobile engine is produced by combustion. In the combustion process, atmospheric oxygen combines with the hydrogen and carbon atoms in the fuel, thereby releasing heat energy. Ethanol has fewer hydrogen atoms per pound than gasoline, and unlike gasoline, ethanol already has oxygen atoms. Hence, less energy can be released by the burning of ethanol. As a result, a gallon of ethanol weighs a little more than a gallon of gasoline, yet releases only 74,200 BTUs[2] of energy when burned. In other words, the gallon of ethanol produces only about 62 percent as much energy as the gallon of gasoline. The flex fuel E-85 is 85 percent ethanol and 15 percent gasoline and contains only two-thirds the energy of gasoline. If a car gets 20 miles per gallon on gasoline, it will get about 13.5 on E-85.

II. The Inefficiencies of Making Corn Ethanol

Ethanol fuel from corn is produced by first converting the starches in the corn kernels into sugars by malting. Malting is the process of keeping moistened corn kernels warm until they start to sprout. The natural enzymes involved then change the starch into sugar. Thereafter, it is the action of living yeasts that ferment the sugars into ethanol.

Growing the corn and getting the corn to market takes a lot of energy, most of which comes from fossil fuels. Because corn is an annual crop, an energy-intensive growth season is required just to provide the seed for the next year's crops that will be converted into ethanol. Plowing and planting corn requires fuel for the equipment. Irrigation often requires pumps, which can be driven by electricity or by an on-site engine. Fertilization requires tractors, and the fertilizer itself is mostly made from natural gas. Harvesting demands fuel for the combines and the haul trucks. If the weather does not cooperate, the corn has to be dried using forced air heat or it will rot.

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Once the corn reaches an ethanol biorefinery, more energy is required to malt the corn and for industrial needs at the distillery, such as heating, cooling, pumping and other processes. Most of the distillery's energy comes from coal burned at power plants to make electricity. The energy required for distillation itself is significant, and comes mostly from direct-fired boilers using mainly natural gas or propane.

Adapted from the work of economist Dr. Steve Stoft, Fig.1a shows an aggregate of the energy required for corn ethanol production.[3] The graph contains some pro-ethanol assumptions because it is based on the Argonne National Lab study by Dr. Michael Wang.[4] Fig.1a shows that 74 percent of the energy required for corn ethanol comes from fossil fuels, and only 22 percent is free energy from the sun. (Other studies, presented later in this paper, show that the 22 percent solar energy gain for corn is overstated.)

In Fig.1b.we see sugar cane-based ethanol energy inputs, which have a far greater input from the sun. The solar input is much greater because less energy is required from fossil fuels for all the cane processing steps.[5]

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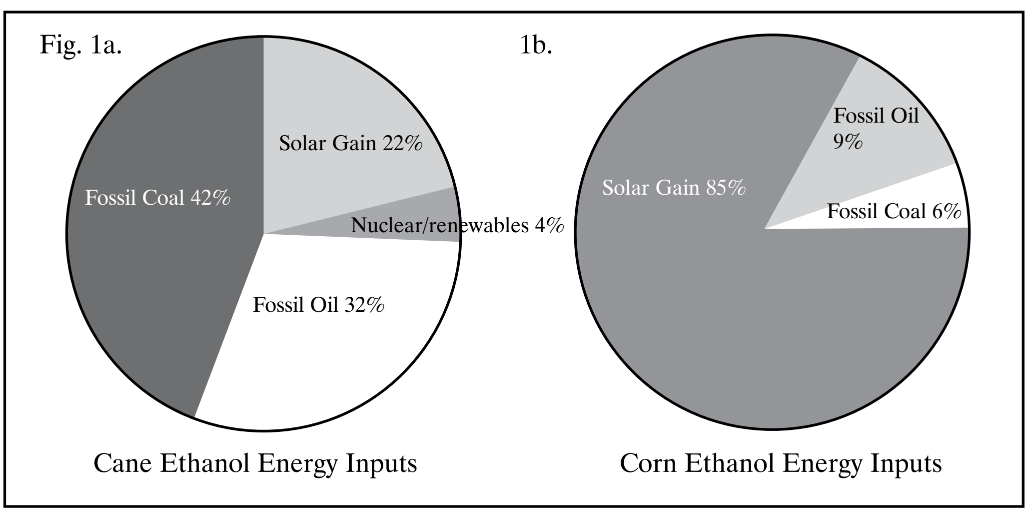
A study of the Brazilian bio-ethanol industry found that roughly 6.7 billion Joules (GJ) of energy per hectare is required for growing and processing sugar cane in Brazil.[6] Most of the energy used to produce cane ethanol is diesel fuel. If the current cane sugar grown in Florida and Louisiana were used for ethanol, the output would be about 3,500 gallons per hectare—much greater than the 1,000 gallons from a typical hectare of corn. Not only can cane ethanol generate much more energy



per hectare than corn ethanol, cane ethanol also requires much less energy to create. The production of cane ethanol needs about a fifth or a seventh as much fossil fuel energy per gallon compared to corn ethanol.

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The economic barrier against much greater use of cane ethanol in the U.S. is the price and quota support system for sugar. Corporate welfare programs keep the price of U.S. sugar artificially high, and thereby all but discourage use of domestic sugar cane for ethanol. The sugar support problem will be discussed further in Section IV, "Corporate Welfare Issues."

A number of researchers have completed studies of corn ethanol energy efficiency. Various studies show energy balances ranging from a very good 1.65 to a very bad 0.58. That is a very large variation. "Energy balance" is the ratio of chemical energy contained in the ethanol divided by the fossil fuel energy required to produce the ethanol. A balance greater than 1.0 is positive; in other words, if the "energy balance is greater than 1.0; it means the energy in the ethanol is greater than the energy used to make the ethanol.

Most widely-known is the 1997 "Argonne study," led by environmental analyst Dr. Michael Wang, which showed a gain of 46 percent (an energy balance of 1.46).[7] Five years later a revised study led by the U.S. Department of Agriculture's Hosein Shapouri, with Wang's participation, showed an energy balance of 1.34.[8] Advocates of corn ethanol subsidies cite the Argonne study and sometimes the 2002 Shapouri revision as definitive proof that corn ethanol production has positive energy returns. The problem is that both studies have omitted major categories of energy usage included by other researchers. Making these additional usage adjustments to the 2002 Shapouri study yields a revised balance of 1.05, which is still thought to be very optimistic.

In 2006, Roel Hammerschlag of The Institute for Lifecycle Environmental Assessment conducted a meta-analysis of previous studies[9] The same year, Professor Tad W. Patzek of the University of California at Berkley updated his research and surveyed still other studies, all of which are very extensive and generally exceed 100 pages.[10] Many variables likely have changed since they were first conducted, and many more will change or emerge over the next 10 years. The very nature of the studies requires the authors to make many assumptions and create many subcategories of energy usage in their analysis.

Because the results of these studies varied so much, I performed a new survey study. The first step in evaluating the papers was to analyze the result differences for each shared sub-category and to re-assign a new weight for an overall sub-category result. For example, it seemed reasonable to discount those portions of Wang's earlier Argonne study that differed sharply from Shapouri, because Wang was a co-author with Shapouri and it was assumed that the more recent work updated the earlier.

How Hammerschlag and Patzek treated these same studies in their surveys was looked at as a second step. For example, the higher-yielding results in the Hammerschlag survey had all included high off-setting values of co-products like corn oil and syrup. However, only a few ethanol bio-refineries actually create co-products such as corn oil or corn syrup.[11] Further, it appears that since ethanol can be distilled from poor quality corn, there will be less incentive to use food quality corn.

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Cornell University professor David Pimentel[12] has written dozens of publications on the subjects of energy efficiency in agriculture. Pointing out that growing corn greatly depletes soils, he argues that in the long run corn yield will decline significantly per acre. The resulting lower yields will drive up energy usage in corn production. While Pimentel might be correct, corn yields will likely remain high over the next few years.

The third step in analyzing why the studies varied so much was to apply the experience of my participation in the family's eastern Nebraska corn farm. For example, we have seen firsthand the soil depletion issue addressed by Professor Pimentel. However, my analysis is less pessimistic than Pimentel's. We rotated between corn and soybeans precisely because soy fixes nitrogen that is depleted by growing corn. However, as the price of corn rises to meet ethanol demand, it becomes more profitable to fertilize and not to rotate in soybeans. Growing only corn drives up the demand for fertilizer because nitrogen-fixing crops like soybeans are not used to replenish the soil. The additional requirement for annual fertilization is often overlooked, causing the energy of fertilizer to be under-represented in some studies.

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The following are points of analysis of the similarities and differences used to sort between the studies and to derive a single energy balance for this paper:

- Pimentel's 2003 estimate of fossil fuel energy plus irrigation is identical with that of Shapouri et al.
- Kim & Dale and Lorenz & Morris use far less fuel for farming than all the other studies because they unrealistically assumed that all the corn was grown by "no-tilling" planting techniques.
- Pimentel's 2003 lime application rate is twice the rate used in all the other studies, but Pimental's figure is best because it reflects the actual 1997 USDA average.
- Pimentel calculated more data for biocides and other soil-building chemicals than did the other studies.
- Pimentel's 2003 transportation energy is higher than in other studies because it includes more extensive cultivation during the growing season. His calculations are consistent with the marketing models used by farm machinery manufacturers.
- The studies by Shapouri, Wang, Kim & Dale, and by Lorenz & Morris all underestimated the fossil energy required to produce seeds.
- Wang, Kim & Dale, Shapouri, and Lorenz & Morris did not include the energy used by the infrastructure for making farm machinery and creating the infrastructure of farms.
- Patzek added his own seed energy estimate but also left out the energy estimate required to make the farm machinery.
- Berthiaume et al. (2001) have not included several of the energy inputs involved in corn farming noted by other studies.
- The estimates of fossil energy inputs range from 19 GJ/ha (Wang) to 33 GJ/ha (Pimentel), with the Patzek estimate being 28 GJ/ha. Just under 30 GJ/ha is consistent with actual farm machinery depreciation rates.
- Wang's farm machinery fuel estimates are consistently too low. Kim & Dale and Lorenz & Morris are also very low. Shapouri's and Patzek's estimates are almost identical.
- The fossil energy use in corn farming is large and equivalent to between 0.4 (Wang) and 0.7 (Pimentel) metric tons of gasoline per hectare and per crop. Shapouri's revision of Wang's study showed a significant increase over Wang and close to Pimentel.
- The Marland & Turhollow and Loenz & Morris studies are now quite dated. As a result, the data from other studies carried more weight.
- The earlier work of Pimentel and Patzek had both been criticized for being too pessimistic. The 2005 publications by Pimentel and Patzek, in which they effectively addressed the criticisms of their previous work, by supplying additional data, were even more pessimistic.
- The "average" energy use in corn farming does not tell the whole story because of the very large variability of energy use from one corn-growing state to another.
- Some studies included "upstream" energy required to get the fuels used in corn and ethanol production to their point of use. Where these calculations were done, those estimates seem too low.

My synthesis of these works is summarized by the graph in fig. 2. The most plausible result is an energy loss of 7 percent, or an energy balance of 0.93. Further, it is believed that the overall energy balance will remain stable at or about 0.93 for the next 10 years.

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III. The Carbon Dioxide Problem

Fueling vehicles with corn ethanol causes the release of much more carbon dioxide than gasoline does for the same vehicle miles traveled. This is because the fossil fuel energy required to make the ethanol is biased towards coal, which is mostly carbon. The result is the release of a large amount of CO2.

The 7 percent efficiency loss in energy means that creating a gallon of ethanol containing 74,200 BTUs[13] of energy requires a calculated 79,500 BTUs of energy from fossil fuels.[14]

Coal is mostly carbon, but the energy content of coal varies greatly depending on the type of coal. Most of the coal used in the corn-raising regions comes from western mines, which average about 80 percent carbon. The rest is mostly non-combustible dirt and ash. When burned, this type of coal produces only 15,000-16,000 BTUs per pound. So to make a gallon of ethanol would require burning about 2.16 pounds of coal—if the coal were burned with 100 percent efficiency. Coal-fired electrical generating plants rarely exceed 60 percent efficiency; so at least another 1.5 pounds is necessary to make up for the inefficiencies. Since western coal is 80 percent carbon, burning 3.66 pounds[15] of coal is really burning 2.9 pounds of carbon. So the electrical energy used in the production of a gallon of corn ethanol will put about 2.9 pounds of carbon into the atmosphere. [16]

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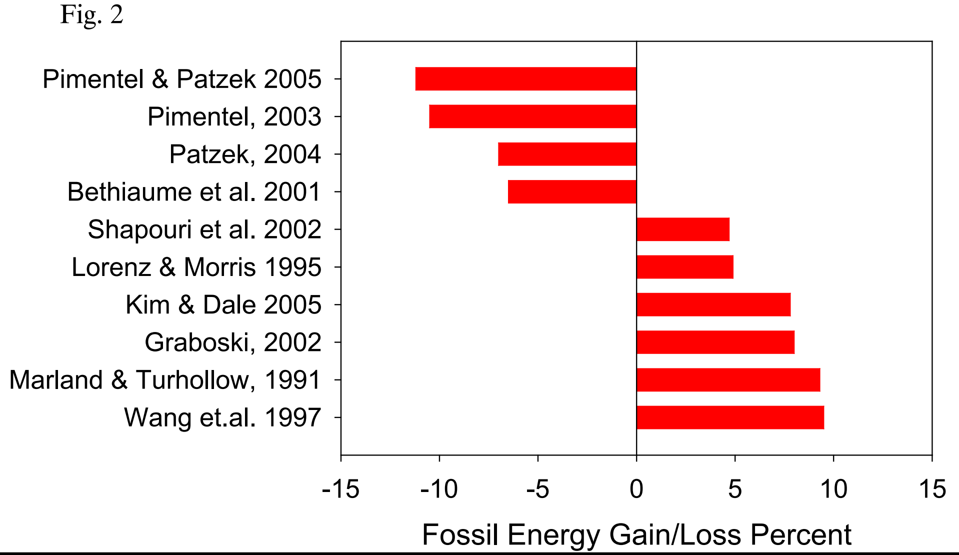
Corn ethanol production also requires energy from natural gas and petroleum. Compared to coal, natural gas and petroleum have a greater abundance of hydrogen.[17] Unfortunately, the engines and machines that release the energy stored in oil or natural gas are usually much less thermodynamically efficient than are coal-fired power plants. Hence, the burning of oil and natural gas for ethanol production releases

Fig. 2



an additional 2.5 pounds of carbon per gallon of corn ethanol.[18]

A carbon atom weighs 12 atomic units, and an oxygen atom weighs 16 units. Therefore, a CO2 molecule weighs 44 units. The carbon from the coal, oil, and natural gas totals 5.4 pounds. This means that there are 19.8 pounds of carbon dioxide released from fossil fuels in all the processes required to make one gallon of ethanol. Because a gallon of ethanol contains only about 62 percent as much energy as a gallon of gasoline, it requires about 1.63 gallons of ethanol to get the same energy to move an automobile the same distance as one gallon of gasoline. Thus, about 32.3 pounds of CO2 will be released from fossil fuels to make the corn ethanol that will move a corn ethanol-powered automobile the same distance as a similar vehicle fueled by a gallon of gasoline.

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A. Carbon dioxide from fermenting and burning ethanol

It is not generally realized just how much carbon dioxide is produced in the fermenting process. It does not matter if the ethanol comes from sugar cane or corn. In the case of corn, the action of the yeast on the glucose molecule produces two molecules of ethanol and two molecules of carbon dioxide. For every gallon of ethanol that is distilled, 6.22 pounds of carbon dioxide are produced.[19]

Because the ethanol molecule itself contains two carbon atoms, burning it in an engine turns the carbon atoms into CO2 molecules. As measured by tests conducted by ASTM,[20] burning a gallon of ethanol in an engine releases 12.5 pounds of carbon dioxide,

B. Comparing the release of CO2 from burning a gallon of gasoline

A gallon of gasoline averages about 84 percent carbon by weight. Gasoline weighs a bit less than 6 pounds per gallon, which means the carbon content is about 5 pounds per gallon. Modern automobiles with catalytic converters turn virtually all the carbon into CO2. The result is the release of 18 and one-third pounds of carbon dioxide per gallon.[21]

There are also the carbon releases from the extraction, transportation, refining and distribution of petroleum products such as gasoline. A field trip to the Alaska Pipeline revealed how efficient extraction and pumping can be. It was noted during a visit to several pumping stations on the Alaska Pipeline that three stations tapped the line and processed the crude in mini-refineries that had the capacity to make up to about 10,000 barrels a day. This fuel runs the pumps and other equipment south of the Brooks Range. The refineries were designed so that any two could make enough fuel to maintain pumping at about 2 million barrels a day of maximum capacity. Also discovered is that there is a similarly-sized operation north of the Brooks Range fueled by natural gas which runs the North Slope operations. Engineering calculations indicate that much less than 1 percent of the energy contained in the current pumping rate of 1.5 million barrels a day is used to run the whole enterprise.

A great deal of North Slope petroleum is shipped to California. Specific fuel efficiencies of ships are difficult to determine because private companies consider it a trade secret and navies consider it a state secret. However, one Australian government study was found that provided specific data up through 1989.[22] A 14-knot, less than six-day trip from Valdez to Long Beach would require 546 tons of fuel to move 230,000 tons of crude oil. A seven-and-a-half day trip, at 11 knots, would require only 335 tons of fuel. The study also predicted that by 2005, fuel efficiencies would have improved by another 15 percent. Considering the hundreds of millions of dollars spent annually worldwide in the quest to improve ship fuel efficiencies, the prediction likely was met. The study also noted that at the same speed, it takes only twice the fuel to move a ship five times as large. The size limit at the port of Valdez is 270,000 dead weight tons. The EXXON VALDEZ carried 200,000 tons or 1.47 million barrels, which is about one day of current pipeline production. Ultra-large tankers are defined as over 300,000 deadweight tons (DWT) and go to more than 550,000 DWT. The rising price of crude on world markets could well mean that just one cargo load could cost $200 to $300 million or more. That is about twice as valuable as the original cost of the ship. Because the time value of money is significant, faster ships capable of 16 to 17 knots mean greater systems efficiency but poorer ship fuel economy. These factors are why the engineering estimate of the energy required to deliver crude oil by ship is less than 3 percent of the energy content of the cargo.

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Petroleum refineries have had more than a century of experience in finding ways to save the costs of their energy consumption, and refiners regard their efficiencies as trade secrets. One way to estimate how much CO_2 is released producing a gallon of gasoline is to monitor the emissions of the refineries.

Science is full of situations where the relationships between phenomena are known, but where the specific targeted phenomena cannot be directly measured. If the related phenomena can be measured, and knowing the relationship, the measurement of the targeted phenomena can be inferred with confidence. This is the technique by which astronomers measure the distance to other galaxies. There is no way to directly measure the distance, but astronomers can measure "red shift." Because the further away galaxies are, the faster they are moving away from us. Their distance is indirectly measured by their light appearing redder.

In California, nearly all the emissions can be sourced back to the petroleum feedstock going into the refineries. Determining the emissions that come from refineries allows observers to infer refining efficiency, and thereby allows us to estimate how much CO_2 is generated in the refining process.

The LBNL[23] Refinery Study for the state of California found that only 3 percent of petroleum-based emissions come from oil refining.[24] Refineries typically use the least marketable components of the refining process to burn as a source of heat for their operations. Virtually all refineries use some of the fuels they make to power their own electrical plants. California is almost a "closed system" when it comes to electrical power and refineries. Conventional electrical generation plants are fueled from the heavier distillates that come from local refineries. Any electrical power not generated at the refinery is very likely purchased from a customer using fuel made by the refinery.[25] Therefore, their efficiency losses are approximately proportional to their emissions, or about 3 percent.

The distribution of refined products is also efficient. Most refined products are sent down pipelines to distribution centers. The final destinations are retailers who are serviced by trucks. Most major urban areas are serviced by pipelines. Thus delivery trucks do not have to travel very far and can deliver for less than 1 percent of the energy of their cargo. This latter point is easily appreciated by observing the relative sizes of the cargo and fuel tanks. Large trucks have a product capacity between 4,000 and 9,000 gallons. The fuel tanks typically are less than 300 gallons. At 5 to 6 miles per gallon,[26] a truck could still deliver about 250 miles from the terminal for 1 percent of the cargo's energy. Most fuel is used in metropolitan areas where people live, and delivery trucks can make many round trips between the refineries or pipe line terminals and retail outlets before refueling.

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On a per-gallon basis, the carbon dioxide released from the time petroleum comes out of the ground until its refinement and distribution is fairly low. Using North Slope crude and California as a model, it can be calculated that extracting, transporting, refining and distribution requires about 8 percent of the energy contained in the petroleum. Because of the uncertainty of the assumptions, and to include other geographic regions that may import from the Middle East and truck significantly farther, another 20 percent was added to obtain the 9.6 percent used to calculate the pounds of CO2 emissions per gallon of gasoline used by the consumer.

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In sum, burning a gallon of gasoline releases about 20 pounds of carbon dioxide into the atmosphere. Compared to the 34 pounds released from the corn ethanol cycle,[27] gasoline is actually "green" by comparison.

C. There really is no good news in corn ethanol production

It takes 7 percent more fossil fuel energy to make corn ethanol than is contained in the ethanol. This means that for the "privilege" of supporting a corn ethanol program, we dig or pump at least 7 percent more fossil fuels from the ground then if we simply stayed with using only gasoline and diesel fuel to propel our cars and trucks.

Worse, making corn ethanol releases 14 more pounds of CO2 to provide the equivalent energy of a gallon of gasoline than if we simply fueled our cars with gasoline. A large portion of the fossil fuel used to make ethanol is coal, which, when burned, releases much more CO2 than using petroleum-based fuels like gasoline.

The CO2 from the fermentation and the subsequent burning of ethanol was originally extracted from the atmosphere by the corn plants. The photosynthesis process that takes place in living plants removes carbon dioxide out of the atmosphere and combines the carbon into new plant material. When plant material is processed into fuels it is done by fermentation at the biorefineries. CO2 generated at the biorefineries could be captured and sequestered or make other products like dry ice. For corn ethanol, that is the end of the good news.

The negative impacts of the corn ethanol programs on the environment are substantial. Certainly, more carbon dioxide being released is a problem, but there are even greater negative consequences, including water and soil depletion, as well as competition with growing food crops and others.

The net effect on American taxpayers is that subsidizing ethanol programs at the federal level is the equivalent of $1.01 per gallon of gasoline. But with new mandates for both more ethanol production and fleet mileage standards, the economic distortions will only grow more severe.

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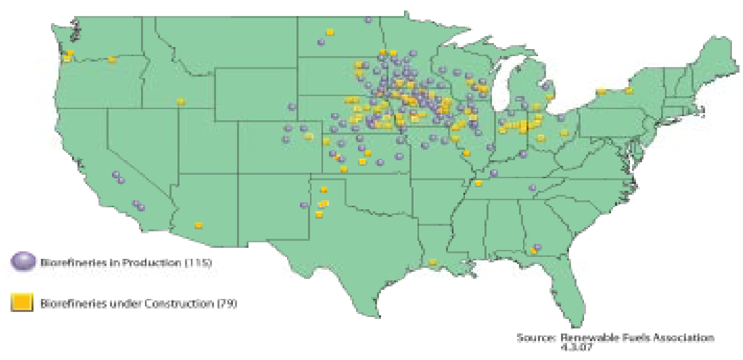
Because of the alliance between government and the special interest group of sugar growers, the interests of taxpayers have taken a long-term hit. Any and all distortions of free markets have had and will continue to have serious negative effects on the citizenry.

IV. Corporate Welfare Issues

Figure 3[28] shows the location of all domestic ethanol plants in 2007. The term "biorefineries" is now the industry-preferred term, probably because it sounds more politically correct than "distilleries." Not surprisingly, the Iowa state government has an especially high subsidy for ethanol distilleries/biorefineries.

Fig. 3

U.S. Ethanol Biorefinery Locations



The current direct per-gallon federal subsidy for ethanol is $.51,[29] which accrues to the distiller. Multiplying the total ethanol subsidy of $.51 times 1.63 (ratio of the energy equivalent of gasoline) results in a subsidy equivalent to $.83 for the energy contained in a gallon of gasoline, and before the price supports in the various agriculture programs.

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It is difficult to tell who really benefits from the ethanol subsidy because most of the biorefineries studied are not owned by publicly-traded corporations. It is possible that major agribusinesses may own about half the nation's corn distillation capacity. Farmers may own about 40 percent and the rest may be owned by other investors.[30]

Economics professors Bob Wisner and Phil Baumel determined that 2004 U.S. corn production was a little over 10 billion bushels per year, 1.37 billion bushels of which was used for ethanol production.[31] In the same year, the federal government paid more than $3 billion in direct subsidies, or about 30 cents a bushel, to corn growers.[32] The subsidy is about 11 cents per gallon, or 18 cents for the energy equivalent to a gallon of gasoline.[33] The combination of crop and ethanol subsidies raises the taxpayer-funded contribution for an equivalent gallon of gasoline to $1.01.

Currently, 115 ethanol biorefineries nationwide have the capacity to produce more than 5 billion gallons annually. Many expansions and new biorefineries are under construction, with a combined additional annual capacity of more than 4.2 billion gallons.[34] This expansion will take many new corn fields to satisfy the capacity and a lot of taxpayer dollars to provide the subsidies.

A. The sugar price support program

The system of sugar quotas, tariffs and subsidies started in 1789 as a means to raise government revenue. The United States did not have significant numbers of sugarcane growers until the Louisiana Purchase in 1803. After the Louisiana Purchase, the newly-American sugarcane growers were worried that the change in sovereignty would disrupt their sales to the French market. By 1816, lobbying was well underway. The system of sugar subsidies, tariffs and quotas is still in place, which is a good indication of what will happen with the ethanol subsidies, tariffs and quotas. U.S. sugar production grew until 1890, when the U.S. Treasury finally

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removed the tariff, resulting in a large inflow of low-priced world sugar. To compensate for the competition, U.S. sugar producers were given a 2-cent bounty per pound. Four years later, the bounty was replaced by a 40 percent tariff. The 40 percent tariff was sufficient to support the U.S. sugar industry until world prices became extremely low. At such low world prices, it became economical to import sugar and pay the tariff rather than to buy U.S. sugar. The increasing imports led to the Sugar Act of 1934, which established the current policy of import limitations and domestic marketing allotments to limit supply and support domestic prices.

Congress allowed the Sugar Act to expire in 1974 because world prices were then high. In May 1977, the U.S. Department of Agriculture instituted an emergency and temporary price support program because prices had fallen. The Food and Agriculture Act of 1977 increased price support subsidies. In 1982, the Reagan administration reintroduced import quotas. Tariffs, quotas and subsidies have been growing ever since.[35]

According to the USDA, as of 2004, "The U.S. sugar subsidy program is at $1.2 billion annually. The United States uses 9 million metric tons of sugar a year of which about 1.6 million metric tons is imported."[36] Before the enlargement of the domestic sugar subsidy program in the 1980s, the United States was importing about 3 million tons a year.[37] In 2005, imports exceeded 3 million tons but dropped to 2 million tons in 2006.

In 2004, the United States produced 7.8 million tons of sugar and 3.4 billion gallons of ethanol, ranking fifth and second in the world, respectively. That year Brazil produced 24.9 million tons of sugar and 3.9 billion gallons of ethanol, first in the world for both.[38]

B. The real costs of the sugar support programs

A recent study by the International Trade Administration (ITA) of the US Department of Commerce[39] found that:

- Employment in sugar-containing products (SCPs) industries decreased by more than 10,000 jobs between 1997 and 2002.
- For each sugar growing and harvesting job saved through protecting high U.S. sugar prices, nearly three confectionery manufacturing jobs are lost.
- For the confectionery industry, sugar costs are a major factor in relocation out of the country, because the cost of sugar was more than labor costs. In 2004, the price of U.S. refined sugar was 23.5 cents per pound compared to the world price of 10.9 cents.
- The subsequent imports of sugar containing products (SCPs) have grown rapidly from $6.7 billion in 1990, to $10.2 billion in 1997, up to $18.7 billion in 2004.

For each sugar growing and harvesting job saved through protecting high U.S. sugar prices, nearly three confectionery manufacturing jobs are lost

The study went on to state that the Federal Reserve reported that the annual cost for each job saved in growing and harvesting sugar is $824,104. At 22,261 sugar jobs saved, the total cost to the U.S. economy is $1.9 billion per year. A small number of sugar growers also directly benefit from the subsidies, receiving an estimated $400 million annually. This subsidy averages about 2.5 cents per pound. In addition, the government has a costly to the taxpayers but generous financing arrangement for the growers.[40]

On November 6, 1984, both Coca Cola and Pepsi announced plans to stop using cane sugar in soft drinks, replacing it with high-fructose corn syrup. U.S. sugar consumption suddenly decreased by more than 500,000 tons a year—equal to the entire quotas of 25 of the 42 nations previously allowed to sell sugar in the United States. The domestic price of sugar plummeted. On January 16, 1985, the Agriculture Secretary announced a 20 percent cut in the quota for all exporting countries, which raised domestic prices back to where they were. This development was not a good deal for U.S. consumers or foreign suppliers.

In early 1990, the Brach Candy Company announced plans to close its Chicago candy factory and relocate 3,000 jobs to Canada because of the high cost of sugar in the United States. Since Canada has no tropical growing regions, the nation has no political incentive for sugar protectionism; thus, in Canada sugar can be bought at the world market price.[41]

At the close of trading on October 12, 2007, the world price for sugar on the New York Board of Trade to be delivered in March 2008 was 9.80 cents per pound. Domestic sugar closed at 20.16 cents.[42] The average world price over the last few years has ranged from 5 cents to 15 cents. Domestic prices have ranged from 20 cents to 24 cents per pound, or from 9 cents to 16 cents more than the world price. The U.S. domestic price is for 112,000 pound lots, and the actual delivered costs would be far more, depending on packaging, purchase volumes, transportation costs and profits. For example, a 50-pound bag from Sam's Club runs 47 cents a pound.

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It is difficult to determine in the absence of tariffs and subsidies if the U.S. could economically produce cane ethanol. An article in Agriculture Online pointed out that Brazil is "allowed" to import 7 percent of US ethanol consumption, but that Brazil has not raised its production in order to meet the potential demand.[43] The reason likely has a lot to do with the 54 cent per gallon tariff on imported ethanol plus the 2.5 percent ad valorum duty.

If U.S. subsidies to domestic sugar growers were eliminated, it would be economically feasible to make cane ethanol from US crops. The analysis is as follows:

The first issue is that cane sugar is largely sucrose, which is a molecule of sugar that is nearly twice as large as the glucose sugar that is fermented in making corn ethanol. The formula for sucrose is C12H22O11. One molecule each of sucrose and water can be fermented into four molecules of ethanol and four molecules of CO2. We know that a gallon of ethanol weighs about six pounds, and the released CO2 weighs a little more. It requires about 12 pounds of sugar to create a gallon of ethanol. Nothing works at 100 percent, so it was assumed that two additional pounds of sugar, for a total of 14, is required to make a gallon of ethanol.

The world price of sugar on October 12, 2007, was 9.8 cents per pound, but that was for quality table sugar that has been doubly refined. It would make no sense to make fuel from food-grade sugar; the lowest grade would work. The raw sugar feedstock to the refining process consists of a slurry of molasses, sugars, ash and other impurities. World prices of sugar have ranged from 5 cents to 15 cents over the last 10 years. Raw sugar feed stock would be less costly than fully-refined sugar. Therefore, a world price of 4 cents per pound for the distillery feedstock sugar content seems reasonable. That would mean that the cane sugar feed stock to create a gallon of ethanol at the world market price would be less than about 56 cents.

A bushel of corn can produce about 2.64 gallons of ethanol. At a $4 cost per bushel, corn ethanol feedstock is $1.51 per gallon of ethanol produced, or 2.7 times as much as the international market cost for cane sugar feedstock.[44] Another major saving in making cane ethanol would be that the energy required from fossil fuels is only about one-seventh of that required for producing corn ethanol.

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C. Passing the reasonableness test

The way to analyze if the engineering assumptions are reasonable is to look at the price spread on the New York Board of Trade during the 1988 to 2004 period when corn prices were relatively stable. Brazilian cane ethanol had been trending down in price towards 80 cents per gallon. If the feed stock cost were as high as 56 cents, then the total value added would have to be in the range of 24 cents. That seems low given that the alternative for the cane sugar growers and mills is more operating margin making table sugar. In turn it means that, if anything, the engineering estimate of 4 cents per pound of sugar feedstock is high. It also means that without tariffs, making cane ethanol in the U.S. is entirely feasible.

The futures markets kept the price of corn relatively stable near $2.70 per bushel from about 1983 to 2006. This 25-year average cost of the corn amounted to about a dollar of corn for each gallon of ethanol produced. The value added in distillation, including subsidies, was about 40 cents a gallon. In short, without the subsidies, corn ethanol would not have happened. We are now looking at a future per bushel cost of corn of $4.17, which is about $1.45 of corn for gallon of ethanol. This cost is driven in great measure by political mandates. If we add in the total subsidies for corn ethanol that now average over $0.56 a gallon, and the direct cost of fossil fuel energy (about $2.00 for each gallon of corn ethanol produced[45]), then the real cost for domestic corn ethanol is five times the world ethanol price.

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Domestic sugarcane would be a far superior source of ethanol feed stock, if American sugar were sold at the world price, rather than the tariff-protected price. Far less conventional fossil fuels and less crop acreage are required for cane ethanol production. The problem is that the current system of quotas, tariffs and subsidies has driven the domestic cost of sugar so high that making ethanol from sugarcane would cost even more than the subsidized cost of corn-based ethanol. Compounding the problem is that the corn lobbies and the corn ethanol lobbies have worked successfully to keep the quotas, tariffs, and taxes on Brazilian cane ethanol.

D. Mandating corn ethanol creates other problems

It takes about 10 acres to raise enough corn to power one car for a year. Smart people are betting their fortunes on the futures markets that corn will soon cost well above $4.00 a bushel. That price increase will absolutely impact other consumer prices.

Already, hog farmers are being impacted by higher prices for feed. In Mexico, the price of tortillas is up sharply.[46] Jacques Diouf, director-general of the United Nations Food and Agriculture Organization, warns that the sharp rise in global food prices, caused in part by First World subsidies for domestic ethanol, would cause social and political unrest in the Third World, where families already spend about 65 percent of their entire income on food. As the Financial Times reported, "Mr Diouf said although the biofuel industry directly increased the consumption of only a handful of agricultural commodities, such as corn and rapeseed, its effect spread to other food products because less acreage was devoted to non-biofuel crops and the cost of feeding livestock with grain was pushed up."[47]

In the United States as well, the increase in corn ethanol production, driven by taxpayer-funded subsidies, will further disrupt the prices paid for other food products like breakfast cereal, beef, chicken, and pork. Consumers of food products should expect the quality of their guacamole chips to decrease as the price goes up. This price increase is because farmers can make more money selling a lower grade corn for ethanol production instead of incurring the extra expense of raising food-grade corn. The shrinking supply of food grade corn then rises in price.

In the United States as well, the increase in corn ethanol production, driven by taxpayer-funded subsidies, will further disrupt the prices paid for other food products like breakfast cereal, beef, chicken, and pork.

The corn ethanol subsidy also harms the environment. The subsidy has produced a "gold rush" mentality, which has led farmers in the upper Midwest to remove an enormous amount of land from the federal Conservation Reserve Program, and begin plowing up native prairie for corn. The Dakotas and Montana are expected to lose at least a million acres of CRP lands by 2010, to the great detriment of the population of ducks and other migratory waterfowl.[48]

Conclusion

The reason for short-term support for the corn ethanol industry seems to be, at best, a partial and hugely expensive solution. The corn ethanol industry can never provide a complete solution for energy independence; the U.S. does not have anywhere near enough land to grow the corn.[49] For that matter, there are not enough suitable places in the U.S. to grow sufficient sugar cane to produce cane ethanol to make much difference, either. The ideas of using switch grass, corn stalks and other cellulose sources still depend on having some future processing breakthrough, and even then, do not greatly improve the situation.

Instead of wasting money on subsidies for corn ethanol, the better strategy would be to remove the corporate welfare system protecting sugar. Then the far more efficient process of producing ethanol from sugarcane could be utilized. The result would be a new ethanol source that did not require taxpayer subsidies. In addition, the prices for all food products that use corn or sugar would be reduced.

Instead of wasting money on subsidies for corn ethanol, the better strategy would be to remove the corporate welfare system protecting sugar. Then the far more efficient process of producing ethanol from sugarcane could be utilized.

Direct subsidies for corn ethanol literally go out the tailpipe. A more constructive way to spend taxpayer money would be to help build capital infrastructures that solve the underlying energy problem. For example, the expenditures for the Tennessee Valley Authority, Hoover Dam, and other capital infrastructure programs have paid for themselves many times over.

Ending the corn ethanol corporate welfare program, tariffs on imported ethanol and allowing sugar cane ethanol to compete in America would be good first steps to a better energy future.

Endnotes

[1] Baumeister, T., ed. *Marks' Mechanical Engineers' Handbook*. 6th ed., (New York: McGraw-Hill, 1958), 7-21.

[2] Ibid., 7-30.

[3] Steve Stoft , December 30, 2007, http://zfacts.com/p/60.html. zFacts is the web site of Steve Stoft, a Ph.D. in economics, who consults in the electricity market.

[4] Wang, M., C. Saricks, and M. Wu. 1997. *Fuel-Cycle Fossil Energy Use and Greenhouse Gas Emissions of Fuel Ethanol Produced from the U.S. Midwestern Corn.* (Argonne National Laboratory, Argonne, IL).

[5] Sugar cane is a giant, thick, perennial grass, and when harvested, 10 percent or more of the entire weight of the plant is sugar. This is a far higher yield per acre than can be obtained from only the kernels of the corn plant. Because the cane plant is a perennial, little energy is required to create seeds; likewise, plowing and planting energy is rarely required. The high sugar yield per ton of cane biomass is also directly fermentable, so no energy is required for malting. The leftover cane stalk and byproducts are a good source of fuel for the distilling process. The result of all these energy savings and use of leftover products for fuel is that the sun provides the largest proportion of the energy in sugar cane ethanol.

[6] Smects, E, et al. 2006. Sustainability of Brazilian Bio-ethanol. *Universiteit Utrecht Report* NWS-E-2006-110. The scientific community and the rest of the world are on the metric system. It takes 2.68 million Joules to equal one horsepower hour and it takes 1,055 Joules to equal one British Thermal Unit (BTU). A GJ is a billion Joules. A hectare is 2.471 acres. Baumeister, T., ed. *Marks' Mechanical Engineers' Handbook*. 6th ed. (New York: McGraw-Hill, 1958).

[7] Wang, M., C. Saricks, and M. Wu. 1997. *Fuel-Cycle Fossil Energy Use and Greenhouse Gas Emissions of Fuel Ethanol Produced from the U.S. Midwestern Corn*. (Argonne National Laboratory, Argonne, IL). Its commonly recognized name comes from the federal laboratory where it was conducted.

[8] Shapouri, H., J. Duffield, and M. Wang. 2002. *The Energy Balance of Corn Ethanol: An Update* (U.S. Department of Agriculture, Office of the Chief Economist, Office of Energy Policy and New Uses. AER-813).

[9] Hammerschlag, Roel. 2006. Ethanol's energy return on investment: a survey of the literature 1990-present. *Environmental Science Technology*. 40, 1744-1750. Studies featured in the meta-analysis notably included: Marland, G., and A. F. Turhollow. 199 1. CO2 emissions from the production and combustion of fuel ethanol from corn. Energy 16:1307-1316; Lorenz, D., D. Morris, 1995. *How Much Energy Does It Take To Make A Gallon of Ethanol?* (rev. ed., Institute For Local Self-Reliance, Washington D.C.); Graboski, M., 2002. *Fossil Energy Use in the Manufacturing of Corn Ethanol*, Colorado Schools

of Mines, Golden Colorado; Shapouri et al., 2002, *The Energy Balance of Corn Ethanol*; Pimentel, D.; Patzek, T. Ethanol production using corn, switchgrass, and wood; biodiesel production using soybean and sunflower. *Nat. Resour. Res.* 2005, 14 (1), 65-76; Kim, S.; and Dale, B., "Environmental aspects of ethanol derived from no-tilled corn grain: nonrenewable energy consumption and greenhouse gas emissions," *Biomass Bioenergy* 2005, 28, 475-489.

[10] Patzek, Tad W. 2004.Thermodynamics of the Corn-Ethanol Biofuel Cycle. *Critical Reviews in Plant Sciences*. 23, 519-567.

[11] The high-value co-products are produced mainly by agri-giants such as ConAgra and Archer Daniels Midland, which own large integrated bio-refineries. Farmer-owned operations typically use a simpler process in their production of ethanol. The simpler processes do not require as much capital equipment and do not produce much in the way of co-products.

12 Pimentel, D. (ed.), *Handbook of energy utilization in agriculture*. (Boca Raton, FL: CRC Press, Inc., 1980); ___. and M. Pimentel, *Food, energy, and society*, (Niwot, CO: University Press of Colorado, 1996); ___ et al., "Renewable Energy: Economic and Environmental Issues," *BioScience*, 44 (1994), 536-547; ___ and W. Dazhong, "Technological changes in energy use in U.S. agricultural production," in *Agroecology*, ed. C. R. Carroll, et al. (New York: McGraw Hill, 1990); ___, "Ethanol fuels: Energy security, economics, and the environment," *J. Agr. Environ. Ethics* 4 (1991), 1-13; ___, "The limitations of biomass energy," in *Encyclopedia on Physical Science and Technology*, (San Diego: Academic Press, 2001), 159-171.

[13] Baumeister, T., ed. *Marks' Mechanical Engineers' Handbook*. 6th ed., (New York: McGraw-Hill, 1958).

[14] The specific ratios of the source of fossil fuels were used from Fig. 1a.

[15] Ibid. 7-3, 7-6. Various editions of the Marks' handbook are useful because old editions often contain information new editions do not. The newest handbook is: Avallone, Eugene A.; Baumeister, Theodore, Marks' Standard Handbook for Mechanical Engineers, 11th Edition, (New York: McGraw-Hill Professional, 2006).

[16] The theoretical maximum efficiency of any heat engine depends on its highest operating temperatures. The maximum possible efficiency for a steam generation electrical plant is derived using an ideal imaginary heat engine such as the Carnot heat engine. Thus the formula:

$$\eta_{max} = 1 - \frac{T_c dS_c}{-T_h dS_h} \equiv 1 - \frac{T_c}{T_h}$$

Where Th is the absolute temperature of the hot source and Tc that of the cold sink, usually measured in degrees Kelvin. (The Kelvin scale basically adds the 273 degrees between absolute zero and zero degrees centigrade to the reading on the centigrade scale.) The hot source is the highest temperature of the superheated steam, so 1,000 degrees Kelvin would be reasonable. The cold side is the temperature of the cooling water, so a little warmer then room temperature, or about 300 degrees Kelvin would be about right. The result is that the maximum possible efficiency is about 70 percent. In practice, it is very difficult to exceed 60 percent efficiency because of all the losses in transferring heat, pumping, air and smoke handling etc.

[17] Baumeister, T., ed. *Marks' Mechanical Engineers' Handbook*. 6th ed., (New York: McGraw-Hill, 1958). section 7, page 7-21, shows an average of about 19,500 BTUs per pound of crude oil and an average carbon content of 84.5 percent. From the same edition, the average carbon content of natural gas is 75 percent.

[18] Using the fossil fuels ratios from Fig. 1b, I multiplied the ratio by the energy released per pound of fuel burned, and then factored this value by the Patzek ratio of one half that comes from oil and half from gas, or ½ x 79,500/19,500 x 32/42 x .845 + ½ x 3.11 x .75 = 2.48 lbs. of carbon from the petroleum used in creating ethanol.

[19] This number is based on the ratio of the molecular weights of ethanol and carbon dioxide.

[20] Baumeister, T., ed. *Marks' Mechanical Engineers' Handbook*. 6th ed., (New York: McGraw-Hill, 1958). ASTM started in the United States as the American Society of Testing Materials. As the economic influence of the United States increased in the 1960's, the organization became international. The long title was changed to ASTM International. Why the organization works is because governments and business around the world need to be able to trust specifications and standards for goods and products from international suppliers. It works because of the enlightened self-interest of governments and business to financially support the many universities, testing laboratories and various standing standards committees. The work products of all the involved scientists, engineers, laboratories and standards committees are published in various reference books and available by subscription or user fees by anyone in the world.

[21] The release of carbon dioxide can be calculated from the fact that gasoline averages about 84.3 percent carbon and weighs 5.935 lbs. per gallon (ASTM data), so it has 5.00 lbs. of carbon per gallon. The ratio of molecular weights yields 18.33 lbs. of CO2.

[22] Kelso, N., B. Cuthbertson and M. Cronin. 1992. *Working Paper 4, Fuel Efficiency of Ships and Aircraft.* (Bureau of Transport and Communications Economics, Canberra).

[23] Lawrence Berkeley National Laboratory, http://www.lbl.gov

[24] Cap and Trade Subgroup Climate Action Team, *Cap and Trade Program Design Options Overview – For Discussion*. March, 15, 2007. http://www.climatechange.ca.gov/climate_action_team/reports/2005-12-08_CAP+TRADE_REPORT.PDF. Energy bills for refineries are about 44 percent of their operating costs as reported by the Energy Information Administration, Form EIA-28 (Financial Reporting System), Table B-32 and reprinted in the LBNL study. The point is that 44 percent is costly so refiners are motivated to constantly improve.

[25] In general, California does not have coal fired electrical generation plants because California has no commercially viable coal deposits. Petroleum delivered by sea is a lot cheaper than hauling coal over the mountains. California imports ever more electricity, probably because their permitting processes for power plants are so tough. Imported electricity was the cause of the Enron/California brown-out fiasco of a few years ago. California is also increasingly relying on more piped-in natural gas electrical generation which has nothing to do with oil refinery efficiency.

[26] U.S. Department of Transportation, Federal Highway Administration, *Highway Statistics*. August 21, 2007. http://ops.fhwa.dot.gov/freight/freight_analysis/nat_freight_stats/docs/04factsfigures/table5_9.htm

[27] There are other energy costs (and consequently, carbon dioxide releases) involved in the production of ethanol similar to the release stream for gasoline that were not included in the initial calculation of the 32 lbs. of CO2 released by the direct use of ethanol. Included are the estimated energy costs involved in the extraction and processing of coal, natural gas and petroleum products used to make ethanol. An additional 2 lbs. of carbon dioxide are estimated to be released as a result from the extraction and processing of the fossil fuels which are necessary to produce ethanol.

[28] Map used with permission from Renewable Fuels Association, One Massachusetts Avenue NW, Suite 820, Washington, DC 20001.

[29] Schedule 3 (Form 8849), (rev. February 2005), Department of the Treasury, Internal Revenue Service. It should be noted that other alcohols qualify for $.60 and agri-biodiesel qualifies for $1.00 per gallon.

[30] Data were found on 27 biorefineries. The Freedom of Information Act is useful for discovering who receives ethanol subsides; public reporting sources such as SEC filings are less helpful because some large agribusinesses are privately owned and not subject to public reporting rules. They could have wholly-owned, partially-owned and joint ventures with other named businesses, and the total extent of their involvement cannot be determined.

[31] Wisner, R. and C. Baumel, 2004. Ethanol, Exports and Livestock: Will there be Enough Corn to Supply Future Needs?, *Feedstuffs*, 76, 32; McVey, M., C. Baumel, and R. Wisner, 2005. Increased Ethanol Production Reduces Corn Shipments Out of Iowa, *Feedstuffs*, 75, 44..

[32] Ibid.

[33] Optimistically assuming a yield of 2.65 gallons of ethanol per dry bushel of corn.

[34] Renewable Fuels Association, *Industry Statistics*. www.ethanolrfa.org/industry/statistics/

[35] Schmitz, A. and D. Christian, 1993, "The Economics and Politics of U.S. Sugar Policy," *The Economics and Politics of World Sugar Policies*; Marks and Maskus, eds. (Ann Arbor: The University of Michigan Press, 1993), 50-52; Another interesting source of the same material is: History of Sugar Programs, *American Sugarbeet Growers Association*. http://www.americansugarbeet.org/secndTier.asp?bid=125.

[36] United States Department of Agriculture, *Briefing Room: Sugar and Sweeteners: Policy* (Washington, D.C.: Economic Research Service, USDA, 2006), http://www.ers.usda.gov/Briefing/Sugar/trade.htm

[37] Ibid.

[38] United States Department of Agriculture, *Table 1 World Production, Supply & distribution; Centrifugal sugar*, www.ers.usda.gov/Briefing/sugar/data/table01.xls; and Portal UNICA, the Sao Paulo Sugarcane Agroindustry Union, *An X-ray of Brazilian Production*, www.unica.com.br/i-pages/home.asp. On the home page, go to "sugar cane agroindustry". The results for sugar are in metric tons, and the results for alcohol are in liters.

[39] The International Trade Administration (ITA) of the U.S. Department of Commerce, *Employment Changes in U.S. Food Manufacturing: The Impact of Sugar Prices*, http://trade.gov/media/Publication/pdf/sugar06.pdf.

[40] Under current law, the federal government makes "loans" to sugar processors, and holds the sugar as collateral. If the processors do not pay back the loans, the only penalty is that they forfeit the sugar. This means that, in effect, the federal government is buying from sugar refiners' sugar for which the government has no use and paying 18 cents per pound for raw cane sugar and 22 cents per pound for beet sugar. This program not only costs the taxpayers, who are forced to issue the bad loans, but also drives up the market price of sugar by creating artificial demand. Washington protects this inflated price by imposing tariffs on imported sugar. The result is a floor on domestic sugar prices.

[41] In many parts of the world, you can buy a can of soda for much less than in the U.S., even though our distribution systems are far more efficient. In India, Coke sells for 7 rupees per 250 ml can. There are 44.5 rupees per U.S. dollar and 250ml is about 8 ½ ounces. Bhattachara, S., Beyond Colas, The Coke Recipe, *The Hindu Business Line*, International Edition, June 03, 2004. This works out to the equivalent of about 22 cents per 12-ounce can. Finding world prices for Coca Cola is surprisingly hard to do. One source for wholesale data is Alibaba Manufacturers Directory – Suppliers, manufacturers at Alibaba.com. From the home page, scroll down to "food and beverages." It can be seen that 12-ounce equivalent (330ml). Coke prices at the wholesale level range from 15 cents in Indonesia, 31 cents in Russia, 32 cents in the Philippines, 33 cents in Great Britain and 37 cents in France. Checking the 2004 SEC form 10K for Coca Cola indicates that foreign sales are far more profitable than domestic sales. It does not take much analysis to conclude that a major reason for both the lower prices and higher profit margins is that the local bottling plants purchase sugar at world prices. There is a growing re-importation business for 12 oz. glass bottles of Coke from Mexico and delivered in the US for 70 cents. According to several importers, the market is for those who prefer their Coke sweetened with cane sugar because they can taste the difference.

[42] The NYBOT sugar markets offer two sugar futures contracts: world Sugar No. 11sm and domestic Sugar No. 14 sm. The major trading volume takes place in the Sugar No. 11 market. Just looking at the price difference between the New York world sugar and domestic sugar contracts on a given day illustrates the difference between the two sugars. On November 15, 2002, for example, the nearby Sugar No. 11 contract (world sugar) was trading at around 7.24 cents/lb. while the Sugar No. 14 contract (domestic) traded at 22.14 cents/lb. Of note is that more current world sugar prices listed elsewhere in this paper are still far below domestic prices.

[43] Prater, L., "Senators: lifting tariff on ethanol imports a 'kick in the face' to rural America," *Agriculture Online*, May 5, 2006, http://www.agriculture.com/ag/story.jhtml?storyid=/templatedata/ag/story/data/1146839070422.xml

[44] The October 2007 price is about $3.51 per bushel, down from the summer price over $4.00. However, corn futures for summer 2008 are again over $4.00 and they are $4.17 for deliveries in July 2009.

[45] The exact mix of energy sources that go into producing corn ethanol is difficult to determine; therefore, total energy costs are difficult to determine. Because it takes more fossil energy to produce corn ethanol than is contained in the ethanol, a model using diesel fuel at $3.00 a gallon, natural gas at two-thirds the equivalent cost and electricity from coal at one-third the equivalent cost results in at least $2.00 a gallon.

[46] Roig-Franzia, M. "A Culinary and Cultural Staple in Crisis," *Washington Post*, Jan. 27, 2007.

[47] Blas, J, "UN Warns of Food Price Unrest," *Financial Times*, Sept. 6, 2007,

[48] Dan Nelson, "Delta Waterfowl to host breeding-grounds tours," *Outdoors Unlimited*, Oct. 2007, p. 14 (magazine of the Outdoors Writers Association of America).

[49] Eaves, J. and S. Eaves,2007 Neither Renewable Nor Reliable, *Regulation*, 24-27. www.cato.org/pubs/regulation/regv30n3/v30n3-1.pdf. Year-to-year variations in crop yields are very large. Over a 20-year period, there is a likely be a year in which corn yields fall by more than 30 percent. The year-to-year volatility risk for corn yields is about twice as large as the year-to-year risk for oil import levels, even accounting for major shocks to the oil market, such as the Arab oil embargo and the Iranian revolution.

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