

## **Food versus Fuel” or the “Salve for Africa”?**

Foreign Affairs magazine recently carried a misleading article titled "How Biofuels Could Starve the Poor". Elsewhere, Lester Brown and others have written extensively on what they perceive as the dangers of corn ethanol. The flaws with these articles are primarily their failure to address the global implications of such a trajectory (like farm subsidies, global security) and show a narrow regional perspective, lack of appreciation of technology trends, or the factors behind global poverty. They also fail to note the environmental benefits of corn ethanol - or note that both the NRDC and the Sierra Club support it as a transition fuel. Furthermore, the critics fail to recognize that it is the best way to get to cellulosic biofuels. Cellulosic is the only viable, cost-effective and scalable alternative to oil. Critics must propose a cost effective alternative that is likely to be adopted or alternatively, proof that oil is a lesser evil than biofuels. Though there can be no guarantee of certainly, we have to pick among the viable alternatives based on their risks and costs. What is the cost and risk of climate change and a rise in the sea level? What is the cost of biofuel alternatives and their risks? The costs and risk or reliability of hydrogen, electric vehicles, and other alternatives?

### **How Biofuels Could ~~Starve~~ Save the Poor**

*Summary/Abstract: The future that Professors Runge, Senauer and Lester Brown and many other critics of corn ethanol see is similar to what we envision – cellulosic and biomass-based biofuels that offer better potential solutions, higher efficiencies, and a better environmental footprint. However, it is vital to note that none of this would have been viable without corn-ethanol in the first place – none of the university research, financial capital, or political backing for cellulosic would exist without the corn-based version proving its functionality and priming the market and infrastructure. Ethanol in its current manifestations has provided a valuable stepping stone away from the age of oil, and the transition to a cleaner and more environmentally friendly future based on cellulosic biofuels.*

### **Corn**

Corn Ethanol inspires a myriad of objections, from people across the political and economic spectrum. Some of these objections are:

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- Corn ethanol does not operate in a free market; it is a heavily subsidized fuel that is not market competitive
- Corn prices are responsible for large price increases in food – fuel is competing with food (particularly internationally)
- Other issues – corn ethanol’s energy content, environmental profile, and role as a fuel in the future

### Corn Ethanol in the Marketplace

A common contention with ethanol is its perceived lack of a “free market,” primarily due to the scale and effect of corn ethanol subsidies. Specifically cited is the 51-cent per gallon federal ethanol credit and the companies which garner a significant portion of these revenues. Professors Runge and Senauer suggest high-ethanol subsidies are a significant factor in demand (thus fueling the need for corn) for ethanol versus gasoline. The ethanol subsidy is due to expire in 2010, an action that we support as it has served its purpose in developing an alternative to big oil. We agree that a system which provides a significant profit to any one industry is not a particularly productive way of allocating government funding. In fact, we go further by supporting the removal of the 54-cent tariff that penalizes Brazilian ethanol, as it is counter-productive to the goal of replacing oil.

What garners more subsidies – ethanol or oil? Conventional wisdom suggests the former, but the data suggests a different conclusion. Ethanol subsidies (from the \$0.51 cent tariff) accounted for about \$3b last year. In comparison, big oil’s subsidies range from favorable accounting rules to capital gains laws, tax breaks, and below market oil extraction rights. Estimates of the total subsidies given to oil are varied, but evidence suggests that direct subsidies add up to at least \$0.25 per gallon<sup>1</sup> (excluding environmental, security, and healthcare costs or most importantly, the value of below market royalties), and it has been suggested that it might be as high as \$3 or more if one includes all the indirect subsidies. Extrapolating from the \$0.25 per gallon number, we calculate annual oil subsidies of approximately **\$35 billion**.<sup>2</sup> By most estimates, the subsidies to oil are far greater (including direct and indirect subsidies) both on a per-gallon and total dollars basis. The GAO estimates of the “excess of percentage over cost” (an accounting tax break that allows the oil industry to depreciate more than the total cost of a plant) subsidy were \$82 billion over the last 30 years. It further estimated that the oil industry has received “alternative fuel credits” for its production of oil from tar sands and oil shale –

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<sup>1</sup> “Greentech Newsletter: Renewable Subsidies”, ThinkEquity, Dec 22, 2006

<sup>2</sup> \$0.25\* daily consumption of 384.7 million gallons \* 365 days

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sources that are actually even less environmentally friendly than regular gasoline! In total, the study estimated that oil had received approximately \$130 billion in direct subsidies (the most conservative accounting possible) – compared to \$11 billion for renewable fuels over the same period.<sup>3</sup> Republican Senator Richard Lugar noted that the US government spends at least \$50 billion a year in defense-related costs to protect oil interests in the Middle East – something that should be included when discussing oil subsidies.<sup>4</sup> Our total Mideast defense costs are dramatically higher. The Energy Bill in 2005 did include ethanol subsidies, but it included far more for oil<sup>5</sup>. The aftermath of Hurricane Katrina included generous aid packages for refineries. Most experts agree that if royalties for oil extraction were based on auctions of the extraction rights, the royalties that the oil companies pay would be substantially higher than they are today. In many states (including California) the oil companies pay almost no royalties to extract oil. When Proposition 87 was put on the state ballot, the oil companies spent more than a hundred million dollars in an eight week advertising blitz to defeat it so they could keep their freebie. These are hard to quantify, additional direct subsidies that the oil companies collect. In summary, we strongly agree with the idea of a free market. Unsubsidized ethanol can compete on a level playing field with unsubsidized oil, but the continual presence of billions of dollars in oil subsidies provides a significantly distorting effect that needs to be removed in order to have genuine market competitiveness.

Many critics criticize the federal ethanol subsidy as another big government boondoggle. Actual data provides the opposite conclusion. Corn subsidies averaged \$9 billion from 2005-2006, including export guarantees and other assorted breaks. The effect of ethanol subsidies on corn subsidies is considerable– the evidence suggests that an increase in the former is more than offset by decreases in the latter. Testimony by Dr. Keith Collins (the USDA’s chief economist) noted that if you look at the fiscal year 2006 corn program, the cost was about \$8.5 billion [2005 crop]. Shift forward 1 year to fiscal year 2007 costs (2006 crop), direct payments are \$2.1 billion for corn – a net decrease of \$6 billion in corn subsidy costs because of \$3 billion ethanol subsidies. Furthermore, it is estimated that only about \$0.25 of the \$0.51 subsidy is actually collected by the ethanol producers because of a subtle nuance of how it was legislated. The subsidy is a “blender’s credit” and is collected by the oil companies that act as blenders. Further, formulating the current subsidy as a blender’s credit is a highly inefficient approach and a significant portion of it is wasted, especially at times of low ethanol prices

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<sup>3</sup> <http://ethanolrfa.org/resource/facts/economy/>

<sup>4</sup> <http://lugar.senate.gov/energy/press/articles/070101nature.html>

<sup>5</sup> [http://www.ucsusa.org/clean\\_energy/clean\\_energy\\_policies/energy-bill-2005.html](http://www.ucsusa.org/clean_energy/clean_energy_policies/energy-bill-2005.html)

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when ethanol producers need the most support. However, it serves oil interests and thus remains structured this way despite its inefficiency, giving roughly 50% of it as a freebie to the oil companies. An interest group's ability to receive subsidies often has little resemblance to its need to compete (that oil companies got \$7 billion in subsidies at the time of record profits from the Katrina disaster – these subsidies were hardly developmental in nature or needed because of hardship). While corn ethanol receives subsidies, they are not necessary for it to compete; competitiveness is a function of the price of oil and the built in oil subsidies. We buy the cheapest, Middle-Eastern oil in the world (i.e., without tariffs) but not the cheapest (and greenest) ethanol in the world from Brazil. Why? We need to separate the politics of ethanol from the economics to accurately assess its ability to compete. If the world accepted a free market for ethanol as it does for oil, we would see significant expansion of Brazilian and worldwide ethanol capacity and a further decline in costs.

How does ethanol fare against gasoline today? Ethanol can be cost competitive with gasoline even at current historically high corn and gasoline prices- approximately \$3.50 per bushel and \$2.66 per gallon of gasoline, compared to \$2.46 per gallon of ethanol (June 2007 data for Nebraska<sup>6</sup> – these are wholesale numbers, before subsidies and taxes). Imagine ethanol's unsubsidized competitiveness if oil did not get direct and indirect subsidies! Using historical corn prices, the competitiveness of ethanol improves dramatically. Mileage is an oft-cited issue - currently, ethanol gets about 25% less mileage per gallon than gasoline (using today's gasoline optimized engines – it's worth noting that ethanol has an octane rating of 113). Moreover, getting the gasoline in the first place is an extremely energy intensive process - Petroleum refining is the most energy-intensive manufacturing industry in the United States. In 2002, the U.S. refining industry consumed 6.391 quads (quadrillion Btu, or 10e15 Btu) of energy, accounting for about 28% energy consumption in U.S. manufacturing.<sup>7</sup> Today, we run ethanol in a gasoline optimized engine at a compression ratio of about nine, which fails to take advantage of ethanol's ability to run at much higher compression ratios. Engines designed for ethanol-first will operate at compression ratios of around sixteen, and will get far more mileage than their energy content would indicate. We see it as probable that ethanol could end up getting the same or even more miles per gallon than gasoline down the line. In Sweden, the SAAB 9-5 Biopower Turbo achieves gasoline-like mileage on ethanol because the turbo runs at higher compression levels (part of the time). Substantial possibilities exist for even better engines, and companies are working on just that.

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<sup>6</sup> <http://www.neo.ne.gov/statshtml/66.html>

<sup>7</sup> Petrochemical Refining: Technology and Economics, 5th Edition, James H. Gary, Glenn E. Handwerk, Mark J. Kaiser, CRC Press, 2007.

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The question that is not being asked is important - what is the cost of the status quo? As a whole, the subsidization argument fails to note the oil industries vast array of government boondoggles – the idea that subsidized ethanol competes against market oil is a myth at best, propelled by a selective overview of the facts. The government’s role in picking winners should be minimal and geared towards creating alternatives and competition to this strategic and unhealthy dependence we have on oil – a dependence that funds terrorism, distorts foreign policy and creates a massive national vulnerability in addition to its disastrous carbon emissions. The suggestion that corn ethanol’s support is picking a winner is ignorant of the scale of the largesse to petroleum. Ethanol with its smaller subsidies can compete with oil with its substantially larger cumulative and per gallon subsidies. We will return to the question of status quo or the cost of the externalities of oil.

### The Effect of Ethanol Usage on Corn

Is ethanol a primary cause of corn price rise? Critics have suggested ethanol is likely to burn up half of US domestic corn supplies in the near-term, and that the high price of corn reflects the effect on corn prices. Also cited are EIA estimates that global energy consumption will rise 71% from now till 2030, pushing oil prices higher and corn over \$5 per bushel. We don’t dispute the expected rise in global energy usage. Yes, corn prices were high – but long before we get to sustained \$5 per bushel corn (as some critics suggest), cellulosic technologies will make corn ethanol uncompetitive. Production cost for cellulosic ethanol is already at \$2 per gallon (Mascoma and Range present two such opportunities) even for small scale immature technology based production, and it will effectively act as a cap on the price of corn and corn based ethanol over the mid to long term. Cellulosic ethanol availability is not matter of “if” but “at what price” – \$2.00 per gallon is feasible using today’s technology (NREL’s Dan Arizu notes that \$1.62 per gallon cellulosic ethanol is a target price)<sup>8</sup>. By 2010, cellulosic ethanol capacity will be online at these (and potentially lower) prices. In fact, the variability of oil and corn prices is more of an issue than the absolute cost of cellulosic ethanol, in determining whether to build cellulosic ethanol plants. Today, only technologies that can quickly get below \$1.50 a gallon (and soon to \$1.25) are being considered for production. Mascoma, Range and many others expect to achieve these goals. This will cap corn ethanol and hence corn prices (we estimate to within \$3.00 per bushel of corn within five years).

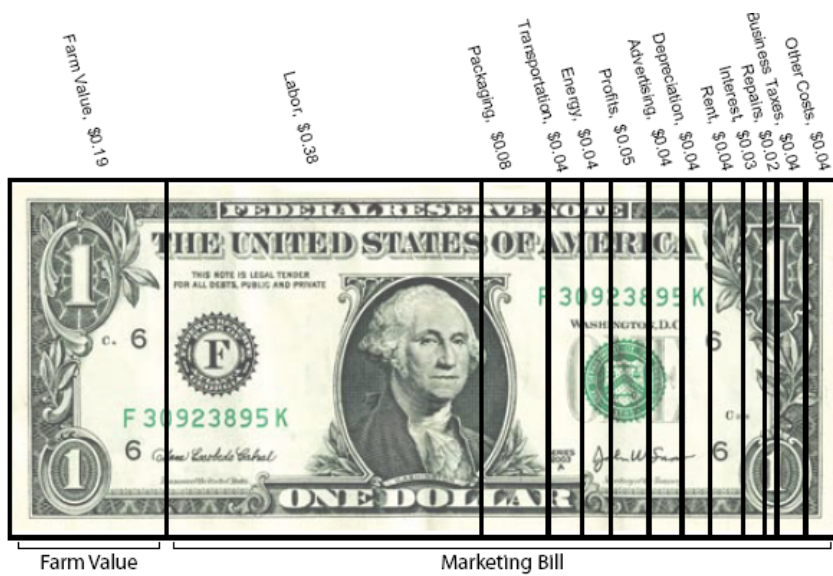
There is much ado about the impact of higher corn prices on food prices. The actual impact of corn prices has been minimal, with inflation for corn based foods (at 2.1%) at lower levels less than

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<sup>8</sup> [http://news.com.com/FAQ+Guide+to+alternative+fuels/2100-11395\\_3-6155212.html](http://news.com.com/FAQ+Guide+to+alternative+fuels/2100-11395_3-6155212.html)

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food inflation (2.9%) overall (as per the Bureau of Labor Statistics). Changes in input costs have had minimal effects on food prices. From January 2006 to May 2007, corn prices doubled from \$1.98 to \$3.76 a bushel ; in the same period, there was a \$0.03 increase in chicken breast (per lb) prices, no increase whatsoever in fresh chicken prices (still \$1.06 per lb), and decreases in the price of milk, cheese, and butter! Even beef (which ought to feel the strongest impact) did not rise significantly – ground beef rose from \$2.74 to \$2.81 per lb while steak went from \$5.06 to \$5.29. As the USDA notes: just 19 cents of every consumer dollar can be attributed to the actual cost of food inputs like grains and oilseeds”<sup>9</sup> – and corn is a small sub-section of that.



Source: USDA's Economic Research Service

At \$2 per bushel corn, a box of cereal will contain 2.2 cents worth of corn – at \$4 per bushel, the cost rises to 4.4 cents.<sup>10</sup> In other words, a \$1 rise in the price of corn is liable to increase cereal prices by a **penny**. In contrast, a corresponding increase in oil prices has a far greater impact on consumer welfare. A study by economist John Urbanchuk notes that “A 33 percent increase in crude oil prices – which translates into a \$1.00 per gallon increase in the price of conventional regular gasoline – results in a 0.6 percent to 0.9 percent increase in the CPI for food while an equivalent (33% ) increase in corn prices (\$1.00 per bushel) would cause the CPI for food to increase only 0.3 percent.”<sup>11</sup> **Increases in energy prices hurt the consumer almost twice as much as increases in corn prices.** If consumers have a complaint about rising inflation, OPEC and Exxon deserve more

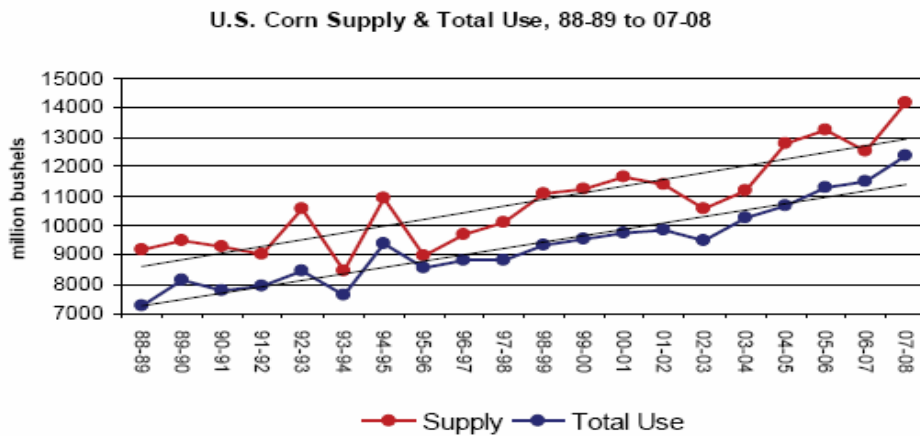
<sup>9</sup> “U.S Corn Growers: Producing Food and Fuel”, NCGA, July 2007

<sup>10</sup> [http://www.omaha.com/index.php?u\\_page=1208&u\\_sid=10085964](http://www.omaha.com/index.php?u_page=1208&u_sid=10085964)

<sup>11</sup> [http://www.ethanolrfa.org/objects/documents/1157/food\\_price\\_analysis\\_-\\_urbanchuk.pdf](http://www.ethanolrfa.org/objects/documents/1157/food_price_analysis_-_urbanchuk.pdf)

blame than ethanol. Additionally, critics citing higher inflation fail to note ethanol’s impact on supply. The 5 billion gallons of ethanol consumed last year effectively reduced gasoline demand. How much might gasoline prices have risen if an additional 4 billion gallons of gasoline was required last year? What impact might it have on the CPI?.

Markets have already reacted to the higher-corn demand with increases supply, which have already dropped prices to about \$3.50 per bushel. The ProExporter Network’s data shows us that while total corn demand in 2007/08 is estimated to be approximately 900 million bushels higher than 2006/07, total supply will increase by a 1.6 billion bushels (sufficient for about 4.8 billion gallons of ethanol or a big proportion of 2007 production!).<sup>12</sup>



Source: USDA, ERS; ProExporter Network  
 Note: 07-08 is based on ProExporter Network projections

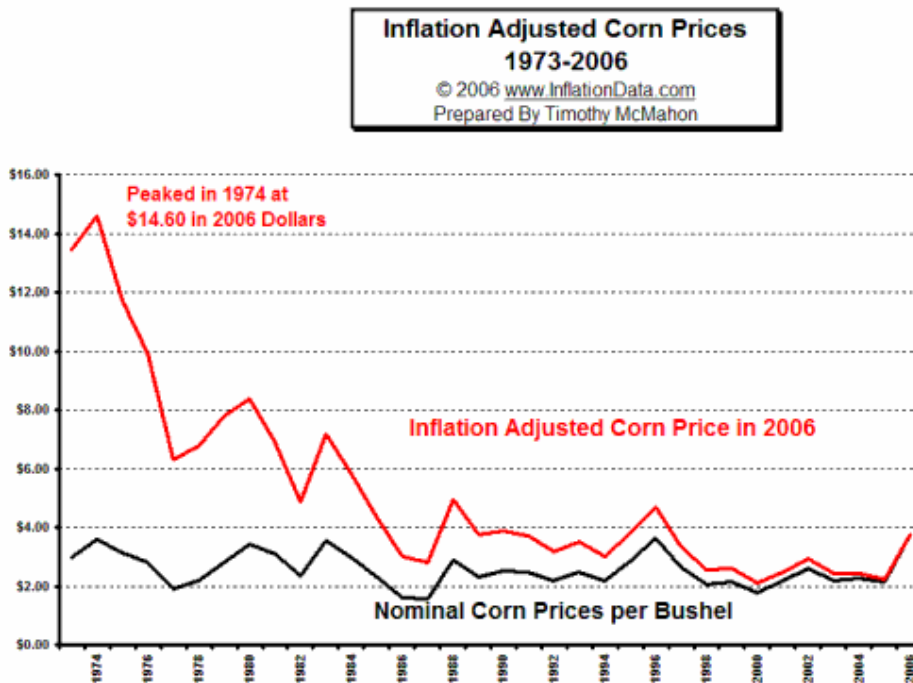
As for the studies often cited, forgive us for the skepticism: a common flaw is the usage of conservative, recursive looking data instead of forward looking estimates (such as Lester Brown’s corn ethanol based estimates). Using Lester Brown’s technique one would have to conclude wind power is bad, because if all of the world’s electricity came from wind, 75% of the population would be without power 75% of the time. Big Oil has not been averse to funding research (witness Exxon’s history of funding the CEI, or its donation of \$100M over 10 years to Stanford University) including active climate-change denial (to be clear, we are not suggesting that either the FA authors or Lester Brown has receive oil funding). Oil interests have spent considerable funds in a massive PR effort against corn ethanol and studies to deny climate change.

The issue of corn subsidies, unrelated to ethanol, is about the economics of corn and to what extent we as a country want to support farmers. There is a negative economic value to planting corn

<sup>12</sup> “U.S Corn Growers: Producing Food and Fuel”, NCGA, July 2007

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(as per a U of Illinois study on the economics of corn vs. miscanthus farming over a 10-year period<sup>13</sup>) and hence the need for subsidies. Corn prices have dropped rapidly over the past 30 years, resulting in a situation where farmers cannot make money at current prices (review the nominal and real price-charts of corn below). There has been consistent, bi-partisan political support to back farmers with subsidies, and it seems unlikely to change in the near future. Given the political realities of farm subsidies, **our question ought to be how to maximize it for public good**. If we as a nation have decided that domestic agricultural production is vital, shouldn't we find the best way to utilize the resulting product?



Does ethanol really compete with food? The Foreign Affairs article notes that filling a 25-gallon tank with ethanol requires about 450 pounds of corn (at today's yields) – or approximately 18 pounds per gallon. Coincidentally, it takes approximately 25 pounds of corn to put a pound of steak on your dinner table (see the table below, which shows the ratio of corn feed necessary to generate one **edible** unit of various meats); should we thus ban steak julienne? If replacing gasoline is not an acceptable usage of corn, does eating unhealthy steak qualify? What is more critical to society – a gallon of ethanol or a pound of steak?

<sup>13</sup> <http://www.ace.uiuc.edu/pERE/conference/papers/long.pdf>

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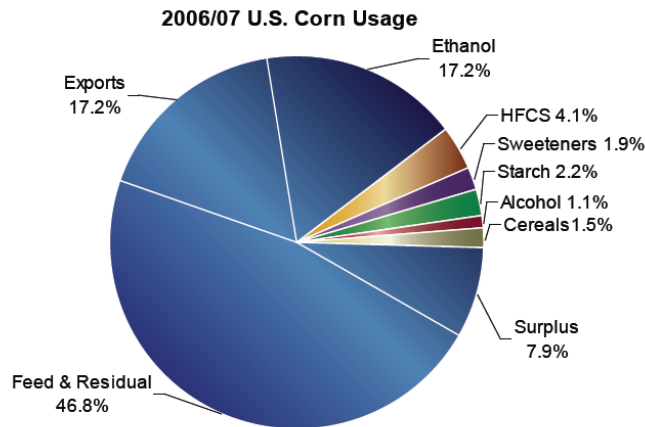
Feed conversion efficiencies for major animal food types.

Food Type	Feed Conversion	
	(kg feed/kg edible weight)	(kcal feed/kcal edible weight)
Beef	25.0	31.4
Pork	9.4	9.1
Chicken	4.5	7.7
Eggs	4.2	29.5
Fish	2.3	6.6
Milk	0.7	4.3

Mass conversions from Smil, 2000, assuming feed is corn; corresponding caloric values from USDA National Nutrient Database for Standard Reference; gov/fnic/foodcomp/search/

Professor Lee Lynd, Dartmouth<sup>14</sup>

The vast majority of US corn production (including exports) is used for animal feed, and not for human consumption.



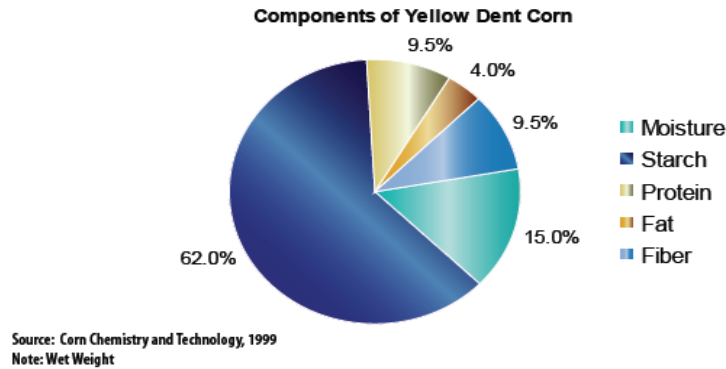
Source: USDA, ERS; Feed Outlook, June 13, 2007  
 Note: Percentages based on Total Supply

If a tradeoff exists, it is between basic food supplies and expensive beef. The National Institute of Livestock and Grassland Science in Japan (as reported by the New Scientist) notes that producing a kilogram of beef “leads to the emission of greenhouse gases with a warming potential equivalent to 36.4 kg of carbon dioxide [it also leads to emissions of sulfur dioxide and phosphate]...In other words, a kilogram of beef is responsible for the equivalent of the amount of CO<sub>2</sub> emitted by the average European car every 250 kilometers, and burns enough energy to light a 100-watt bulb for nearly 20

<sup>14</sup> Excerpt from “Energy and American Society Thirteen Myths”, Editor: Benjamin K. Sovacool, Marilyn A. Brown, 2007

days.”<sup>15</sup> Somehow, we consider it unlikely that cattle ranchers will be subject to anywhere near the criticism that ethanol has received.

Another common misconception is that corn once used for ethanol is lost for the feed market. On the contrary, ethanol uses only the **starch** portion of the corn kernel, leaving the more valuable “rest” for other uses, principally animal feed.



The vast majority of the protein in corn is recovered as distiller’s grain when ethanol is produced. The leftover protein is then used as animal feed, dramatically cutting down the amount of primary corn the animal needs. Only the (relatively) easily abundant carbohydrates are removed. Further, with improved techniques (like the fractionation of corn oil from the distiller’s grain) a much higher percentage of the livestock’s feed can come from distiller’s grain. In 2006/07, more than 12 million metric tons of distiller’s grains were produced by ethanol plants and fed to livestock and poultry.<sup>16</sup>

### International Food Supplies

The Foreign Affairs authors note: “*The International Food Policy Research Institute, in Washington, D.C., has produced sobering estimates of the potential global impact of the rising demand for biofuels. Mark Rosegrant, an IFPRI division director, and his colleagues project that given continued high oil prices, the rapid increase in global biofuel production will push global corn prices up by 20 percent by 2010 and 41 percent by 2020. The prices of oilseeds, including soybeans, rapeseeds, and sunflower seeds, are projected to rise by 26 percent by 2010 and 76 percent by 2020, and wheat prices by 11 percent by 2010 and 30 percent by 2020. In the poorest parts of sub-Saharan Africa, Asia, and Latin America, where cassava is a staple, its price is expected to increase by 33*

<sup>15</sup> <http://environment.newscientist.com/article/mg19526134.500-meat-is-murder-on-the-environment.html>

<sup>16</sup> “U.S Corn Growers: Producing Food and Fuel”, NCGA, July 2007

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*percent by 2010 and 135 percent by 2020. The projected price increases may be mitigated if crop yields increase substantially or ethanol production based on other raw materials (such as trees and grasses) becomes commercially viable. But unless biofuel policies change significantly, neither development is likely.”*

Despite its misplaced pessimism about corn-ethanol, the excerpted section does note that the advent of cellulosic ethanol would mitigate the purported price rises; as production capacity for cellulosic ethanol ramps up, it will be competitive, even without further improvements in technology. Cellulosic ethanol will act as price-ceiling on corn ethanol, much as corn ethanol can do for oil today. Nonetheless, the pessimism that the world’s poor starve because we don’t produce enough food is absurd. The Food and Agriculture Organization (FAO) notes that there is more food per-capita today than ever before – the lack of infrastructure, income, and distribution networks are the real causes of hunger, and not corn prices (indeed, the U.S exports just 17% of its corn production, and the majority of even this exported crop is used for livestock feed). Instead of rebelling against corn ethanol, the developing world (and Africa in particular) has been pushing the western world for agricultural subsidy reductions in the West, noting that their farmers cannot compete (and earn income) against such heavily discounted products. Critics conjure up images of starving children as innocent byproducts of corn ethanol; meanwhile, the EU actually pays farmers not to grow food (and thus to reduce supply). The (subsidized) low prices of agricultural products like corn have made foreign farmers in poor countries uneconomic producers. According to the New York Times (Aug 18, 2007), “CARE, the big global charity, had decided to stop selling subsidized American farm products in poor African countries because the program was inefficient and undercut local farmers.” Corn ethanol, by helping make corn more economic to grow and hence reducing corn subsidies, is actually helping the poor.

This same approach is reflected in the attitudes and policies of the developing countries themselves. The developing world’s competitive advantage is in labor-intensive industries such as agriculture; heavily subsidized developed-world farmers act as a distortion on the market. The developing countries in the Doha round of trade talks has been pressing the US (and far more egregiously, the EU, through its notorious Common Agricultural Policy) to give up their farm subsidies and thus stop artificially suppressing agriculture prices. There are millions of acres of arable African land that goes unutilized because of the depressing effects of these subsidies on prices.

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In the long run, an increase in real corn prices will do more to benefit Sub-Saharan Africa than current policies, especially because the positive impact will be felt in the farmers' checkbooks. Most importantly, in the future world of cellulosic ethanol, the \$300 billion the US spends on oil purchases<sup>17</sup> and the EU's \$136 billion spending on oil imports<sup>18</sup> could be allocated in a more distributed fashion to Africa with its vast potential for biomass cultivation. It would also help developing economies in China, India and Latin America by reducing the price of energy. It may be the single most important poverty alleviation tool we have. A focus on biomass will generate new income for Africa, India and Latin America's rural poor in addition to America's rural population. Almost certainly, America will produce all its own fuel given its agricultural advantages; Latin America might supply Europe and China; Africa might supply Europe, China, and India and result in a new, more distributed and diverse geopolitical balance on energy and incomes. On a larger scale, in any fundamental-shift there are winners and losers, and the author's point is duly noted. By and large though, the developing world has underutilized land resources that are more likely to benefit from a shift - biofuels may be a key resource that can help African economies and Latin American economies get going. Unfortunately, the oil rich Middle-East will be the loser in this transaction.

While we disagree with critics on corn ethanol, we share their beliefs on biodiesel. Classic biodiesel does not have the trajectory of a large-scale solution. Biodiesel yields are about 500 gallons per acre - similar to ethanol. However, the seed products from which vegetable oil is extracted are well optimized crops and yields are not likely to rise significantly (Despite our optimism on corn yields, we recognize this as a valid argument against too much reliance on corn ethanol). This in turn makes biodiesel land inefficient, which limits its scalability as a fuel. As such, biodiesel is likely to lose its cost effectiveness if oil prices suffer even minor declines, making it a short-term bet. We have noted that some of the biodiesel today even fails the environmental test - A fast emerging source of biodiesel is palm oil based biodiesel from Indonesia and Malaysia. This is just greenwashing a "not quite" clean fuel made by cutting down rain forests and releasing more carbon monoxide from the bogs they clear; more carbon is released than will be saved from replacing diesel with biodiesel. Nonetheless, some critics make the mistake of not distinguishing between the various biofuels approaches; cellulosic ethanol and Indonesian biodiesel do not occupy the same sphere, and have vastly different profiles and future roles. As a diesel replacement, Cellulosic diesel (and cellulosic hydrocarbons as a whole) offers long term-scalability, sustainability, and low production costs. When evaluating diesel replacements,

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<sup>17</sup> <http://lugar.senate.gov/energy/security/>

<sup>18</sup> EU Energy Commission website – 2004 numbers

its worth noting that one is good (cellulosic) and the other (biodiesel) a dead-end strategy with a poor “future trajectory.”

Stopping bad policy is a worthwhile goal, but we should not abandon all biofuels. There is no doubt that we can produce biofuels in the right or wrong way. However, at each step, we need to evaluate the costs of biofuels vs. the long-term costs of continuing with our current path. There exists vast tracts of underutilized pastureland worldwide and good energy crop practices can improve the sustainability of farming while meeting our energy needs. Lester Brown’s assertions that food supplies are likely to be threatened by corn ethanol (800M motorists vs. 2 billion poor people) is illogical and ill-thought out – the data is extrapolated from corn ethanol projections (without a basic understanding that cellulosic, and not corn ethanol, is the long term future) is flawed at best. To repeat what we have cited before: taking this “logic” to Brown’s idealistic vision of wind power – it would be akin to extrapolating to “if we produced all our electricity with wind 75% of the planet would be without electricity 75% of the time (or worse!)”. Irrational, fear-mongering extrapolation of data leads to irrational results.

### The Mexican Tortilla Story

One oft-cited example of “food vs. fuel” is the “Mexican tortilla story.” The Foreign Affairs article states that “Even major oil exporters that use their petrodollars to purchase food imports, such as Mexico, cannot escape the consequences of the hikes in food prices.” The facts of the case suggest a different story - the price rise had more to do with Mexican import policies than US corn prices. President Calderon did cap prices in Mexico, but he failed to change the import policies that motivated the price rise in the first place. As the *Economist*, (Feb 1 2007) notes:

*“Nearly all Mexican tortillas are made of home-grown white maize, rather than the yellow variety that is more common in the United States. The growing popularity of subsidized ethanol across the border has prompted the price of yellow corn, quoted in Chicago, to rise by over 50% since October. So industrial users of imported yellow corn in Mexico (for animal feed and syrup) started buying white maize instead. **The government was slow to react. The tariff on imported maize is not due to disappear under the North American Free Trade Agreement until next year. But the government could have blunted the price rise by waiving the tariff or moving quickly to expand the tariff-free quota, says Luis de la Calle, a former trade official. ... Officials point out that the higher price is good news for the rural poor, who***

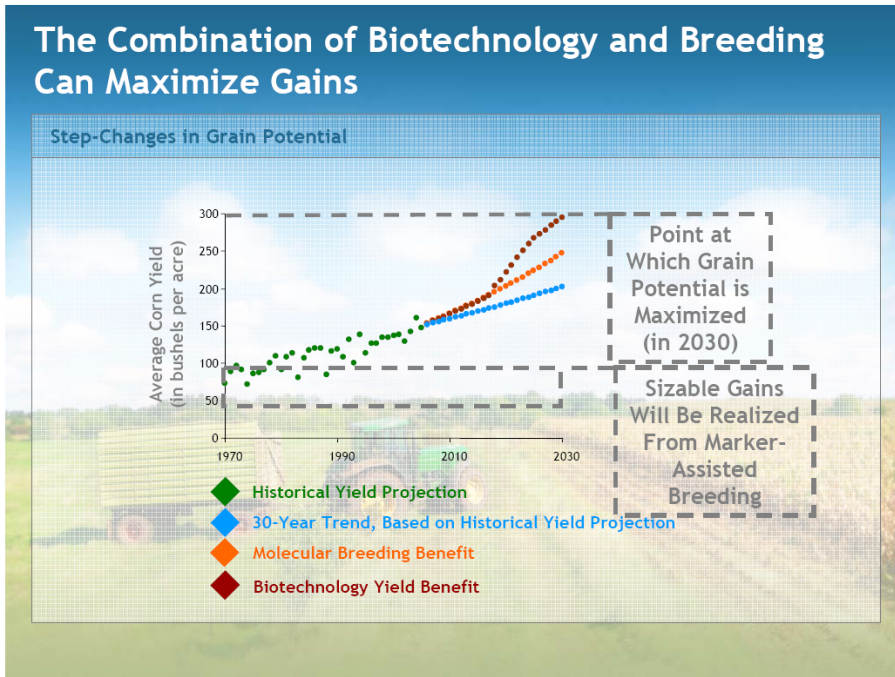
*grow maize. Mexico's Federal Competition Commission is investigating the import and distribution of maize. But Eduardo Pérez Motta, the commission's president, says he thinks that import quotas rather than monopolies are to blame for the price spike.*<sup>19</sup>

### Corn Ethanol – Yields, Environmental Impact, and Energy

Corn yields have been increasing for decades - and even larger increases are in store. While we are convinced the cellulosic ethanol will eventually supplant corn ethanol, corn still has room for improvement. Monsanto's projections of corn yields per acre suggest that the advent of biotechnology combined with molecular breeding will result in yields of around 300 bushels per acre providing a 100% increase in the corn supply. Domestic usage of corn (excluding the surplus and ethanol usage) makes up approximately 57% of total usage. With the doubling yields, **we could dedicate approximately 140% of today's total corn production** to biofuels and still meet all domestic needs for corn (holding demand and available land use constant – clearly, both are factors that could change). Corn ethanol would also make American corn farming economically viable on an unsubsidized basis for the first time in decades, potentially reducing the net consumer price rise as food prices go up slightly and fuel prices go down. For the last decade the price of corn has been substantially under its cost of production because of lack of demand. With red meat consumption switching to poultry, actual corn usage for livestock has been declining (from our earlier numbers - a gallon of ethanol and a 16oz steak fillet use about the same amount of corn while poultry takes a lot less) providing excess corn. The combination of the dietary trends amongst the populace along with the gain in yields per acre (the table below shows the expectations) to approximately 300 bushels/acre are likely to increase the supply of corn. This is true without increased land use.

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<sup>19</sup> [http://www.economist.com/displayStory.cfm?story\\_id=8633178](http://www.economist.com/displayStory.cfm?story_id=8633178)



Despite what critics say, the vast majority of evidence suggests that corn ethanol is an environmentally friendly fuel. Why else would both the NRDC and the Sierra Club support ethanol? The NRDC notes that “On average, ethanol produced from corn in the United States today reduces global warming pollution by 18 percent for every gallon of gasoline displaced. But not all gallons are created equal. Many of the newest corn ethanol plants rely on much more efficient systems and natural gas for process heat, reducing emissions by about 35 percent.”<sup>20</sup> Meanwhile, hybrids-vehicles have captured the public imagination as an environmentally friendly technology – even though corn-based ethanol offers the same “carbon emission per mile driven” benefits as the usage of hybrids, at 1/100<sup>th</sup> the cost per car. How often do we see “hybrid carbon emission reductions” criticized? Why?

	Hybrid	Flex Fuel Vehicle
Cost	\$3,000	\$30
Gasoline Savings (12,000 miles per year, 27 mpg)	157	477

Despite this, we are somewhat optimistic about hybrids; in the long-run, they might well lead to plug-in versions which offer significant environmental benefits. We also believe that both technologies (corn ethanol and hybrids) are compatible with each other, and could lead to flex-fuel hybrids. While

<sup>20</sup> <http://www.nrdc.org/air/transportation/biofuels/right.pdf>

it's clear that the high cost of hybrids will lead to a lower penetration rate, we think plug-in hybrids may be the ideal long run- solution and we are investing in hybrid battery technologies. However, in the next two decades hybrids are likely to be immaterial solutions to carbon emissions because of their likely low worldwide penetration.

The energy content of ethanol is another old and rehashed debate. Corn-based ethanol is twice as energy-efficient as petroleum; the NRDC's review of six major studies suggested that all except one (Pimentel and Patzek) showed a positive energy balance, ranging from 1.29 to 1.65<sup>21</sup> while gasoline is below 1. Even more important though, is corn ethanol's 90% reduction in petroleum uses. This is a seldom highlighted fact. Meanwhile, would-be critics of corn ethanol's energy balance fail to note that electricity is four times worse on energy balance than corn ethanol, with significantly higher fossil fuel usage. Why are we not critiquing electricity? The important thing to note is that all energy is not the same. Too many critics have a tendency towards worst-case assumptions on every projection without proposing alternative solutions. Rather, they complain about "what is" without understanding "what can be". There is always a role for questioning data and projections, but not at the expense of any action whatsoever! The larger issue is the underlying belief behind the approaches – ours is focused on finding solutions, as contrasted with a simple, "naysayers" approach.

#### In Defense of Corn Ethanol:

To reiterate, it must be recognized that corn ethanol's greatest value is as a "stepping stone" and transition-point to cellulosic ethanol, butanol, and even more attractive cellulosic fuels. Corn ethanol offers the first step in the trajectory from 500 gallons per acre to 3,000 gallons of fuel per acre – it mitigates many of the early, technological and capital risks associated with cellulosic ethanol, and helps to develop the infrastructure necessary for cellulosic ethanol, as well as other biofuels. We need to hone our production technologies, get the flex-fuel automobiles (FFV's – it costs just \$35 to make a new car capable of handling both E85 and gasoline) in place and the infrastructure for pumping, storing, and transporting ethanol implemented – in effect priming the pump. Incidentally, most such infrastructure will also apply to many future liquid fuels like butanol that are being considered. Additionally, corn ethanol can be produced cheaply in the US, and is a proven energy commodity. Equally importantly, ethanol is compatible and complementary to other petroleum use reduction technologies like hybrids and plug-in electric hybrid cars. Corn ethanol is not the long-term future fuel that will replace all of our oil needs – it is unlikely that we will produce more than 15 billion gallons,

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<sup>21</sup> <http://www.nrdc.org/air/transportation/ethanol/ethanol.pdf>

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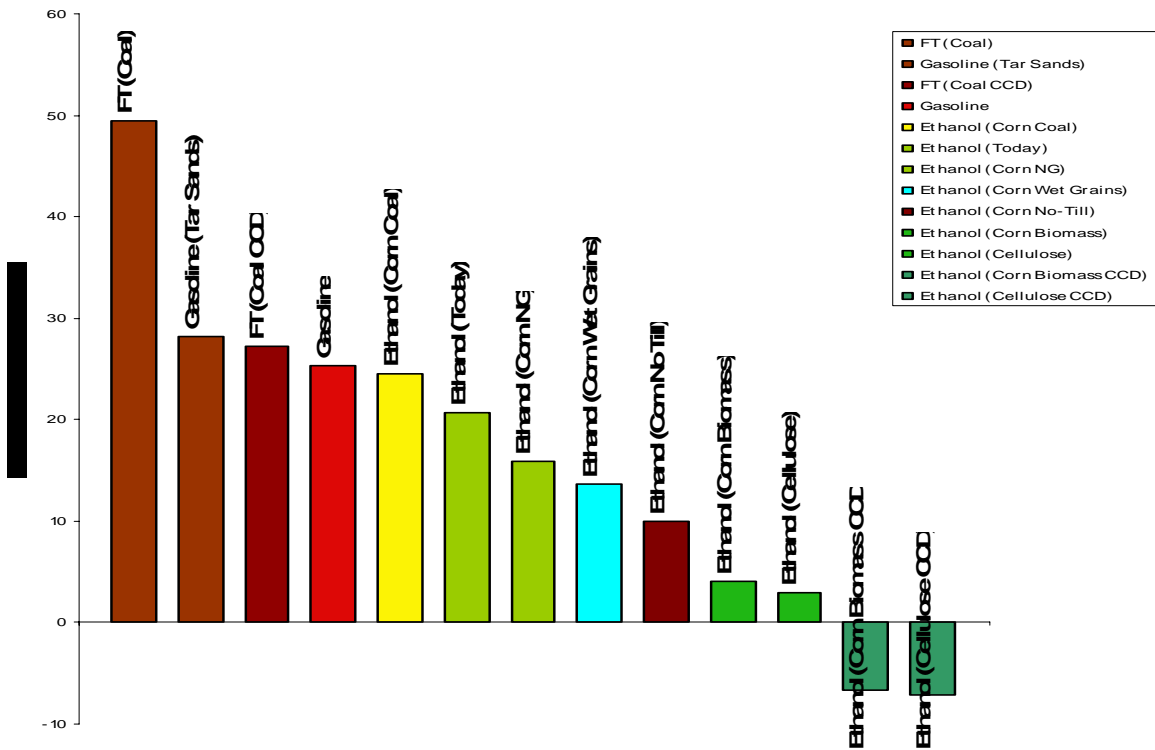
and most ethanol beyond 2015 or so will be cellulosic. But it is a key fuel that is critical to finding an alternative to petroleum. As the cellulosic technologies scale over the long run, corn's limits will be self defining. Till then, it is a vital building block in the vital transition away from petroleum. The cellulosic ethanol it enables will in-turn, encourage other even better fuels based on cellulosic feedstocks like butanol, or cellulosic gasoline and diesel. American's entrepreneurs and technologists are working on all these future options. We address the various pathways and fuels in our "Biofuels Pathways" paper, available at [www.khoslaventures.com/resources](http://www.khoslaventures.com/resources).

### CELLULOSIC ETHANOL

While corn ethanol is an area of significant disagreement, most serious critics recognize the potential of cellulosic ethanol. It is worth reiterating: cellulosic ethanol can be produced at \$2.00 per gallon using today's technologies. Range Fuels was recently awarded a construction permit to start building a commercial scale cellulosic plant in Georgia, and other plants will soon be on their way – by 2009/2010, cellulosic ethanol will be in the marketplace at \$2.00 per gallon prices. Range expects a half a dozen plants by 2011 with production costs of about \$1.25 per gallon. **Incidentally, cellulosic ethanol using the Range process not only reduces carbon emissions over 75%, it uses 75% less water than corn ethanol, and we estimate it will use 75% less land than corn ethanol too within a decade.** A significant reason for the potential growth of cellulosic ethanol (and the investment in it) is because of the priming of the infrastructure by corn ethanol, which the critics treat with disdain. From our perspective, we note that if corn ethanol did not create the market (and bear much of the initial risk), we wouldn't be investing in cellulosic ethanol.

The environmental benefits of cellulosic ethanol are immense –projections suggest that it can reduce greenhouse gas emissions per mile driven by 60-80% over gasoline. The Foreign Affairs authors agree – they note that the benefits of biofuels are significant “when plants other than corn or oils from sources other than soybeans are used.” Moreover, “Ethanol made entirely from cellulose (which is found in trees, grasses, and other plants) has an energy ratio between 5 and 6 and emits 82 to 85 percent less greenhouse gases than does gasoline.” It should be noted that the same can be achieved with corn-ethanol, as a demonstration plant in Mead, Nebraska shows. The NRDC projects that with appropriate technology choices, we may well have negative carbon emission per mile driven. Imagine a scenario where driving more could actually lead to lower levels of carbon emissions! Why not institute policies that incentivize biofuels to meet carbon reduction criteria?

**CO2 emissions from alternative fuels**



Many critics, mostly economists or scientists with little knowledge of significant technology progress in the small venture funded private companies, dismiss cellulosic ethanol as too far away. We disagree. A little help for cellulosic ethanol can go a long way - the Department of Energy went looking for three projects they could promote and found six that they described as “meritorious” enough to deserve funding. Today, a commercial scale cellulosic ethanol plants can meet corn ethanol production costs if one was built (as Range is doing). A wide variety of feedstocks have potential; to take one example, bagasse based ethanol has the potential to more than double Brazilian ethanol output without any additional crop usage. Going back to Range Fuels (and their initial wood-waste utilizing plant), estimates suggest that just the forest slash (that is today left abandoned) could produce twice as much ethanol in the Southeast US alone as was produced from corn in 2006. Elsewhere, the ability to generate fuels from biomass means that closed paper-mills across the US could find use again. Plants and demonstration plants are not pipedreams - they are being built right now by at least a half dozen separate companies. Are they all wrong? We have invested more than our word in these beliefs –

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we've invested our money, which is the only objective test of belief about readiness. The volume problem ("fueling an ethanol plant with switchgrass, a much-discussed alternative, would require delivering a semitrailer truckload of the grass every six minutes, 24 hours a day") is again off-base, and fails to note that every American uses 20 pounds of coal per person, per day.<sup>22</sup> We manage to deliver this to its destination. How much crude oil do we deliver every day across thousands of miles? In the most likely scenario, we would probably ship biomass 30 miles on average, produce fuels in a distributed fashion around the country, and generate many more jobs and value – all in the US (with oil, roughly \$70 of the \$75 per barrel "value" of refined oil is shipped overseas when made from imported crude). Distributed cellulosic plants have the potential to meet all of our production needs and retain most of the value here in the US.

In the long run, these are the technologies that will overtake corn based ethanol – however, corn ethanol is the gateway to spur investment in these technologies. In fact, this is already happening to some extent – our investments in companies such as Mascoma, Range, Celunol (now Verenum), LS9, Amyris, Lanza, Gevo, Coskata and Kior suggest that the pathway to biofuels extend far beyond corn ethanol. Entrepreneurs have designed and produced new biofuels, created new bioprocess technologies to cost-effectively convert biomass to ethanol, and revising old production techniques (such as fermentation and catalytic conversion) while using feedstocks of all varieties, above and beyond corn. Some of the feedstocks include miscanthus, sorghum, switchgrass, algae, municipal sewage, industrial waste and others. Municipal sewage is perhaps the most intriguing – a problem that is becoming an opportunity. There is sufficient municipal sewage (and potentially waste) to produce tens of billions of gallons of ethanol or successor fuels like butanol. It is available in large enough quantities in most major cities to justify plants and has a negative cost, usually a tipping fee. Depending upon local circumstances, other feedstocks like used trees, paper mill waste, and forest residue could all make sense. One of our favorites is a proposal to take all the waste carbon monoxide from steel mills (already collected and piped, available to go into a process!) to make ethanol. There is enough carbon monoxide coming out of today's steel mills to produce over **50b gallons of ethanol**. In effect, we find ourselves in agreement with the many critics that the key to an oil-free future is dependent on transcending corn ethanol.

### Land Use for Cellulosic Ethanol

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<sup>22</sup> Goodell, Jeff "Big Coal: The Dirty Secret Behind America's Energy Future", 2006

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For cellulosic ethanol to be a material climate change solution, it must show the ability to scale to meet our needs. Along these lines, we need to determine how much cellulosic ethanol we can produce, what cost can we produce it at, and how much land will be required. Our projections suggest that we can meet these thresholds at a cost below \$1.25 per gallon. In reality, the land requirements are likely to be lower (as discussed later). If all of our biofuel needs are met from energy crops, we expect the following:

<b>Year</b>	<b>Biomass Yield (Tons/Acre)</b>	<b>Acres Planted (Millions)</b>	<b>Cellulosic Ethanol (billions of gallons)</b>	<b>Corn Ethanol (billions of gallons)</b>	<b>Total Ethanol (billions of gallons)</b>
2012	8.9	5	4.4	12.0	16.5
2017	12.5	19	24.8	14.6	39.4
2027	23.1	49	124.4	14.6	139.0

In terms of raw materials, we believe that the focus should be on land efficient feedstocks that will ensure the long-run scalability of cellulosic fuels. The scalability of cellulosic feedstocks is one of the primary reasons for our optimism regarding cellulosic ethanol and other cellulosic fuels. Fortunately, there are a variety of potential sources – many of which have not been optimized. Once ethanol becomes a substantial market, all parts of the production process, crops & feedstocks, manufacturing, chemistries, transportation, and more will be the subject of intensive attention and innovation. The world does not stay still when large scale economics are involved.

Some facts about biomass yields:<sup>23</sup>

- Miscanthus averaged 16.5 dry tons per acre per year, where switchgrass averaged 4.6 at 3 Illinois sites, with data taken over 3 years
- Sugarcane experts in Brazil are breeding energy cane that will likely result in a yield of 25 dry tones per acre/year of harvestable biomass
- Approximately 75 million acres of crop and pasture land in the US can easily be converted to cultivating energy crop without impacting domestic food production (Ceres)<sup>24</sup>
- DOE estimates suggest that collecting existing biomass with only a small change in agricultural practices could generate 1.3 billion tones of biomass in the US and still be able to meet all food, feed, and export demands.<sup>25</sup>

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<sup>23</sup> Professor Lee Lynd – Dartmouth

<sup>24</sup> Ceres company presentation

<sup>25</sup> Technical Feasibility of a Billion-Ton Annual Supply, US Department of Energy Report , April 2005  
[http://www.eere.energy.gov/biomass/pdfs/final\\_billionton\\_vision\\_report2.pdf](http://www.eere.energy.gov/biomass/pdfs/final_billionton_vision_report2.pdf)

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- High yield sorghum can be grown in 35 US States and produce yields as high as 25 dry tones per acre/year<sup>26</sup>
- Researchers at Texas A&M have developed new “freakishly tall sorghum plants” that reach heights of nearly 20 feet – more than double the height of regular sorghum and yielding double the amount of crop per acre.<sup>27</sup> They use little water, and have been bred to prevent flowering (thus trapping more energy), and can be grown on marginal crop lands.

Our estimates suggest that with some increases in CAFE standards, less than 50m acres of biomass crops will replace most US gasoline usage (see our yield and production estimates later in this paper)- a small price for saving the US economy \$300 billion per year in imports and reducing the cost of our oil dependence. To help the world’s starving poor, direct aid (via a fraction of these economy-wide cost savings) is significantly better than farm subsidies (only a minute portion of which ever benefits the poor in countries like Africa). Cellulosic ethanol also improves the sustainability of farming because of carbon fixing and improving soils if the right crop rotation schemes are followed. From an environmental perspective, the negative carbon emission per mile driven (as per the Natural Resources Defense Council)) could play an important role in reducing global warming and carbon emission reduction costs if sustainable energy crop practices are developed (see our Biofuels Pathways paper at [www.khoslaventures.com/resources.html](http://www.khoslaventures.com/resources.html)).

The potential is enormous – we believe this will lead to \$1.00 per gallon cellulosic ethanol within a decade, coupled with lower costs to US consumers as well as improved agricultural practices. Higher yields from new crops (like Monsanto corn) can be directed towards short-term biofuel needs (via corn ethanol); as yields increase and less land is needed for corn for other uses, the remaining land can then be directed toward energy crop production. We believe that **39 billion gallons of biofuels production is possible in the U.S by 2017 on 19 million acres (at a reasonable cost); and 139 billion gallons by 2027 on 49 million acres.** A fraction of the land currently used for (subsidized) export crops will replace much of our US oil (the development of new engines, and increased CAFE standards could further dramatically alter the oil use equation).

Below are Khosla Ventures projections of the expected yields of cellulosic ethanol from 2008 to 2030, accounting for improvements in yield of biomass crops, efficiency of ethanol production per ton of biomass, and increases in land usage. Over the period, crop yields are likely to increase four-fold! Additionally, it’s worth noting that the gasoline demand does not take into account increased

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<sup>26</sup> Professor Mark Holtzaple, Texas A&M

<sup>27</sup>[http://www.grainnet.com/articles/Gulf\\_Ethanol\\_Corp\\_\\_Advances\\_Production\\_Plans\\_for\\_Texas\\_A\\_M\\_Sorghum\\_Ethanol\\_Plant\\_-46989.html](http://www.grainnet.com/articles/Gulf_Ethanol_Corp__Advances_Production_Plans_for_Texas_A_M_Sorghum_Ethanol_Plant_-46989.html)

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engine efficiencies (such as that proposed by Transonic Combustion, one of our investments) or large increases in CAFE (Demand in the table below is projected to grow 1% per year along historical lines, though we hope technology improvements and policy both reduce our per mile driven consumption of liquid fuels - a technology like Transonic is developing can reduce our gasoline/diesel needs in half).

Year	Million Acres Biomass Ac.			Production Cellu.Eth. Gals (Billions)	Production Corn Eth. Gals (Billions)	Production Total Eth (gals) (Billions)	Ethaol Prod. Gas. Eq Gals (Billions)	Gasoline Demand(1%) (Billions Gal)
	Yield (tons/ac)	Yield (Gals/ton)						
2008	6.9	90.0	0	0.0	6.9	6.9	5.5	144.2
2009	7.3	93.6	0.1	0.1	8.3	8.4	6.7	145.7
2010	7.8	97.3	1	0.8	10.0	10.7	8.6	147.1
2011	8.3	98.3	3	2.5	10.9	13.4	10.7	148.6
2012	8.9	99.3	5	4.4	12.0	16.5	13.2	150.1
2013	9.6	100.3	7.5	7.2	13.2	20.4	16.4	151.6
2014	10.2	101.3	10	10.4	14.6	24.9	19.9	153.1
2015	10.9	102.3	13	14.6	14.6	29.1	23.3	154.6
2016	11.7	103.3	16	19.4	14.6	33.9	27.1	156.2
2017	12.5	104.4	19	24.8	14.6	39.4	31.5	157.8
2018	13.4	105.4	22	31.1	14.6	45.7	36.5	159.3
2019	14.3	106.5	25	38.2	14.6	52.8	42.2	160.9
2020	15.4	107.5	28	46.2	14.6	60.8	48.6	162.5
2021	16.3	108.6	31	54.8	14.6	69.3	55.5	164.2
2022	17.2	109.7	34	64.3	14.6	78.9	63.1	165.8
2023	18.3	110.0	37	74.4	14.6	89.0	71.2	167.5
2024	19.4	110.0	40	85.3	14.6	99.8	79.9	169.1
2025	20.5	110.0	43	97.2	14.6	111.7	89.4	170.8
2026	21.8	110.0	46	110.2	14.6	124.8	99.8	172.5
2027	23.1	110.0	49	124.4	14.6	139.0	111.2	174.3
2028	24.5	110.0	52	140.0	14.6	154.5	123.6	176.0
2029	24.5	110.0	56	150.9	14.6	165.5	132.4	177.8
2030	24.5	110.0	60	161.7	14.6	176.3	141.0	179.5

Progress is happening (and will continue to do so) on energy crops, eliminating fertilizer use, limiting water use, and improving biomass yields. We should encourage these when formulating policy. The idea that energy independence is a “chimera” is simply an unsupported conjecture - our estimates of biofuels production capacity show a pathway towards reaching these goals.

Our most critical assumption is on land efficiency – we believe biomass yields per acre will improve 3-4 times from today’s un-optimized biomass crops. Enough incidental data exists to make these yield assumptions reasonable. We assume gasoline demand will keep increasing in the US about 1% per year. Achieving a cumulative 50% increase in engine efficiency over 25 years (or yearly improvements of about 1.5%) would reduce these numbers dramatically and if engine efforts at companies like Transonic are successful, we will see a 100% increase in efficiency in engines. These dramatic improvements, though possible, are not assumed in the forecasts. Our expectation of ethanol

yields per ton are to increase about 25% over 25 years (or less than 1% per year!) are well below what many commercial ventures are planning. How much land will we need? The NRDC, using conservative assumptions estimated that 114M acres would be able to meet all of our transportation fuel needs<sup>28</sup>. More forward looking research from George Schultz and Jim Woosley suggests 30M acres of land could meet half of our gasoline needs, assuming some efficiency gains<sup>29</sup>. Our own projections suggest the number is close to 50M for a significant majority of our gasoline needs, without taking into account major efficiency increases or a significantly more stringent CAFE standard, the latter of which appears to be inevitable. Where would these 50M acres of land come from?

**Domestic:** In the US, we currently have over 120 million acres of CRP and export crop lands.<sup>30</sup> This land should be able to meet our needs, even in the most conservative scenario (the 114M acres estimate above by the NRDC). Moreover, using this crop land for biofuels provides significant benefits to the US in three distinct ways:

- (1) A lowering of the U.S trade balance, which is both economically and politically beneficial. At first glance, this may appear counter-intuitive – the reduction of exports increasing the trade balance? However, while we would be reducing crop exports, the crop land (along with the CRP land) would now be devoted towards ethanol (and other biofuel) production – thus replacing a portion of the approximately 12 million barrels of petroleum a day that the US currently imports<sup>31</sup> to meet its domestic consumption needs. In essence, we would be replacing relatively low-value (\$500 per acre) and low-margin crop with high-value (\$5,000 per acre), gasoline replacement fuel.
- (2) An increase in farm incomes. Dr. Collins, chief economist of the USDA, has noted as much in Senate testimony - “Biofuel production is increasing farm income and rural economic activity”<sup>32</sup>. As more land is devoted towards the growth of miscanthus and/or other energy crops, farm income is likely to continue to increase. Net Farm Income in the US is expected

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<sup>28</sup> <http://www.nrdc.org/air/energy/biofuels/biofuels.pdf>

<sup>29</sup> <http://www.energybulletin.net/11013.html>

<sup>30</sup> Ceres presentation

<sup>31</sup> EIA data for 2006 - average for 4 quarters

<sup>32</sup> [http://epw.senate.gov/hearing\\_statements.cfm?id=262516](http://epw.senate.gov/hearing_statements.cfm?id=262516)

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to be approximately \$6 billion higher in 2007 than 2006, with corn (and by extension, ethanol) having a significant impact.<sup>33</sup>

- (3) An increase in farm income will lead to decreases in farm subsidies. The previously cited testimony of Dr. Collins notes that ethanol has actually been a net positive for the federal treasury because of its role in increasing corn prices. The RFA affirms this and notes “According to agricultural economist John Urbanchuk, the U.S. spent \$2.5 billion in the form of tax credits available to gasoline refiners who choose to blend ethanol. The growth in the ethanol industry as a result of the increased demand for ethanol returned some \$2.7 billion back to the federal government in the form of tax revenue. Moreover, farm program payments are expected to be reduced by some \$6 billion due to the higher value of a bushel of corn. Taken together, the \$2.5 billion investment by the federal government has yielded nearly \$9 billion in new tax revenue and budget savings. Including the estimated \$2.3 billion in state and local tax revenues, the new revenue and budget savings greatly exceed \$10 billion.”<sup>34</sup> (note: these are 2006 numbers) Higher prices and lower subsidies are beneficial for American farmers as well as their international counterparts..

Beyond the benefits of utilizing the export crop and CRP land, there are specific benefits associated with the usage of fallow land. Professor David Tilman’s (University of Minnesota) research offers an overview of the benefits:

“ In a 10-year experiment reported in Science magazine in December, we explored how much bioenergy could be produced by 18 different native prairie plant species grown on highly degraded and infertile soil. We planted 172 plots in central Minnesota with various combinations of these species, randomly chosen. We found, on this highly degraded land, that the plots planted with mixtures of many native prairie perennial species yielded 238 percent more bioenergy than those planted with single species. High plant diversity led to high productivity, and little fertilizer or chemical weed or pest killers were required.

The prairie "hay" harvested from these plots can be used to create high-value energy sources. For instance, it can be mixed with coal and burned for electricity generation. It can be "gasified," then chemically combined to make ethanol or synthetic gasoline. Or it can be burned in a turbine engine to make electricity. A technique that is undergoing rapid development involves bioengineering enzymes that digest parts of plants (the cellulose) into sugars that are then fermented into ethanol.

Whether converted into electricity, ethanol or synthetic gasoline, the high-diversity hay from infertile land

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<sup>33</sup> <http://www.ers.usda.gov/Briefing/FarmIncome/nationalestimates.htm>

<sup>34</sup> <http://www.ethanolrfa.org/resource/facts/economy/>

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produced as much or more new usable energy per acre as did fertile land planted with corn for ethanol. And it could be harvested year after year.

**Even more surprising were the greenhouse gas benefits. When high-diversity mixtures of native plants are grown on degraded soils, they remove carbon dioxide from the air.** Much of this carbon ends up stored in the soil. In essence, mixtures of native plants gradually restore the carbon levels that degraded soils had before being cleared and farmed. This benefit lasts for about a century.

Across the full process of growing high-diversity prairie hay, converting it into an energy source and using that energy, we found a net removal and storage of about a ton and a half of atmospheric carbon dioxide per acre. **The net effect is that ethanol or synthetic gasoline produced from high-diversity prairie hay grown on degraded land can provide energy that actually reduces atmospheric levels of carbon dioxide.**<sup>35</sup>

**To summarize – utilizing degraded land that is not being farmed today can vastly increase our available land while lowering our overall carbon emissions.** Additionally, we might reclaim degraded land that can no longer be farmed, back into energy crop cultivation. The same polyculture results could increase productivity of export crop lands as well, albeit probably not at the same percentage increases.

We believe that a crop rotation scheme combined with mixed grass cocktails or “polyculture” (or polycultivation as companies like Ceres are proposing) with perennial energy crops grown in seven or ten year crop rotations with today’s corn/soy crop rotations will improve row crop yields while reducing the demand for fertilizer and other inputs into farming. It could well make all agriculture, not just energy crop agriculture, more sustainable with many collateral benefits like increases in biodiversity, less nitrogen pollution etc. Polyculture and crop rotation are just two of many more powerful tools that can be devised for sustainable, high yield energy and row crop cultivation using perennial crops. Adding energy crops like switchgrass and miscanthus in a 10 x 10 year rotation with corn/soy crops would add carbon to the soil and make up for topsoil loss during the row crop cultivation cycle – thus making today’s farming more sustainable while reducing carbon emissions from transportation fuels. The NRDC study “Growing Energy” suggests that this mix will enhance the soil, keeping farmland more productive and provide biodiversity. Finally (in the US), we can get substantial amounts of biomass from winter over crops without increasing the amount of land under cultivation ,as suggested by Prof. Barnsby of Auburn University. Additional substantial biomass can be produced from forestry wheat, utilizing feedstocks from the many paper mill plantations that are underutilized today, municipal sewage, organic waste from municipal land fills, and many other

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<sup>35</sup> <http://www.deseretnews.com/dn/view/0,1249,660207597,00.html>

sources. In reality, we expect that some combination of winter over crops, waste biomass, and energy croplands will be used. All these carbon sources will substantially reduce the need for additional land in the US. The DOE estimates that just the waste biomass today could provide substantially all of our biofuels needs.

A word of caution is in order though. Like any technology tool, we can use biofuels technology well or use it poorly. There is potential for misuse of land in unsustainable practices to produce biofuels. While we cannot afford to throw the biofuels baby out with the bathwater, caution and legislation to ensure good environmental practices in biofuels feedstock production is vital. We can attempt brute force approaches or use finesse; use ecologically destructive approaches or sustainable ones. Biomass crops must be done sustainability – today, we have the ability to do it the right way or the wrong way. We also need to maximize the use of conservation and efficiency as tools.

**International:** On an international level, there is also further room for improvement. Much of the data cited above (and particularly Professor Tilman’s study) is applicable worldwide. In Asia and Africa, the large tracts of underutilized land and pastureland offer significant room for biomass cultivation. C4 photosynthetic energy crops that grow well in the tropical belt (which is also the poverty belt) make particularly good energy crops. We believe that energy crops can increase the yield of traditional agriculture while reducing the need for chemical inputs in the developing world. They can help put degraded lands back into production with the appropriate crop rotation schemes, while also increasing rural and farm income. African countries are already taking notice. In South Africa, the government approved an industrial strategy for biofuels. The government spokesman stated that “Cabinet noted the country has the potential to produce biofuels which could contribute up to 75 percent of our renewable energy by 2013, without negatively impacting on food security or requiring excessive support.”<sup>36</sup> In Europe, utilizing the Common Agricultural Program’s \$80 billion annual budget towards energy crop production (instead of overtly-generous price floors/guarantees) offers one potential area of improvement. We strongly believe in the potential of Africa as a potential energy producer for Europe. Worldwide, there is also substantial potential to increase crop yields, freeing up significant amounts of agricultural land for energy crops.

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<sup>36</sup> [http://english.people.com.cn/200612/08/eng20061208\\_329831.html](http://english.people.com.cn/200612/08/eng20061208_329831.html)

**THE RISKS OF DOING NOTHING:**

The fundamental problem with many critics is their lack of solutions to our continued oil addiction – and the costs associated with that. What is the opportunity cost of doing nothing? On a planetary scale, which gambles do we wish to take?

Fundamentally, we face a problem of risk management, and the best approach towards it. By reinforcing the status quo, we face the problems of significant planetary global warming risk, increasing Middle Eastern dependence, high military expenses, and minimal energy security - all from an energy source that is being depleted far more quickly than we can replenish it. There are undoubtedly risks associated with biofuels, and we've noted some of them here. However, the risk of doing nothing is so onerous that not protecting ourselves is foolhardy.

Even taking the estimates cited in the Foreign Affairs article, none of them come close to the cost of dependence on oil (referring back to Senator Lugar's 8/29/06 speech on the subject<sup>37</sup>). To get an accurate account, we must add to these costs the costs of producing oil, the cost of the environmental damage, the cost of geopolitics, global security, global human rights abuses related to oil (Nigeria, Sudan, Iran, Saudi Arabia, Venezuela), and its effect on development at large. To quote Tom Friedman, "It is no accident that when oil prices were low in the 1990s, Iran elected a reformist Parliament and a president who called for a "dialogue of civilizations." And when oil prices soared to \$70 a barrel, Iran's conservatives pushed out the reformers and ensconced a president who says the Holocaust is a myth (I promise you, if oil prices drop to \$25 a barrel, the Holocaust won't be a myth anymore.)"<sup>38</sup> Oil leads us to support of non-democratic regimes, overlook massive corruption (Kazakhstan, Nigeria again, the various Saudi princes) and align our foreign policy based on resources instead of shared interests (Would we spend \$50 billion a year protecting the Persian Gulf without oil?). As we advance to cellulosic fuels, even the critics acknowledge that their estimates may be "mitigated." We expect they will be essentially eliminated — we expect cellulosic biomass to take over in the long run. Should we imagine the future and make it a more positive one, or remain "naysayers" in the face of imminent danger?

The need to tackle global warming is a topic that is not broached (the GAO notes that insurers are already pricing global warming risk into their models). Corn ethanol will lead to cellulosic ethanol and other biofuels which are viable solutions, primarily because they lack the negative outcomes associated with the various fossil fuels. The alternative is ominous - should we accept a 20% reduction

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<sup>37</sup> <http://lugar.senate.gov/energy/press/speech/purdue.html>

<sup>38</sup> <http://www.nytimes.com/2007/04/15/magazine/15green.t.html?pagewanted=3&ei=5087&en=c87e7dac744e99d3&ex=1180843200>

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in worldwide GDP as the Stern Report from the UK estimates? Should we let climate change disproportionately impact the poorer countries?<sup>39</sup> Holland can deal with the cost of rising sea levels – can Bangladesh do the same? Are there alternatives the critics propose to reduce the impact of climate change that is relatively economical, practicable, politically doable, and socially acceptable? Would we prefer the idealists’ approach of banning cars, forcing people to drive less, building hydrogen networks from scratch, or spend trillions on all electric cars infrastructure (to name a few of the ideas that we’ve seen proposed)? Are they likely to happen? Can we and will we fund these efforts? The idea that resorting to biofuels would leave an extra 600 million people chronically hungry is absurd. It fails to account for the 600 million people (mostly in the poorer countries) that might be displaced by global warming, or the planetary changes that carbon emission might cause. Amongst many other flaws, it fails to consider the increases in income that the usage of biomass would provide. While we acknowledge the right (and the need) for some skepticism, the critics’ lack of examination of the opportunity cost is problematic at best. The world (we suspect) is open to realistic alternatives, but criticisms need to be backed up with solutions if they are to be constructive. Which mix of “lesser evils” should we accept?

Many critics, having made the case that high oil prices are a problem (and thus making our case for the development of alternatives), also switch tack and argue that the current “speculation” in ethanol would lead to potential problems if oil prices decline to \$30 (involving a bailout of the ethanol industry). This is cherry-picking – EIA estimates suggest that high oil costs are here to stay. If anything, the \$150 oil scenario (a terrorist attack upon Saudi oil fields, or at refinery capacity) is more likely in the near term than \$30 oil. Lord Oxburgh, the former chairman of Shell, noted recently that the oil industry had its head “in the sand”, and predicted that oil prices could hit \$150 per barrel within 20 years. In additional, he noted that “we may be sleepwalking into a problem which is actually going to be very serious and it may be too late to do anything about it by the time we are fully aware.”<sup>40</sup> Over 80% of the world’s oil reserves are held in state-owned entities from Russia to Venezuela, Iran to Kazakhstan. This makes oil far more susceptible to shock in the long run – unlike private capital, where profit is the only motive, oil can and will be used as a geopolitical shock tool. Examples such as Hugo Chavez in Venezuela, or OPEC oil price manipulations persist. If nothing else, ethanol serves as an insurance policy for an economy heavily dependent on oil – a commodity with extreme volatility

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<sup>39</sup> [http://www.hm-treasury.gov.uk/independent\\_reviews/stern\\_review\\_economics\\_climate\\_change/stern\\_review\\_report.cfm](http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/stern_review_report.cfm)

<sup>40</sup> <http://news.independent.co.uk/business/news/article2966842.ece>

and diminishing supply. Tackling climate change, limiting geopolitical costs and proving energy security (all while further aiding the developing world) are all factors in that make ethanol worth pursuing. .

There are naysayers and prognosticators that pontificate on all these matters. Some clearly approach the problem with the best of intentions, but we see them as naïve about their forecasts - conducting linear extrapolations without understanding the power of technology. Others are funded by the petroleum interests, and their writing is often amplified by massive PR dollars (witness the widespread coverage of the Mexico tortilla crisis) or by other competing interests (As we were told, one wind researcher was afraid that interest in biofuels was reducing the research funding for wind - motivating him to write negative articles about the former). There is certainly room for a sense of caution as with any new approach.

### **EFFICIENCY AND POLICY**

Efficiency is once again, a wonderful concept in theory, although less so in practice. We wholeheartedly support increased efficiency standards . However, we question whether they can make enough of a difference and how soon they can do it. Automakers estimate that every additional MPG in fuel standards costs them roughly \$400, per car – are we (publicly and politically) prepared for an additional \$10,000 per car for a middle-class Mississippi family? We welcome steps towards higher efficiency, and certainly recognize the inherent benefit of a system that does not require wholesale change over the long run. We support the strictest standards that congress can institute for CAFE - in fact, we have made investments in companies that aim to improve the efficiency of gasoline and diesel engines with proprietary fuel injection technology or completely redesign of the current model for combustion engines. Efficiency is a part of the solution that's worth pursuing, but it cannot solve our problems. It does however have the potential to cut or fuel needs in half or more over the next fifty years.

The role of policy, as a whole, is certainly worth debating. Government has the ability to create markets through mandates. It can make technologies cost effective (through incentives, subsidies, and production/investment tax credits). It can be used for good and bad purposes and generate business profitability or foreclosures. For example, we believe a Renewable Fuels Standard (RFS) of some level is needed and likely along with the likely passage of higher CAFE standards and the eventual adoption of some sort of carbon taxation scheme. As venture capitalists, our preference is always to allow markets to do their job, and allocate capital as and when needed. However, the government's role in

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failing to price in externalities previously has led to a system where some degree of mandates and policy proposals are needed – much like national defense. If there was a dumping fee for carbon dioxide akin to that for most pollutants, and fees for government services to the oil industry, we might reach level playing fields without government intervention. The externalities associated with fossil fuels at large are immense, and replacing their dominant role in our energy and economic infrastructure requires a combination of public and private efforts and policy. Our belief is that “developmental” legislation, which allows for initial deployment of competitive alternatives to today’s energy sources legitimately meets the public interest criteria, justifying some degree of government support – thus the basis for our support for 7-10 year maximum “startup period” subsidy for oil alternatives. Subsidies are a legitimate option to get alternatives started and increase competition - but not when volumes in new business increase to significant levels. In the long run, we are convinced that nothing can be done without the backing of private capital – government funding simply is not enough to solve the problem at hand.. To achieve these goals, we must provide services that consumers want and prefer over their non-sustainable fossil competitors, while at the same time be profitable for business. From a free trade perspective, we support the reduction of tariffs on Brazilian sugar cane ethanol, and are clear in our belief that any subsidies for biofuels should be developmental and with clear end goals in sight – unlike today, where the oil industry continues to feed at the public trough.

### **THE INNOVATION ECOSYSTEM CAN DISRUPT CONVENTIONAL WISDOM**

Nothing signals opportunity as much as the best and brightest people working on solving a problem. This is exactly where we find ourselves today in the renewables industry. Under what set of circumstances would the worlds best known academic plant biologist, molecular biologist and chair of the chemical engineering dept at Stanford be working together on a new biofuels start-up? Can you imagine a Silicon Valley executive from Apple moving to Denver, running a company in the back of a pipe fitting shop founded by an aging wildcatter up to his ears in debt? An academic in Dartmouth now at the epicenter of the hottest field in science (and winning the highly regarded MIT Lemelson award)? Would Silicon Valley investors travel to Australia and make their largest investment in Australian technology? How about investing in a start up company (in New Zealand) that is converting waste gas from steel mills into ethanol? How about Amyris, a company funded by the Gates Foundation to develop a malaria drug – that is now adding biofuels to its product mix? Or Gevo, a company started by a couple of graduate students doing research in synthetic biology now taking on BP-Dupont in the

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race to commercialize biobutanol? These and other companies are working on ethanol, butanol, cellulosic hydrocarbons, and more. This is the innovation ecosystem at work that leads to real solutions.

A traditional hundred year old business like telecommunications, with its old equipment infrastructure, hundreds of billions in investment and unionized workforces, was upended by the internet in a decade. The static media business was turned on its head by web companies like Google and Yahoo. Google, barely a “graduate student office” a few years ago, is worth more than most of them. The pharmaceuticals business was shown up by biotechnology companies and the old line computer business and the Goliaths like IBM, Burroughs and Control Data were brought down by the seemingly toyish microprocessors “David”? It can happen in the energy business. The innovation ecosystem that has disrupted all these other businesses is again at work on the energy empire.

### **SUMMARY**

Our faith in the innovation ecosystem is an important reason for our belief in the eventuality of a cellulosic fuel future replacing oil – the transition period has already begun. The future that many of our critics see is similar to what we envision – cellulosic and biomass-based biofuels that offer better potential solutions, higher efficiencies, and a better environmental footprint. However, it is vital to note that none of the university research, financial capital, or political backing for cellulosic would exist without the corn-based version, which proved ethanol’s functionality and the viability of a marketplace in the first place. Having done that, significant steps still need to be taken to imagine the future. From a policy perspective, we’ve highlighted the need for government to level the playing field for ethanol (vis-à-vis Big Oil), implement higher CAFE standards, and eventually adopt a carbon tax or cap-and-trade scheme to capture the externalities associated with petroleum usage. While we believe that government can help start the development of biofuels, long-run biofuel penetration depends on attracting the trillions of dollars in private capital. One such source of capital is the oil industry itself – by investing judiciously and intelligently in biofuels, the Exxons of today can avoid becoming the Burroughs and Control Data of tomorrow. Fundamentally, the power of capitalism and Wall Street (billions of dollars attacking a trillion-dollar market), innovation in the marketplace, and the innovation ecosystem is a significant force; the entrepreneurial energy witnessed in the development of the

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internet in the late 90's is being replicated in biofuels. In the US, the advent of biofuels will bring significant benefits to rural America (increasing farm income, creating new jobs, creating a sustainable long-term, agricultural alternative of gasoline), increasing the rural % of GDP and stemming the rural to urban migration over the past 50 years. On a national level, an oil-alternative would allow us reduce our carbon emissions and combat climate change, while reducing our economic risks (not needing to spend \$320 billion on oil imports, or \$50 billion protecting oil interests in the Middle East) and our geopolitical ones (reduced dependency on Russia, Iran, Iraq, Venezuela). Internationally, the developing world's ability to generate its own biofuels (due to the widespread availability of biomass) and reducing its exposure to expensive, volatile oil will enable China, India, and other fast-growing economies to meet their energy needs without the environmental and economic risks of oil. Many critics see the replacement of oil as filled with insurmountable risks – we see it as the ultimate opportunity.