Biofuel Production and Consumption in the United States:
Some Facts and Answers to Common Questions

Gregory M. Perry
Munisamy Gopinath
William Jaeger
Thorsten M. Egelkraut[1]

---

[1] Faculty in the Department of Agricultural and Resource Economics at Oregon State University. The report benefitted from comments on an earlier draft provided by Bruce Sorte, Emery Castle, Thayne Dutson, and Brent Searle.

Biofuel Production and Consumption in the United States: Some Facts and Answers to Common Questions

Executive Summary

This report summarizes and provides background on the information presented at a conference about the biofuel industry sponsored by Oregon State University and the Chambers-Eisgruber Fund. Details and copies of the conference papers are available at http://arec.oregonstate.edu/faculty2/PerryFiles/foodenergyhome.html. Groups and individuals are making claims and counterclaims about biofuels creating energy independence, reducing pollution and global warming, and strengthening rural economies. The authors surveyed the vast literature on this topic, particularly relating to energy issues in Oregon, and summarized information relevant to Oregon biofuel policy.

The United States faces very real challenges regarding energy. Fossil fuel availability and low price transformed the US and world economy during the 20th century. When domestic fossil fuel supplies declined the US needed to import more fossil fuel to maintain its strong economy. Reliance on imported fossil fuel created a fundamental problem for US policymakers. , Relying on foreign suppliers for such an important input creates very real national security issues, particularly because the volatile Middle East sits on over half the proven world oil reserves.

Biofuels have been touted as one way to move toward energy independence and bring the US trade deficit into balance. For most of three decades an effort to establish an ethanol industry in this country was spurred by energy security issues and the desire of Midwestern agribusinesses to develop new markets for corn. Despite decades of research, consumer acceptance, and a developed marketing system, corn ethanol is economical mostly because of federal, state, and local mandates, and production subsidies. Without subsidies and mandates the ethanol industry would be much smaller than it is. The smaller biodiesel industry is also dependent on subsidies and mandates for survival.

The rise of the ethanol industry inadvertently tied food and energy markets together, and contributed to higher food prices. Research suggests that expanding corn acreage will lead to negative world environmental consequences. Many policymakers think cellulosic ethanol is the long run solution to problems associated with corn ethanol, particularly environmental ones. However, it also faces some major challenges. The long-promised breakthroughs that could make cellulosic ethanol competitive with corn and sugarcane ethanol appear to be years away and may require even larger subsidies. Even if the breakthroughs do occur, the biomass needed for a cellulosic ethanol plant is daunting. Federal mandates notwithstanding, it remains an open question whether cellulosic ethanol can ever compete with corn ethanol. Cellulosic ethanol may become a major source if political leaders decided the higher cost of cellulosic ethanol is preferred over the higher environmental damage from corn ethanol or continued reliance on imported fossil fuel. Although cellulosic ethanol has less environmental impact than corn-based ethanol, the impact is not insignificant.

All of this suggests corn ethanol and biodiesel cannot be more than a minor part of the US drive to energy independence. Ethanol and biodiesel will be more expensive than traditional fossil

fuel, to consumers and the environment. But, ethanol and biodiesel are the least expensive liquid fuel alternatives to petroleum currently. If increased energy independence is one of our domestic policy goals, ethanol and biodiesel may receive even more government support.

Achieving energy independence only from the supply side is neither possible nor advisable. The United States cannot come up with enough new supplies of fossil fuel nor develop sufficient alternative energy sources to eliminate importing fossil fuel. Instead of placing emphasis on increasing supply, a more balanced approach is advisable. Such an approach would include reductions in demand with increases in energy supplies from various sources.
In Oregon, Governor Kulongoski has made energy independence a major theme of his administration. In August 2008 he called a summit to discuss Oregon's energy future. In his opening remarks, he stated,

> "With fuel costs rising. With energy demand outstripping domestic supply. With climate change no longer a theory – but a proven fact. With renewable energy, energy efficiency, and conservation the wave of the future – but no clear path for transitioning to that future…. It is *not* too late to take control of our energy destiny and solve the biggest threat to Oregon's cherished way of life. That threat is the perfect storm of too much carbon, too high energy costs, too much risk to the competitiveness of Oregon businesses, and the lack of a strategic energy vision for how we get from where we are today – to where we want to be in the future."

Oregon can do several things to produce more energy. It has the geography and climate to develop and produce solar, wind, and geothermal energy to complement its hydroelectric power. Wave energy holds promise and is worth further research. These are energy sources where Oregon seems to have a comparative edge in production. These, along with other strategies, are part of the state's policy goals (see http://www.oregon.gov/ENERGY/RENEW/RenewPlan.shtml)

It is unclear whether Oregon has any advantage in producing biofuel. Most of the corn in Oregon's ethanol industry is brought in from the Midwest, which is considered a disadvantage by the industry (Andrejczak). Although Oregon is a large state, most land east of the Cascades has little water and cannot support expanding farmland for a new crop. Irrigated land is already devoted to higher value crops, making corn and canola, at best, secondary rotational crops. Although Oregon is a major producer of wood products, most milling and paper processing by-products are already diverted into economic activities. Corn ethanol, cellulosic ethanol, and biodiesel from canola will not likely expand beyond federal, state, and local mandates, and their net contribution (when subtracting the energy used to produce them) toward Oregon's energy needs is unlikely to exceed a fraction of one percent of the state's fossil fuel consumption. The ethanol and biodiesel industries are capital intensive, but create few jobs, so any new processors in Oregon will provide only a few jobs to the state. The recent bankrupcies of companies involved in production of ethanol in Oregon illustrate just how small the margin of success is for Oregon ethanol producers (Andrejczak).

Biofuel Production and Consumption: Some Facts and Answers to Common Questions

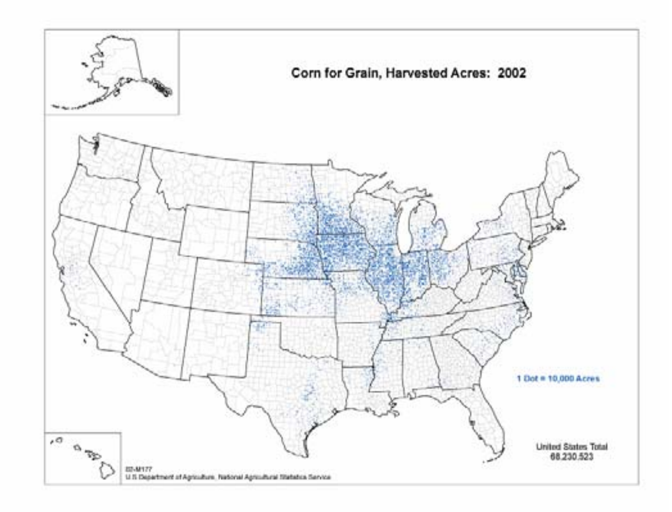
On October 2, 2008, Oregon State University sponsored a conference, "Rising Food and Energy Prices: US Food Policy at a Crossroads." Most of the conference focused on the effect biofuels had on food and energy markets. What became clear was the abundance of claims and counterclaims about the biofuel industry, most from individuals and groups advocating a particular position. The result is a great deal of confusion about the importance or potential of biofuel in the agriculture and energy economies. At the same time, several points have general agreement. The conference and this report were to help evaluate the biofuels debate and sort fact from fiction. This report summarizes the information and serves as a starting point for those who want to explore particular questions.

Biofuel Facts

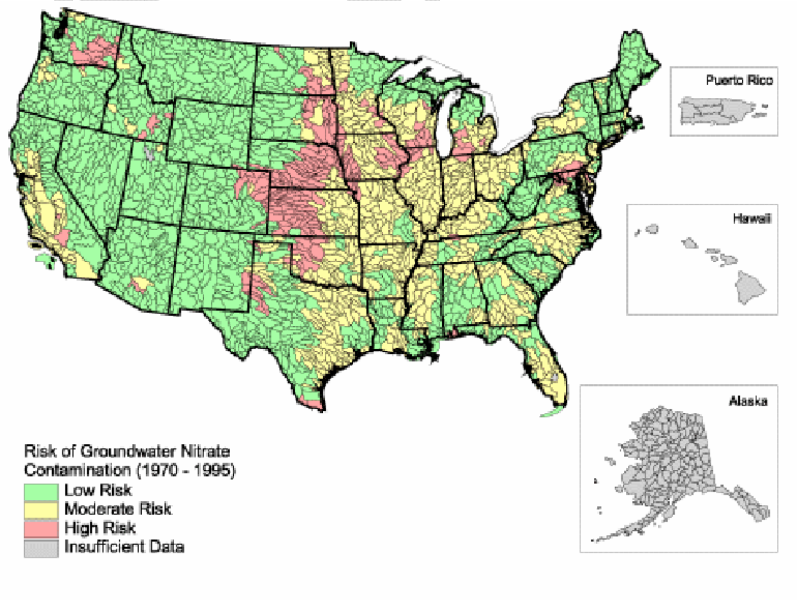
Despite the debate about biofuel in the US food and energy markets, some important points are not in dispute.

1. In 2006, liquid fuel represented 40% of all energy consumed in the United States. In the same year, 35% of all US energy was imported, almost all liquid fossil fuels, oil and natural gas. In 2006, 60% of US petroleum consumption was imported oil. This declined to 58% in 2007 and 57% in 2008. In 2007, OPEC supplied 29% of all US petroleum. The Persian Gulf countries, members of OPEC, provided 11% of all US petroleum needs (Department of Energy – Energy Information Agency). The US petroleum production peaked around 1970 and has been declining since.
2. Importation of oil has a major impact on the US Balance of Trade. In August 2008, the US exported $164.7 billion in goods and imported $223.9 billion, for a trade deficit of $59.2 billion. Oil imports were $37 billion, 17% of all imports, and 63% of the total trade imbalance that month.
3. According to November 2008 statistics, average US refinery yield for a gallon of crude oil in August was 42% gasoline, 28% distillate fuel oil (mostly diesel), 10% jet fuel, and 20% many other petroleum products (Department of Energy – Energy Information Agency). The proportions can vary to some extent based on the type of oil and refining techniques. Ethanol can substitute only for gasoline; biodiesel substitutes only for distillate fuel oil. Consequently, moving toward true energy independence means finding non-fossil fuels for most, if not all, petroleum products.
4. Biomass fuels, including, but not limited to, corn ethanol and biodiesel, represented 2.8% of all 2008 US liquid fuel consumption on a gallon-basis. In 2005 this was 1.2%. Over 90% of US ethanol is produced in the US, almost all was from corn. Biodiesel was less than 0.1% of 2008 US liquid fuel. At present, ethanol and biodiesel are the only liquid fuel alternatives to fossil fuel widely available to consumers (Department of Energy – Energy Information Agency).

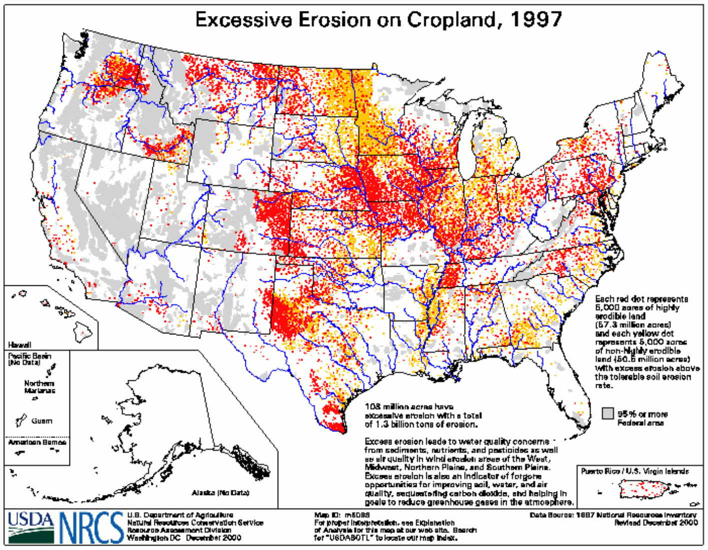
5. Corn production in the US is mostly in the Midwest (diagram at right). Although the map is from 2002 Census of Agriculture data, the concentration in the Midwest has not changed in the past six years. In 2007, the US reached an all time high of 93.6 million acres of corn. The leading corn producing states by acreage were Iowa (14.2 million), Illinois (13.2 million), Nebraska (9.4 million), Minnesota (8.4 million), and Indiana (6.5 million). Oregon produced 60,000 acres. The Midwest has a competitive advantage over Oregon in corn because Oregon's location and climate make it better to produce higher value, specialty crops.



6. Corn requires intensive farming, affecting the soil and water more than most crops. Land in corn is usually tilled each year, with high levels of nitrogen and phosphorus use. Movement to GMO core varieties has reduced chemical use, but frequency of applications still exceed those for soybeans, sorghum, or oats. Nitrogen and phosphorus are water soluble. When soil becomes saturated, both will move with the excess water. Farmers can manage irrigation water to reduce movement of inputs. However, only about 13% of the US corn crop is irrigated. Irrigated lands cause great concern about nitrate pollution because farmers consistently over-irrigate (see Risk of Groundwater Nitrate Contamination map by EPA). Natural rainfall areas, such as those in the Midwest, are completely at the mercy of the weather. For this reason, most of the Midwest faces a moderate to high risk for nitrate groundwater pollution. Too much phosphorous in watersheds can cause algae blooms, leading to public health risks and failure of the aquatic system. Excess nutrients flowing into the Mississippi River are a major cause of the "Dead Zone" in the Gulf of Mexico.



The corn producing states of the Midwest are also very vulnerable to soil erosion (see Excessive Erosion on Cropland map). Despite extensive research and educational programs to encourage no till farming, more than 75% of Midwestern corn acreage is tilled before planting. It is not surprising, therefore, that the areas of highest erosion (in red) are found in high corn producing states, Iowa, Illinois, Nebraska, and Missouri.


Excessive Erosion on Cropland, 1997

Each red dot represents 5,000 acres of highly erodible land (57.3 million acres) and each yellow dot represents 5,000 acres of non-highly erodible land (50.5 million acres) with excess erosion above the tolerable soil erosion rate.

108 million acres have excessive erosion with a total of 1.3 billion tons of erosion.

Excess erosion leads to water quality concerns from sediments, nutrients, and pesticides as well as air quality in wind erosion areas of the West, Midwest, Northern Plains, and Southern Plains. Excess erosion is also an indicator of forgone opportunities for improving soil, water, and air quality, sequestering carbon dioxide, and helping in goals to reduce greenhouse gases in the atmosphere.

U.S. Department of Agriculture
Natural Resources Conservation Service
Resource Assessment Division
Washington DC December 2000

Map ID: m5089
For proper interpretation, see Explanation of Analysis for this map at our web site. Search for "USDABOTL" to locate our map index.

Data Source: 1997 National Resources Inventory
Revised December 2000

7. Although biodiesel can be made from several waste products, like grease from restaurants and spent oil from vehicles, supply is small. To create a noticeable difference in diesel supply requires biodiesel from plant oils. Soybean, canola, sunflower, and palm oils are all good sources. These oils can be burned directly in a diesel engine, but are usually chemically altered by transesterification to make them more like fossil fuel diesel. Biodiesel produces about 9% less energy than traditional diesel.[2] Soybeans have the most acreage among the oil-producing crops, 64.7 million acres in 2007. Soybeans and corn are the dominant rotation in the Midwest, so most soybean production is there. Canola is important in Canada, but the US, in 2007, had only about 1.2 million acres. Sunflower is an important source for biodiesel in Europe, but the US had only 1.7 million acres in 2007. Sunflower and canola production in the US is limited to the Great Plains, particularly Montana, North Dakota, and South Dakota. The US does not produce palm oil. Soybeans and sunflowers are not produced west of the Rocky Mountains. Canola is grown on few acres in Oregon, but faces limits and economic obstacles to increased production in areas such as the Willamette Valley (Jaeger and Siegel 2008).
8. Biodiesel is 100% vegetable diesel or a mixture of fossil fuel and vegetable diesel. Commonly used mixes are B5, 95% fossil fuel, and B20, 80% fossil fuel. There are no national requirements on what proportion vegetable biodiesel must be included with fossil diesel to call the product biodiesel. Because vegetable oils begin to cloud up at around the freezing point and can plug filters at 22°F, a biodiesel mix of mostly fossil diesel is needed, particularly in northern climates, to keep it liquid at lower temperatures.
9. Because ethanol is an alcohol, it has less energy per gallon than the same amount of gasoline. This energy difference is sizeable: About 1.5 gallons of ethanol are needed to produce the same energy as a gallon of gasoline. Adjustments to vehicle engines can improve the efficiency of a gasoline-ethanol mix, but very few automobiles are flex-fuel vehicles, capable of handling different mixes of gasoline and ethanol.

---

[2] There are claims that vegetable oil biodiesel provides better lubricity, better combustion, and less pollution, somewhat offsetting the pure differences in energy.

10. Methyl Tertiary Butyl Ether MTBE, from natural gas, is an additive that helps gasoline burn more efficiently, boosting the gasoline octane, and producing less pollution. Small amounts of MTBE can contaminate entire aquifers if it leaks from gasoline storage tanks. In 2000, the USDA and EPA recommended a gradual phase out of MTBE, to be replaced by ethanol. Since then, about half the states banned adding MTBE to gasoline. In the Energy Policy Act of 2005, Congress refused to shield MTBE manufacturers from lawsuits that might be filed as the result of MTBE groundwater contamination. Consequently, with the increase of ethanol availability, MTBE has been pretty much replaced nationally by ethanol. Babcock estimates that the demand for ethanol to replace MTBE is about 3 to 4 billion gallons annually. This is a clear, national, market floor on demand for ethanol.
11. Another important floor for the ethanol market is the current federal mandate. According to Babcock, the Energy Independence and Security Act of 2007 mandated that ethanol use grow from 9 billion gallons in 2008 to 13.2 billion in 2012, 15 billion in 2015, and 36 billion in 2022. In 2010, cellulosic ethanol consumption is required to be 100 million gallons, rising to 3 billion gallons in 2015, and 16 billion gallons in 2022. The requirements demand that the ethanol come from something other than corn. Sugarcane, sugar beets, or cellulosic sources would all qualify. These government mandates create a set demand. Congress could change the mandates if the political environment were to change. Annual 2008 US gasoline consumption was 142 billion gallons; the current mandate would be about 6% of gasoline consumption in terms of gallons, or 4% on an energy-basis (Btus).
12. The EPA limits ethanol to no more than 10% in a gasoline-ethanol mix. Mixtures up to 85% ethanol can be used in motor vehicles, with some minor adjustments to the engine. The 10% limit is a barrier to increasing demand for ethanol as a motor fuel. Babcock noted that the ethanol industry is pressuring the EPA to increase the limit to 15%. The recent focus by automakers on producing flex-fuel vehicles is from the need for vehicles that automatically adjust to the mix of gasoline and ethanol.
13. About 30% of the US corn crop is used to produce ethanol. Corn is the largest US crop by acreage. It is used in livestock feed and, extensively, in processed foods. These links inadvertently tied the US food and energy markets together. When the price of oil increases, it causes corn price to also increase because of the increased demand for corn ethanol. (Babcock; deGorter).
14. The role of biofuels in contributing to the recent increases in food prices is in debate. However, significant evidence shows the quantity of corn used to produce ethanol in the United States had driven up the price of corn. As Babcock noted, about one in four acres of corn will be diverted into ethanol production, if the 15 billion gallons per year federal mandate stays in place in 2015. This much corn cannot be diverted away from the traditional food and feed markets without having a significant upward effect on prices. Because the United States is generally the largest exporter of corn, the effect will extend all over the world. The magnitude of the initial spike in price was temporary, however. How much decline occurs in long-term corn price will depend on the world economy, the amount of new corn acreage worldwide entering production, and technological changes that improve corn yield.
15. Biofuels receive significant subsidies within the US, both directly and indirectly. These subsidies include

- A $0.51/gallon ethanol federal subsidy paid to "blenders," those who mix gasoline and ethanol for direct consumption. This drops to $0.45/gallon in 2009 (Renewable Fuels Association).
- An ad valorem tariff on ethanol imports equivalent to 2.5% of the product value. For an ethanol price of $3.00/gallon, the tax is $0.075/gallon. A secondary duty of $0.54/gallon is levied on ethanol judged to be subsidized by the producing country (Renewable Fuels Association). Brazil is the second largest producer of ethanol in the world and the leading source of ethanol imported to the US, 188 million gallons in 2007. Brazil's ethanol is subject to the secondary duty. The Caribbean Basin Initiative exempts several Caribbean countries from this secondary duty. If the world market price for ethanol is lower than the domestic price, the tariff is an indirect subsidy; it keeps domestic prices higher than they otherwise would be.
- Cellulosic ethanol subsidized under the 2008 Farm Bill at $1.01/gallon. The subsidy is reduced by the amount of the blender's credit, $0.51/gallon.
- The Biodiesel and Small Agri-Biodiesel Producer Tax Credit at $1.00/gallon credit for the sale of agribiodiesel fuel, produced from an agricultural source, such as soybeans or canola. For more detail on biodiesel economics and policies both nationally and for Oregon see Jaeger and Siegel (2008).
- Various subsidies from about 35 states to both biofuel producers and consumers. In Oregon, the state has mandated all gasoline contain at least 10% ethanol (see Jaeger et al., 2007; Jaeger and Siegel 2008). Portland requires all diesel sold within the city be B5. There are also tax exemptions and subsidies of up to $20 million for companies that construct alternative fuel processors within the state.

16. The general consensus among economists is that ethanol would not be competitive with fossil fuels if the combination of tax subsidies and congressionally mandated consumption requirements were eliminated. The only exception is that ethanol would continue to be the low cost alternative to MTBE as a fuel additive in gasoline. Biodiesel is also not cost competitive with traditional diesel, unless diesel prices increased above historical levels, as they were in 2008.

1. What factors contributed to the commodity price boom in 2007-2008?

During 2007-2008, agricultural commodity prices rose up to 200%, e.g. rice, corn, oilseeds. There is broad agreement that commodity prices grew faster than non-commodity prices and inflation. However, there has been a serious debate on which of the following factors significantly contributed to high commodity prices (Abbott, Hurt and Tyner, 2008; Babcock, 2008; de Gorter, 2008):

- Increased demand for agricultural and processed food products from rapid economic growth in middle-income or "emerging" economies such as China and India
- Easy credit availability (expansionary monetary policy) in high-income economies with historically low nominal interest rates
- Spike in energy prices, especially crude-oil prices, which raised incentives for the production of alternative fuels, e.g. corn ethanol or biodiesel

- Natural disasters such as floods in the US Midwest and consecutive droughts in Australia, which reduced global commodity stocks available for end users.
- The generally sluggish response of agricultural supply due to time lags in production and mixed growth trends in yield/acre and farm-sector productivity.
- Speculation in commodity markets of high-income economies, where investors were betting on higher future prices
- Since international markets value commodities in US dollars, the falling value of the dollar meant higher price for US consumers, and
- Export taxes or bans in low-income and middle-income countries, which curtailed global supplies and stocks.

In trying to sequence these multiple forces affecting commodity prices, Mitchell (2008) argued that rising energy prices led to higher fertilizer prices, and in turn, higher food production costs and consumer prices. Simultaneously, the incentives to produce alternative fuels, e.g. biofuel, increased with every dollar increase in crude oil prices. Commodity producers in the United States, European Union, Russia, and Ukraine responded to such incentives by diverting a large amount of cropland to produce biofuel feedstock (e.g. corn, canola). Uncomfortable with the risks posed by the rising trajectory of commodity prices to the poor, countries like India, Russia, and Argentina began limiting exports. While these events occurred over a period of 9-18 months, their cumulative effect has been a substantial reduction in carryover stocks and increased speculation, which further contributed to an upward spiral in commodity prices. Tracing through these forces in sequence, Mitchell attributed three-quarters of the 140% increase in the World Bank's food price index to biofuel production and the subsequent tightening of global commodity markets.

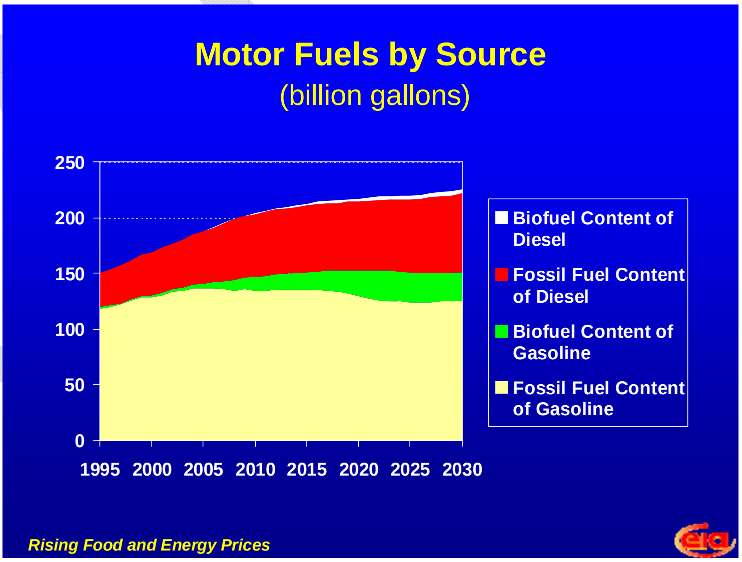
Other studies quantifying the impact of biofuels on commodity prices include de Gorter (2008), who attributed 39% to 97% of the short-run increases in corn price to biofuel policies. Higher biofuel demand in the United States and the European Union (EU) has not only led to higher corn and soybean prices, but also increased prices for substitution crops and the cost of livestock feed (Mercer-Blackman 2007). In a study by the International Food Policy Research Institute, it is estimated that biofuels "accounted for 30 percent of the increase in weighted average grain prices. The biggest impact was on maize prices, for which increased biofuel demand is estimated to account for 39 percent of the increase in real prices. Increased biofuel demand is estimated to account for 21 percent of the increase in rice prices and 22 percent of the rise in wheat prices" (von Braun, 2008). Babcock (2008) noted that if high crude oil prices are here to stay with us, then long-run corn prices will be largely determined by oil price, regardless of biofuel policies.

Others have argued that the 2007-2008 increase in all commodity prices – oil, gold, food, fiber, and non-fuel commodities – was a delayed effect of easy credit or money (Krichene, 2008). Historically low nominal interest rates encouraged lending with little regard for borrowers' creditworthiness, causing a strong world-wide expansion of demand for homes, cars, travel and other services. Since energy is a critical input in the production of such goods and services, what began as increases in the crude-oil price also impacted non-energy commodity markets. Hence, easy credit or expansionary monetary policy is considered by some to be the driving force of the commodity price boom of 2007-2008. Another popular explanation from government agencies, in particular, of high-income economies has been globalization. This argument attributes the price boom to demand in emerging economies, where globalization has induced energy-intensive industrialization and urbanization. Moreover, people of these countries earned high-incomes, changed diets, and saved money. The money was invested in government backed debt in high-income economies, especially the United States. This allowed the US to pursue an easy credit policy, which led to the commodity demand shock.

A common theme in the above arguments is that the current trend in commodity prices comes from the demand side, unlike the supply shocks of the early 1970s and 1980s. Commodity markets appear to have had a fundamental change. If the recent demand-side forces are not countered by those on the supply side, commodity prices are anticipated to have an upward trajectory. Since September of 2008, agricultural commodity prices have decreased along with the price of crude oil, a consequence of the anticipated fall in demand due to the global recession. Nevertheless, the key underlying forces affecting agricultural commodity prices remain in place, which are likely to emerge again as the global economy emerges from the current recession (Abbott, Hurt and Tyner, 2009).

2. Will bioenergy help create energy independence for the US?

Based on assumptions about current and future U.S. policies and mandates, Shaal estimates that by 2022 ethanol would represent 7.7% of all liquid fuel in the US on a gallon basis (see graph at right). In addition, 1.6% of the supply could come from non-ethanol liquid fuel made from coal and biomass, with biodiesel estimated to provide another 0.4% of the total. In total, these estimates suggest all biofuels could represent about 10% of the liquid fuel market (on a gallon basis). As will be discussed below, the share represented by biofuels on an energy-basis (Btus) would be smaller, as would their “net contribution” after inputs required to produce biofuels are subtracted.



During the same period, liquid fuel consumption is projected to increase by about 6%. Net imports of liquid fuels are projected to decline only slightly, from 66% in 2008 to 62% in 2022. And biofuels cannot be expected to do much to reduce the US demand for oil imports.. On the total energy front, net energy imports should decline from 34% in 2008 to 30% in 2022. Other renewables including wind, solar, nuclear, ethanol, and biomass could also help reduce imports, but the magnitude of their contributions may be relatively small.

Major strides toward energy independence will require a significant reduction in total domestic consumption. In 2006, the US used just over 24% of the world oil supplies, while producing 10%

(Department of Energy – Energy Information Administration). Cutting 2007 domestic consumption from 24% to 15% of world supply would leave the US as the world's largest petroleum consumer. It would also reduce US oil imports from 66% of total supply to 14%. The recent economic downturn also illustrates this point. Domestic petroleum production is projected to increase 1%, 5.06 to 5.25 million barrels, but demand is projected to drop 7.5%, 20.68 to 19.12 million barrels. Because of the decline in demand, petroleum prices should drop 31% from 2007 to 2009 (Department of Energy – Energy Information Administration –Short Term Energy Outlook).

3. What is the net energy contribution of ethanol and biodiesel?

The net energy contribution of a biofuel is the energy in the fuel itself (measured in British Therman Units or "Btus"), minus the energy needed to produce, process, and transport it. This issue is important because the overall contribution of biofuels to our national energy supply will be their net contribution. A useful measure for these purposes is the net energy ratio (NER), or the energy inputs used to produce a biofuel divided by the energy in the fuel itself, or:

$$NER = \frac{Total\ Energy\ Inputs}{Total\ Energy\ Available\ for\ Consumption}$$

This ratio can be interpreted as the fraction of input energy required to make one unit of energy available to consumers. For example, if three gallons of ethanol (or the energy equivalent) are required to produce five gallons of ethanol, the NER is 0.60 (3 divided by 5). This ratio becomes important in replacing fossil fuels with ethanol. The exact ratio for ethanol and other biofuels has stirred controversy. A small minority of researchers claim that for corn ethanol the energy inputs exceed the energy in the fuel. Nearly all authoritative Most studies, however, find that the NER for corn ethanol is between 0.6 and 0.75 (see table below).

Study authors	Net energy ratio	Net energy value (BTU/gallon)	Year published
Wang, Saricks and Santini	0.70	22,500	1999
Agriculture and Agri-Food Canada	0.72	29,826	1999
Shapouri, Duffield, and Wang	0.75	21,105	2002
Shapouri, Duffield, and McAloon	0.60	30,528	2004

Several additional points should be noted about the efficiency of ethanol production. First, Wang et al. (2007) found sugarcane ethanol in Brazil is much more efficient than corn ethanol and would compare favorably to fossil fuels. Second, the amount of energy used to produce corn ethanol is greater than that used to produce gasoline or diesel. Ethanol needs more energy than gasoline or diesel just to grow the crop, before the ethanol can be produced. But, third, ethanol and biodiesel do markedly reduce fossil fuel use. Fossil fuels are the end product and are also used to produce the end product. Corn ethanol and biodiesel are end product substitutes for petroleum products, but rely on fossil fuels to be produced.

4. What are the environmental benefits and consequences of producing ethanol from corn?

Ethanol production affects the atmosphere, air quality in congested areas, fresh water, oceans, groundwater, surface water, biological issues, soils, soil erosion, and land use. Ethanol affects the environment directly when the feed stocks (like corn) are produced and, later, when burned in motor vehicles.

a) Direct Effects – The environmental benefits of biofuel have been a key motivation for their promotion – especially regarding greenhouse gas (GHG) emissions. A gallon of gasoline is estimated to produce 25.6 pounds of carbon dioxide. The carbon in this carbon dioxide was stored in petroleum underground. Using it in a motor vehicle, for example, releases stored carbon into the atmosphere. Ethanol was first thought to have minimal net effect on carbon dioxide release into the air because the carbon dioxide released when ethanol was burned came from the air via the corn or sugarcane plant. In fact, substituting 1.5 gallons of ethanol for a gallon of gasoline does not reduce greenhouse gas emissions by a full gallon's worth of gasoline greenhouse gas. The energy required to produce ethanol includes fossil fuels, which emit greenhouse gas. It can take 3 BTU of input energy to produce 5 BTU of ethanol, so the greenhouse gas associated with each gallon of ethanol can be significant. One study estimated that corn ethanol greenhouse gas emissions were just 13% lower than for gasoline (Hill). Another study reported a reduction of 20% (Searchinger et al.).

Brinkman et al. developed the Greenhouse gases, Regulated Emissions, and Energy use in Transportation model (GREET) to track both the efficiency of producing various energy products and the amount of greenhouse gases and other pollutants produced. GREET was used to estimate carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur oxides (SO_x), and particulate matter 10 microns or less in diameter (PM10). The calculations for 2008 were based on a standard car with spark ignition or, with diesel, a standard compression motor. Five fuel types were evaluated: (1) conventional gasoline; (2) E10, gasoline with 10% corn ethanol; (3) E85, or 85% corn ethanol and 15% gasoline; (4) E10C, gasoline with 10% wood ethanol; (5) compressed natural gas; (6) conventional diesel; (7) B20, or 80% regular diesel and 20% biodiesel; and (8) electricity, using an electric-powered vehicle. All calculations included pollutants released in the entire process, from the well or energy source to final consumption in a vehicle. All pollutants were reported as grams per mile.

	Greenhouse gas output (grams per mile)				
Fuel type	CO_2	CH_4	N_2O	SO_x	PM10
Conventional gasoline	465	0.553	.017	.125	.083
E10 from corn	454	0.544	.027	.138	.093
E85 from corn	326	0.559	.166	.357	.263
E10 from woody material	461	0.554	.016	.118	.080
Compressed natural gas	371	1.434	.013	.140	.076
Conventional diesel	388	0.433	.013	.103	.064
B20	318	0.366	.014	.048	.043
Electricity	311	0.420	.004	.747	.431

Several conclusions can be drawn from this table. First, most any fuel replacing gasoline will reduce CO_2 emissions. Second, even an almost pure mix of ethanol (E85) does not do as well in reducing CO_2 emissions as B20. B20 performs well across the range of pollutant categories. Third, corn ethanol contributes to increases in N_2O, SO_x, and PM10. Using a high ethanol mix, like E85, increases these three pollutants compared to gasoline. Nitrous oxide becomes a particularly bad problem, mostly because the nitrogen from fertilizer goes into the air. According to the EPA, nitrous oxide traps heat in the atmosphere over 300 times more than carbon dioxide. Fourth, cellulosic ethanol seems to slightly reduce all pollutants compared to gasoline.

One study that took issue with the air pollution benefits of ethanol focused on ozone. Ozone is beneficial high in the stratosphere, but harmful near the ground. High level ozone blocks the Earth from many ultraviolet rays. Ground level ozone, in high concentrations, contributes to smog and respiratory problems for those with asthma and other chronic lung diseases. Jacobsen used computer models to determine that widespread use of E85 (85% ethanol) fuel would cause ozone to increase and add to pollution in congested areas. So long as ethanol remains a small part of the gasoline-ethanol mix, the ozone issues raised in this study seem inconsequential.

b) Indirect Effects – Babcock noted the acreage devoted to corn for ethanol in the US is equivalent to the entire state of Iowa. Losing this acreage from food will trigger several responses: (a) a rise in corn price and a corresponding reduction in corn consumption for food and feed; (b) an increase in corn acreage at the expense of other crops; (c) tilling acreage now in the Conservation Reserve Program (CRP)[3], pasture, or rangeland; and (d) converting virgin land outside the US into tilled land.

Wu and Langpap created a land use model to predict what higher commodity prices would do to land use patterns for the Midwest, Northern Great Plains, and Lake states. They assumed higher corn prices would be matched with increases in prices for soybeans, wheat, hay, and sorghum. As corn prices increased, farmers were predicted to shift toward more corn acreage, more intensively farmed crop acreage, and more continuous corn rotations. The Northern Great Plains would have large conversion of pasture and rangeland into crops. More nitrogen would percolate and wind and water soil erosion would increase.

Searchinger et al. projected the corn acreage diverted to ethanol production would be made up by expanding acreage, mostly outside the US. They found that converting virgin land or land in perennial crops released a lot of greenhouse gases, which more than offset the environmental gains from using ethanol. Their computer model of global agriculture projected that greenhouse gas emissions would nearly double when using corn ethanol and would increase 50% with cellulosic ethanol. Several critiques were written about the Searchinger et al. paper. One authoritative review was commissioned as part of an ongoing UK government analysis (Sylvester-Bradley). It concluded that indirect greenhouse gas effects cannot be ignored and it is "eminently feasible that effects of biofuels on indirect GHG emission could be significant in relation to intended GHG savings." They cautioned, however, that the Searchinger approach

---

[3] The CRP is a federal program designed to take environmentally sensitive lands out of production. About 34.5 million acres of farmland are in CRP, about 7.5% of US crop acres.

involves much uncertainty. Some assumptions in the Searchinger analysis are likely both to have increased and decreased the estimated indirect greenhouse gas emissions.

A study used global economic models to simulate results with and without coproduct credits (Taherpour et al.). It showed that including coproducts reduced the increases, in response to biofuel mandates, 39% in US cereal production and price. Their estimates of the differences in land use changes from international biofuel mandates suggest that including coproducts in the analysis reduces land use changes an average of 37%. One must be cautious when considering coproducts in these calculations. First, it is unclear whether demand would exist for large amounts of coproducts. Second, cheap animal feed may increase animal production. These animals produce significant CO2 and methane releases, both of which would have to be accounted for as negative.

Fargione et al. examined land use conversions in Brazil, Indonesia, Malaysia, and the United States for biofuel and found they created a large carbon debt. It would require decades or even centuries for the benefits of producing biofuel to reduce greenhouse gases to offset the release of carbon when these lands are cleared. Kline and Dale took issue with both the Fargione et al. and Searchinger et al. studies. They argued that biofuels are not the cause for clearing much of tropical savannas and forests, many other factors are at work. They noted that perennial biofuel sources in the tropics could enhance carbon sequestration. The general criticisms regarding both the Fargione and Searchinger studies did not reject claims of negative environmental effects. Instead, the debate seemed to be more of size, scope, and effect. A paper recently published in *Science* by Robertson et al. provided a concise summary of the environmental issues surrounding grain biofuel production:

> “Though many questions about biofuel sustainability remain unanswered--indeed, some remain unasked--what we now know with reasonable certainty can be readily summarized. First, we know that grain-based biofuel cropping systems as currently managed cause environmental harm. In addition to questions of carbon debt created by land cleared elsewhere to replace displaced food production, farming our existing landscapes more intensively, with even greater quantities of biomass extracted, can easily exacerbate existing environmental problems. The effects of more intense agriculture are well documented: increased soil erosion, greater nitrate and phosphorus loss, and a decline in biodiversity, with concomitant impacts on ground and surface water quality, air quality, and biodiversity-based services such as pest suppression and wildlife amenities. Business as usual writ larger is not an environmentally welcome outcome.”

There have been efficiency imporvements for corn ethanol production. Nevertheless, ethanol from corn is a mature technology that is not likely to see anything more than minor gains in efficiency (DiPardo).

5. How do the subsidies for biofuels compare to those for fossil fuels, nuclear fuel, and renewable fuel sources?

The Department of Energy – Energy Information Administration recently released a report summarizing all subsidies provided by the federal government for various energy sources. They calculated the federal government subsidy received per BTU produced. The results are provided in the following table:

	Electricity net generation, quadrillion BTUs	Electricity FY2007 subsidy & support ($ million)	Non electricity, quadrillion BTUs used	Non electricity subsidy & support ($ million)	Total subsidies ($ million)	Total quadrillion BTUs subsidized	Subsidies per million BTU
Coal	6.64	$854	1.93	$78	$932	8.57	$0.11
Refined coal	0.25	$2156	0.16	$214	$2370	0.41	$5.84
Natural gas & petroleum	3.14	$227	55.78	$1921	$2148	58.92	$0.04
Nuclear	2.71	$1267	0	$0	$1267	2.71	$0.47
Biomass and biofuel	0.14	$36	0.57	$3249	$3285	0.71	$4.65
Geothermal	0.05	$14	0.04	$1	$15	0.09	$0.16
Hydroelectric	0.88	$174	0	$0	$174	0.88	$0.20
Solar	0.003	$14	0.07	$184	$198	0.07	$2.70
Wind	0.11	$724	0	$0	$724	0.11	$6.84

These are current subsidies and ignore subsidies for previous years. The results also ignore state and local subsidies. About 35 states provide subsidies for the ethanol or biodiesel industries. It should also be noted that gasoline is taxed at the federal, state and local levels with the average being about $0.45 per gallon. So the subsidy of biofuels relative to gasoline is larger than the figures above suggest. Federal subsidies to reduce consumption through conservation were less than $1 billion. From these numbers it is clear that three energy sources were much more heavily subsidized than the rest – wind, refined coal, and biomass. Refined coal is raw coal altered to improve its heat and emissions content. It is mostly used in power plants or in smelters because it generates more heat and fewer pollutants. Almost all biomass subsidies were used to support the production of ethanol and biodiesel. It should not be a surprise to see most subsidies going to the relatively new energy industries. Government investment is designed to drive down the cost of adopting these new technologies, thereby accelerating growth in adopting them.

When we consider the subsidy per gallon for ethanol ($0.51/gallon), and also recognize that it takes about 4.5 gallons of ethanol to generate the net energy equivalent to one gallon of gasoline, this means that the federal subsidy on ethanol comes to about $2.35 to create the net equivalent of one gallon of gasoline.

6. What effect will the ethanol industry have on rural employment in the US?

Claims about job creation benefits arising from ethanol vary widely. Partridge (2008) takes issue with some claims made about the job creation benefits of biofuels. For example, he indicates that a report by Urbanchuk for the Renewable Fuels Association, an advocate arm for the ethanol industry, overstated the job benefits by a wide margin. The Urbanchuk report estimated a 50 Million Gallon a Year (MGY) processor will produce 40 direct jobs and 578 indirect jobs, 618 jobs overall. Increasing processor size to 100 MGY would generate 50 direct and 1087 indirect jobs. Partridge argued that, for ethanol to be competitive in contributing to the nation's energy needs, the industry must be competitive with other sectors producing energy, and this has meant keeping labor costs low.

Indeed, a couple of studies conducted at land grant universities shed more light on this difference in results. David Swenson, an economist at Iowa State University, estimated a 50 MGY processor would produce 35 direct jobs, 75 indirect jobs, and 23 induced jobs, making 133 total jobs. A processor with double the capacity, 100 MGY, will only increase total jobs to 170. Swenson repeated the analysis for the state of Iowa in exactly the same manner as was done for the US analysis, generating a multiplier of 4.38. Swenson also estimated that the national jobs multiplier for ethanol produced in Iowa is 4.38. Iowa's 27 ethanol processors in production at the end of 2007 employed about 1242 people, 5440 total jobs. With current facilities under construction, these figures are expected to grow to 1865 direct and 8129 total jobs in Iowa. If Oregon were to have three 100-million gallon ethanol processors, the Iowa results suggest they would employ 138 people directly and add 604 total jobs to the Oregon economy. Given the federal subsidies of $0.51 per gallon, this represents a taxpayer cost of $370,000 per direct job created.

For a small community, a processor could have a noticeable effect on local employment, and the tax base for schools and local government. However, the proportion of these new jobs that will initially go to local residents is uncertain. New firms often will make some hires from outside the area and job opportunities often attract outside job seekers. Because of worker mobility, in the long term a new ethanol processor cannot be expected to lower the unemployment rate in a community. Nevertheless, it can expand the local economy in the short-run. In a 2001 study evaluating a potential cellulosic ethanol processor using wheat straw in Washington state, Sorte projected a regional employment multiplier of 3.33 and statewide a multiplier of 4.22. These multipliers relied on using locally produced wheat straw. Over time these short-run impacts can be expected to diminish in size, and we do not have good estimates of the long-term impacts which will be smaller than the short-run estimates.

In the short-run, arguments are made that constructing ethanol processors provide a temporary economic boost to the local economy. Swenson argued that this claim for Iowa "…is greatly overestimated." Construction benefits those who do the design and construction work. If out-of-state workers and companies are employed, the local economy receives about half the economic effects. Most of the construction benefits can be captured within the state.

Low and Isserman conducted an analysis of local effects from construction of three ethanol processors in Illinois. They found results similar to those reported by Swenson and made a couple of additional observations. Consistent with similar studies, they found that the local impact depends very much on the size of the local economy. Placing the processor near livestock feeding operations may be beneficial because it creates by-products that become inexpensive cattle feed. Ethanol processors offer many of the same economic benefits as any other manufacturing facility. If their profitability is tied to advantages of a local site (corn, land, transportation access, water, and energy), they are less likely to move to take advantage of lower manufacturing costs elsewhere. At the same time, changes in policy, shifts in corn price, or replacing corn with a lower cost crop could quickly shift a processor from being profitable to being forced out of business. The facility may or may not be used for producing other goods.

Currently the federal government is mandating that 15 billion gallons of ethanol be produced in the United States by 2015 (Babcock). Ethanol production capacity in 2008 was 13.7 billion gallons, with 83% in the corn producing states of the Midwest. The concentration of the industry in the Midwest makes economic sense. Feedlots for beef and pork have largely disappeared in Oregon because both depend heavily on feeds, particularly corn and soy meal, produced in the Midwest. It is less expensive to bring cattle to the Midwest and fatten them there before slaughter than it is to bring the feed to where the livestock are. The disparity in cost between transporting raw commodities and meat products may be greater than the difference in transporting raw commodities and ethanol (Low and Isserman). A ton of grain corn produces about 200 gallons of ethanol. Each gallon of ethanol weighs about 6.6 pounds, so 2000 pounds of corn can be used to produce 1320 pounds of ethanol.

A caveat in this simple comparison is the relative cost of transporting ethanol versus grain corn. Because ethanol is both dangerous and corrosive, it must receive special care when transported. Because of this, the transportation cost difference may be enough to make it profitable to produce ethanol in Oregon for the local market instead of shipping the ethanol in from the Midwest. Other factors, such as input and regulatory costs will also make a difference. In 2005, Oregon consumed 1.1% of all gasoline in the United States. Assuming a 10% ethanol mix in all Oregon gasoline, ethanol consumption in Oregon would be about 157 million gallons of ethanol, about the amount supplied by the two ethanol processors in Boardman and Clatskanie. Both of these processing plants are in economic trouble, illustrating the small margin for profit that exists for ethanol production in Oregon.

Given these numbers, it will be very difficult for ethanol to produce the benefits to the local economies that some are hoping for. The market for ethanol in Oregon is small. Corn needs to be imported to operate an ethanol processor. The ethanol industry would have a modest benefit on the state and regional economies and a very small benefit, if any, on the growers in areas most interested in attracting ethanol processors. If corn production is critical to the viability of ethanol production, Oregon will not be able to sustain an ethanol industry of any size. If the high cost of transporting ethanol becomes the major driver, the ethanol industry in Oregon will be small, large enough to support statewide needs and nothing more.

7. What are the prospects of alternative sources of ethanol?

7.1. Ethanol from sugarcane and sugar beets

The US biofuel debate has focused on ethanol from corn. However, the US is not the only large ethanol producer and consumer. With 5.0 billion gallons, Brazil ranked second behind the US in 2007 for ethanol production. Together they accounted for about 88% of global fuel ethanol production (Renewable Fuels Association, 2008). Brazil’s ethanol industry relies on sugarcane.

Sugarcane offers several advantages over corn. It requires little farm energy and fertilizer. Moreover, it is a perennial and can be harvested, on average, five times before needing to be replanted. After harvest, the crop is washed, chopped and shredded; the juice is pressed out and then processed either into sugar or fermented and distilled into ethanol. The extraction residues, bagasse, are burned to generate the thermal and electrical energy for running the mill. The excess electricity is sold into the grid. All waste, such as vinasse, which is sugarcane water, suspended organic matter, and minerals; filtercake, from cleaning the juice; and bagasse boiler ash are used as fertilizer on the sugarcane crop, making a closed system (Macedo, 2005).

Because no outside energy is needed, producing cane ethanol has a low NER, making it energy efficient. Using GREET, Wang et al. (2007) estimated each million BTU cane ethanol produced in Brazil had a NER of 0.04 (only 0.04 million BTUs needed per million BTUs of ethanol produced. The average NER for corn ethanol is 0.77.according to Wang et al. Even with improved processing in the future, corn's NER will likely be 0.40, still higher than for sugar cane.

Sugarcane ethanol reduces greenhouse gas emissions 3.8 times better than corn ethanol, when indirect effects are omitted. The best case for improved corn processing technology to reduce these greenhouse gases was 52% compared to close to 80% for sugarcane (Wang et al., 2007). This may be optimistic for both sugarcane and corn. They assume a constant carbon content in the soil and ignore the release of greenhouse gases from land use changes tied to expanded production (Searchinger et al., 2008). Energy gain and greenhouse gas reductions also depend somewhat on the processing plant's location; sucrose deteriorates quickly and sugarcane's high water content makes transport over long distances unprofitable. Similar to the US, where ethanol processing facilities are near the crops, Brazil's sugarcane mills are usually in the center of a cane producing area, with about 20-25 km radius.

The US is one the world's largest sugar producers. The 2009 harvests were projected at 4.4 million short tons raw value from sugar beets, primarily in the upper Northwest, and 3.7 million short tons raw value from sugarcane, primarily in Louisiana, Florida, and Texas (Haley et al., 2008). Despite the crop's favorable characteristics as a biofuel source, no ethanol is produced from sugar in the US. This is frequently attributed to the higher cost of sugar in the US. Brazil not only saw substantial government support into the sector, but also enjoys readily available land and labor. Moreover, due to different climates, the harvest in the U.S. is 3 to 6 months compared to 9 months in Brazil (Shapouri et al., 2006). Climate and significant government support of sugar price, make US sugar price about twice Brazil's (Haley and Ali, 2007). As a result, ethanol from sugarcane and sugar beets is not competitive with corn ethanol at current ethanol prices. However, policymakers are encouraged to assess the different government programs affecting the sugar and corn ethanol industries. They should examine whether a shift of government support toward the most beneficial biofuel sources could show net energy gain, reduce greenhouse gas, and contribute towards energy independence.

7.2. Ethanol from cellulosic material

Ethanol produced from cellulosic material appears to have potential environmental benefits similar to sugarcane and sugar beets (Wang et al., 2007). Cellulosic materials, such as corn stover and cobs, wheat and grass straw, wood by-products, biomass from forest thinning, and other by-products are readily available and, and in some cases has little or no value. Crops like switchgrass can provide the feedstock for cellulosic ethanol. Because it is perennial, switchgrass and other cellulosic feedstocks may have the additional benefit of providing wildlife habitat, reduce soil erosion and water pollution, and better use existing soil nutrients. Cellulosic materials could also be grown on forest land, pasture, and range, where they would compete less directly for cropland (US Dept of Energy, Office of Science).

However, some significant problems must be overcome to make cellulosic materials economically viable for liquid fuel:

a. These materials are bulky making transportation costly. They must be harvested and transported to a central processor. Current estimates are that one dry ton of biomass can produce 50 gallons of ethanol. A study conducted in 2000 estimated that wheat or grass seed straw could produce 60 gallons of ethanol per ton (Graf and Koehler). By comparison, if it takes a bushel of corn to make 2.6 gallons of ethanol, a ton of corn produces 200 gallons of ethanol (Shapouri, Duffield, and Wang). The area around the processor must be able to produce enough biomass to feed a sizeable processor. Long distance transportation costs would make them unprofitable, even if the biomass were free.

b. It is difficult and costly to convert biomass into cellulosic ethanol. By nature, plant material is designed to resist breakdown into basic sugars that can be converted into ethanol. Current technology can convert cellulosic material into ethanol, but requires extra processing. That raises costs, making it uncompetitive with current liquid fuels. This is an area of major research, however, and advances in technology are possible.

The technological challenges of cellulosic ethanol should not be underestimated. Ten years ago, the US Department of Energy projected that cellulosic ethanol would match corn ethanol production by 2009. At present, almost all ethanol in the US is produced using corn (Wald and Barrionnuevo). In a 1999 study, DiPardo estimated that corn ethanol production costs were $1.10/gallon, compared to $1.29/gallon for cellulosic ethanol. He estimated that, with good advances in technology, cellulosic ethanol costs could be reduced to $0.69/gallon by 2015. He also projected cellulosic ethanol would enter the market in 2003. In 2006 the US Energy Secretary, Samuel Bodman, in testimony before a congressional committee, indicated that corn ethanol could be produced for $1.10/gallon, but cellulosic ethanol costs were about $2.20/gallon. Another study pegged the processing costs at $2.65/gallon (Osborne).

One way to offset the higher processing costs is to find a plant that costs less than corn. At $3.00/bushel for corn, Osborne estimated that the cost of the corn, before adding processing costs, was $1.07/gallon of ethanol. Switchgrass is a commonly mentioned source of cellulosic ethanol. If it takes a ton of switchgrass to make 60 gallons ethanol, Osborne estimated the cost of producing, harvesting, and transporting the switchgrass would have to be $60/ton or less for it to replace corn. Higher corn prices may make switchgrass more competitive, depending on differences in production, transportation, and processing costs.

Large scale production is needed to make cellulosic ethanol viable because of the significant economies of scale. A state of the art ethanol processor in the Midwest is structured to produce 100 million gallons of ethanol per year. Assuming the cellulosic technology improves, so 100 gallons of ethanol can be produced per dry ton of biomass, a processor would need one million tons of biomass annually. Assuming yields like those in the Midwest, 4 tons/acre, a cellulosic ethanol processor producing 100 million gallons per year would require 250,000 acres of switchgrass. If this were to occur in Oregon, it would make switchgrass the fourth largest crop in Oregon in acreage, behind wheat, alfalfa, and grass hay. Switchgrass, however, does not grow well in Oregon. So, how many Oregon cellulosic ethanol processors could be supported using crop residue, forest biomass, or waste products from the timber industry? Bowyer et al. estimated that the amount of woody biomass that could be removed from Oregon's forests annually, over 20 years, is 1 million tons of dry material. This would be enough to feed one large ethanol processor. But, this material is dispersed. Transportation costs would render some of this material unprofitable for an ethanol processor. Other sources of feedstock for cellulosic ethanol include pulp and paper mill sludge and municipal waste (Graf and Koehler).

The 2007 Federal Energy Bill mandates 36 billion gallons of ethanol production by 2022, with 21 billion gallons coming from cellulosic ethanol. With technology running behind earlier projections and the competition that will ensue for land to produce cellulosic sources for ethanol, our assessment is that this mandate will be difficult to attain without major subsidies and without disrupting agricultural and wood production. It is also difficult to see how the prospect for ethanol production in Oregon would change even if technological improvements made cellulosic ethanol more competitive. A study by Jaeger, Cross, and Egelkraut (2007) outlined the difficulties that cellulosic ethanol faces to become cost competitive in Oregon.

A recent study by the Energy Information Agency (EIA/OECD 2008) contains the following key messages:

- Technical barriers remain for 2nd generation biofuel production.

- Production costs are uncertain and vary with the feedstock available, but are currently thought to be around USD 0.80 - 1.Oll/litre of gasoline equivalent.

- There is no clear candidate for "best technology pathway" between the competing biochemical and thermo-chemical routes. The development and monitoring of several large-scale demonstration projects is essential to provide accurate comparative data.

- Even at high oil prices, 2nd -generation biofuels will probably not become fully commercial nor enter the market for several years to come without significant additional government support.

- Considerably more investment in research, development, demonstration and deployment (RDD&D) is needed to ensure that future production of the various biomass feedstocks can be undertaken sustainably and that the preferred conversion technologies, including those more advanced but only at the R&D stage, are identified and proven to be viable.
- Once proven, there will be a steady transition from 1st - to 2nd -generation biofuels (with the exception of sugarcane ethanol that will continue to be produced sustainably in several countries).

8. What effect will higher commodity prices have on farmland values?

During the late 1970s and early 1980s, a rapid increase in commodity prices spurred a rapid rise in farmland value. When prices declined and input costs rose substantially, a number of farmers found their land was worth less than the debt owed on it. This triggered many foreclosures and defaults, resulting in a major crisis among farm lenders. The recent spurt in commodity prices has created another rapid rise in land values reminiscent of 30 years ago. Penson conducted an analysis of farmland values in the Midwest and projected how those values might change, depending on commodity price trends. He found that higher land prices can be supported if commodity prices remained higher than production costs. Most other scenarios suggested a decline in land prices will occur. Costs could rise faster than commodity prices. Commodity prices could level off, while costs continued to rise. Commodity prices could drop and costs remain the same or increase. With the current state of the economy and highly volatile nature of commodity prices and input costs, it is almost impossible, at this point, to project future farmland prices.

References

Agriculture and Agri-Food Canada. *Assessment of Net Emissions of Greenhouse Gases From Ethanol-Gasoline Blends in Southern Ontario*. Prepared by Levelton Engineering Ltd. #150-12791 Clarke Place, Richmond, B.C. and (S&T)2 Consulting Inc., J.E. & Associates. August 1999.

Abbott, P., C. Hurt and W. Tyner. What's Driving Food Prices? Farm Foundation, July 2008 (March 2009 update)

Andrejczak, M. "Pacific Ethanol units join others in bankruptcy court." *Marketwatch*, May 18, 2009. Available online at http://www.marketwatch.com/story/pacific-ethanol-joins-others-in-bankruptcy-court?dist=dist_smartbrief?dist=dist_smartbrief&dist=dist_smartbrief&dist=dist_smartbrief .

Babcock, B. "Ethanol and Its Place in U.S. Agriculture." Paper presented at conference *Rising Food and Energy Prices: US Food Policy at a Crossroads*, October 2, 2008 at Oregon State University, Corvallis. Paper can be found at http://arec.oregonstate.edu/faculty2/PerryFiles/foodenergyhome.html .

Brinkman, N., M. Wang, T. Weber and T. Darlington. *Well-to-Wheels Analysis of Fuel/Vehicle Systems – A North American Study of Energy Use, Greenhouse Gas Emissions, and Criteria Pollutant Emissions.* Argonne National Laboratory. May 2005. Available online at http://www.transportation.anl.gov/pdfs/TA/339.pdf.

Bourke, J.K., Jr. "Green Dreams." *National Geographic* (October 2007):41-47

Bowyer, J. Biomass Energy and Biofuels from Oregon's Forest. Oregon Forest Resources Institute. 2006. Available at http://www.oregonforests.org/media/pdf/Biomass_highlights.pdf

De Gorter, H. Explaining Agricultural Commodity Price Increases: The Role of Biofuel Policies. Paper Presented at the Conference, "Rising Food and Energy Prices: U.S. Food Policy at a Crossroads" Oregon State University, Corvallis, Oregon, October, 2008.

DiPardo, J. *Outlook for Biomass Ethanol Production and Demand.* Energy Information Administration, US Department of Energy. 1999. Located at http://tonto.eia.doe.gov/FTPROOT/features/biomass.pdf

EIA/OECD (Energy Information Agency/Organization for Economic Cooperation and Development), 2008. From 1st- to 2nd – Generation Biofuel Technologies: An overview of current industry and RD&D activities. International Energy Agency.

Environmental Protection Agency. *Emission Facts: Greenhouse Gas Emissions from a Typical Passenger Vehicle*. EPA 420-F-05-004. February 2005. Available on-line at http://www.epa.gov/oms/climate/420f05004.htm.

Environmental Protection Agency. *Nitrous Oxide*. Informational website located at http://www.epa.gov/nitrousoxide/index.html

Environmental Protection Agency. *Risk of Groundwater Nitrate Contamination*. US map, available online at http://www.unl.edu/nac/atlas/Map_Html/Clean_Water/National/Risk_groundwater_nitrate_contamination/Risk_groundwater_nitrate_contamination.htm .

Fargione, J., J. Hill, D. Tilman, S. Polasky and P. Hawthorne. "Land Clearing and the Biofuel Carbon Debt." *Science* 319(29 February 2008):1235-1238.

Food and Agricultural Organization: "Soaring Food Prices: Facts, Perspectives, Impacts and Actions Required." High-Level Conference on World Food Security, Rome, June 2008.

Gallagher, E. Review of the indirect effects of biofuels production. The Renewable Fuels Agency, U.K. 2008. Available at http://www.dft.gov.uk/rfa/reportsandpublications/reviewoftheindirecteffectsofbiofuels.cfm

Graf, A. and T. Koehler. *Oregon Cellulose-Ethanol Study: An evaluation of the potential for ethanol production in Oregon using cellulose-based feedstocks.* Report prepared for the Oregon Office of Energy, June 2000. Available at http://www.oregon.gov/ENERGY/RENEW/Biomass/docs/OCES/OCES.PDF

Hebert, H.J. "Study: Ethanol may add to global warming." *USA Today*, February 28, 2008.

Hill, J., E. Nelson, D. Tilman, S. Polasky and D. Tiffany. "Environmental, Economics and Energetic Costs and Benefits of Biodiesel and Ethanol Biofuels." *Proceedings of the National Academy of Sciences* 103(2006):11206-11210.

Ho, S.P. "Global Warming Impact of Ethanol Versus Gasoline." Presented at 1989 National Conference, "Clean Air Issues and America's Motor Fuel Business." Washington DC, October 1989.

Jacobs, J. "Ethanol from Sugar: What are the Prospects for U.S. Sugar Co-Ops?" *Rural Cooperatives* 73(September/October 2006). Available on-line at http://www.rurdev.usda.gov/rbs/pub/sep06/ethanol.htm

Jacobson, M. "Effects of Ethanol (E85) Versus Gasoline Vehicles on Cancer and Mortality in the United States." *Environmental Science and Technology*. Available at http://www.stanford.edu/group/efmh/jacobson/es062085v.pdf .

Jaeger, W., R. Cross and T. Egelkraut. *Biofuel Potential in Oregon: Background and Evaluation of Options.* Special Report 1078, Oregon State University Extension Service. July 2007. (http://extension.oregonstate.edu/catalog/pdf/sr/sr1078.pdf)

Jaeger, W.K. and R. Siegel, 2008. Economics of Oilseed Crops and Their Biodiesel Potential in Oregon's Willamette Valley. Special Report 1081. Oregon State University Extension Service, May. (http://extension.oregonstate.edu/catalog/pdf/sr/sr1081.pdf)

Keeney, D.R., and T.H. DeLuca. "Biomass as an Energy Source for the Midwestern U.S." *American Journal of Alternative Agriculture*, Vol. 7 (1992), 137-143.

Kline, K.L. and V.H. Dale. "Biofuels: Effects on Land and Fire." *Science* 321(11 July 2008):199-201.

Krichene, N. "Recent Inflationary Trends in World Commodities Markets." Working Paper 08/130, International Monetary Fund, May 2008.

Kulongoski, T. Opening Remarks to "Summit on Oregon's Energy Future 2008." Delivered August 27, 2008 in Portland, Oregon. Available at http://governor.oregon.gov/Gov/speech/2008_0827_open.shtml .

Langpap, C. and J. Wu. "Potential Environmental Impacts of Increased Reliance on Corn-Based Bioenergy." Paper presented at conference *Rising Food and Energy Prices: US Food Policy at a Crossroads*, October 2, 2008 at Oregon State University, Corvallis. Paper can be found at http://arec.oregonstate.edu/faculty2/PerryFiles/foodenergyhome.html .

Lazear, E. "Responding to the Global Food Crisis." Testimony before the Senate Foreign Relations Committee, U.S. Congress, March 2008. *The Farm Foundation*. "What's Driving Food Prices?" Issue Report, July 2008

Lorenz, D., and David Morris. *How Much Energy Does it Take to Make a Gallon of Ethanol?* Revised and Updated. Institute for Local Self-Reliance, Washington, DC. August 1995.

Low, S. and A.M. Isserman. "Ethanol: Implications for Rural Communities." Selected paper presented at 2008 AAEA Meetings, Orlando, FL. July 2008.

Marland, G., and A.F. Turhollow. "CO2 Emissions From the Production and Combustion of Fuel Ethanol From Corn." Oak Ridge National Laboratory, Oak Ridge, Tennessee. Environmental Sciences Division, No. 3301. U.S. Department of Energy. May 1990.

Mercer-Blackman, V. H. Samiei,and K. Cheng 2007,Biofuel demand pushes up food prices. IMF Research Department. IMF Survey Magazine.

Mitchell, D. "A Note on Rising Food Prices." Working Paper No. 4682, The World Bank, July 2008.

National Ocean Service, NOAA, Department of Commerce. *Hypoxia in the Gulf of Mexico: Progress towards the completion of an Integrated Assessment.* Available online at http://oceanservice.noaa.gov/products/pubs_hypox.html

Nebraska Government Website. *Ethanol Production by State*, August 2008. Available online at http://www.neo.ne.gov/statshtml/121.htm .

Osborne, S. *Energy in 2020: Assessing the Economic Effects of Commercialization of Cellulosic Ethanol.* Office of Competition and Economic Analysis, International Trade Administration, US Department of Commerce. November 2007. Paper can be found at http://www.trade.gov/media/publications/pdf/cellulosic2007.pdf .

Partridge, M. "The Biofuel Boom: How Will It Shape Rural American Families and Communities?" Paper presented at conference *Rising Food and Energy Prices: US Food Policy at a Crossroads*, October 2, 2008 at Oregon State University, Corvallis. Paper can be found at http://arec.oregonstate.edu/faculty2/PerryFiles/foodenergyhome.html .

Pimentel, David. "Ethanol Fuels: Energy Security, Economics, and the Environment." *Journal of Agriculturaland Environmental Ethics*, Vol. 4 (1991), pp 1-13.

Pimentel, David. "The Limits of Biomass Energy." *Encyclopedia of Physical Sciences and Technology*, September 2001.

Pimentel, David. 2003. *Ethanol Fuel: Energy Balance, Economics, and Environmental Impacts are Negative*. Vol.12, No.2.: 2003 International Association for Mathematical Geology, Natural Resources Research.

Pimental, D. and T.W. Patzek. "Ethanol Production Using Corn, Switchgrass and Wood; Biodiesel Production Using Soybean and Sunflower." *Natural Resources Research* 14(2005):65-76.

Renewable Fuels Association. *Ethanol Facts: Trade.* Available online at http://www.ethanolrfa.org/resource/facts/trade/

Robertson, G.P., V.H. Dale, O.C. Doering, S.P. Hamburg, J.M. Melillo, M.M. Wander, W.J. Parton, P.R. Adler, J.N. Barney, R.M. Cruse, C.S. Duke, P.M. Fearnside, R.F. Follett, H. K. Gibbs, J. Goldemberg, D.J. Mladenoff, D. Ojima, M.W. Palmer, A. Sharpley, L. Wallace, K.C. Weathers, J.A. Wiens, and W.W. Wilhelm. "Agriculture: Sustainable Biofuels Redux." *Science* 322 (3 October 2008):49-50.

Schaal, M. "Projections for Energy Markets 2008-18 and Beyond." Paper presented at conference *Rising Food and Energy Prices: US Food Policy at a Crossroads*, October 2, 2008 at Oregon State University, Corvallis. Paper can be found at http://arec.oregonstate.edu/faculty2/PerryFiles/foodenergyhome.html .

Shapouri, H., J. A. Duffield, M.S. Graboski. 1995. *Estimating the Net Energy Balance of Corn Ethanol*. U.S. Department of Agriculture, Economic Research Service, AER-721, 1995.

Shapouri, H., J.A. Duffield, and M. Wang. *The Energy Balance of Corn Ethanol: An Update.* USDA Office of the Chief Economist, Office of Energy Policy and New Uses. Agricultural Economic Report 813. July 2002.

Shapouri, H., J.A. Duffield, and M. Wang. 2003.*The Energy Balance of Corn Ethanol Revisited*.: 2003 American Society of Agricultural Engineers, Vol.46 (4): 959-968.
Shapouri, H., J. Duffield, and A. McAloon. "The 2001 Net Energy Balance of Corn-Ethanol." USDA, Office of the Chief Economist. 2004. Available online at http://www.ethanol-gec.org/netenergy/NEYShapouri.htm

Searchinger, T., R. Heimlich, R.A. Houghton, F. Dong, A.Elobeid, J. Fabiosa, S. Tokgoz, D. Hayes, and T.H.Yu. "Use of U.S. Croplands for Biofuels Increases Greenhouse Gases Through Emissions from Land Use Change." *Sciencexpress*, Published online 7 February 2008. Available at http://www.princeton.edu/~tsearchi/writings/Searchinger_et_al-ScienceExpress.pdf

Swenson, D. "The Economic Impact of Ethanol Production in Iowa." January 2008. Available online at http://www.econ.iastate.edu/research/webpapers/paper_12865.pdf .

Sylvester-Bradley, R. "Critique of Seachinger 2008 & related papers assessing the indirect effects of biofuels on land-use change." Cambridge, UK: ADAS Insight

Trostle, R. "Global Agricultural Supply and Demand: Factors Contributing to the Recent Increase in Food Commodity Prices." Report WRS-0801, Economic Research Service, U.S. Department of Agriculture, May 2008.

US Department of Energy. Transcript of Press Roundtable with U.S. Energy Secretary Bodman & U.S. Agriculture Secretary Johanns. September 7, 2006. Available online at http://www.energy.gov/news/4141.htm.

University of Illinois Extension. US Tillage Trends. *Land & Water*. January 2005. Available at http://www.wq.uiuc.edu/Pubs/U.S.TillageTrends-1-13-05.pdf .

Urbanchuk, J.M. "Contribution of the Ethanol Industry to the Economy of the United States." Prepared for the Renewable Fuels Association. February 2008. Available at http://www.ncga.com/ethanol/pdfs/ethanoleconomiccontributionrev.pdf.

U.S. Dept of Energy, Office of Science. "Cellulosic Ethanol: Benefits and Challenges." Located at http://genomicsgtl.energy.gov/biofuels/benefits.shtml .

US Dept of Energy, Energy Information Administration. *Annual Energy Outlook, 2008.* Report Numer DOE/EIA-0383(2008). June 2008. Available online at http://www.eia.doe.gov/oiaf/aeo/.

US Dept of Energy, Energy Information Administration. *Consumption, Price and Expenditure Estimates*. State Energy Data System. February 2008. Available online at http://www.eia.doe.gov/emeu/states/_seds.html.

US Department of Energy, Energy Information Administration. *International Petroleum Monthly*. 2007 Data. Available online at http://www.eia.doe.gov/ipm/demand.html

US Department of Energy, Energy Information Administration. *Petroleum Monthly Supply, October 2008*. Available online at http://www.eia.doe.gov/oil_gas/petroleum/data_publications/petroleum_supply_monthly/psm.html.

US Department of Energy, Energy Information Administration. STEO Table Browser. Available online at http://www.eia.doe.gov/emeu/steo/pub/contents.html.

US Department of Energy, Energy Information Administration. *Federal Financial Interventions and Subsidies in Energy Markets 2007*. Report #:SR/CNEAF/2008-01. April 2008. Available online at http://www.eia.doe.gov/oiaf/servicerpt/subsidy2/index.html.

von Braun, Joachim, 2008. Congressional testimony by IFPRI Director-General, June (http://www.ifpri.org/pubs/testimony/vonbraun20080612.asp).

Wald, M.L. and A. Barrionnuevo. "A Renewed Push for Ethanol, Without the Corn." April 17, 2007 article in *The New York Times*.

Wang, M., C. Saricks, D. Santini. 1999. *Effects of Fuel Ethanol Use on Fuel-Cycle Energy and Greenhouse Gas Emissions*. U.S. Department of Energy, Argonne National Laboratory, Center for Transportation Research, Argonne, IL, 1999.

Wang, M. "Fuel Choices for Fuel Cell Vehicles: Well-to-Wheels Energy and Emission Impacts." Paper presented at 2002 Fuel Cell Seminar, Palm Springs, CA, November 2002. Available online at http://www.ethanolrfa.org/objects/documents/86/260.pdf .

Wang, M., M. Wu, H. Huo and J. Liu. "Well-to-Wheels Energy Use and Greenhouse Gas Emissions of Brazilian Sugarcane Ethanol Production Simulated by Using the GREET Model." 2007. Paper available online at http://www.dep.state.fl.us/ClimateChange/team/file/2007_0720_wang_suga_cane_ethanol_paper.pdf

Wang, M. and Z. Hag. "Response to Article by Searchinger et al. in *Sciencexpress*." Available at http://www.ncga.com/ethanol/pdfs/2008/Wang-HaqResponseSciencexpressArticles.pdf

Westhoff, P. "Farm Commodity Prices: Why the Boom and What Happens Now?" *Choices*, 2nd Quarter, 2008.

The World Bank: “Rising Food Prices: Policy Options and World Bank Response.” Policy Note, April 2008.

.