# Ethanol Opinion —Beyond the Eighth Grade Level*

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A friend of mine who, unlike myself, was able to hold a corporate job all his adult life once said to another friend of mine, "The best thing that ever happened to Hudson was the 1988 drought." What he meant was that as the hot and dry summer of 1988 proceeded, with its corn crop withering and margin calls on the Chicago Board of Trade expanding to the hundreds of millions, the grain company for whom I worked jettisoned a hundred employees, including me, and I was forced to start my own business.

The yield of US corn in that summer of 1988 fell 25 percent from its trend to about 85 bushels per acre. But the next year, the corn yield rebounded and resumed its trend growth. Sixteen years later in 2004, the record high yield of US corn occurred, at about 12 percent above trend, or 160 bushels per acre. So the last twenty years of weather over the US cornbelt have shown an extreme of –25 percent on the low side and another of +12 percent on the high side, which is a range of 37 percent.

Grant me two more calculations, and I will stop: First, 37 percent of a 10 billion bushel harvest is 3.7 billion bushels. Second, this many bushels of corn would produce about 10 billion gallons of ethanol, which is over 5 percent of the total US motor gasoline supply. And so here's my point: If weather (that is, the variations in effective solar energy) can account for such an enormous change in energy production, why should there remain any doubt about the so-called "energy balance" of corn?

Let's go back to the comparison of 1988 and 2004 and ask another question. Suppose the weather in each year had been "normal" (and that I was still perhaps a corporate citizen), how much has the trend yield of corn changed, and why? The trend in 1988 was 113 bushels per acre, and the trend in 2004 was 143, so the growth in trend was 27 percent. What caused this strong growth? Was it due to more fertilizer? Nope, the average application of nitrogen fertilizer in 1988 was 127 pounds per acre, and in 2004 the application was 140 pounds—so the growth in nitrogen inputs was only 10%. Where did the other 17 percent growth in trend come from? The answer is that this growth came (and is still coming) mainly from better farming practices and better seeds (that is, the application of "better knowledge" or more "intellectual capital").

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* It is frequently asserted that the nation's media must phrase news and opinion at no more than the eighth grade reading level in order to assure its grasp by the public. If so, then we deserve what we get. This essay is aimed at readers who want to spend the time to tackle ideas about ethanol at a more serious level. The essay is not intended to endorse or condemn the industry, but to contribute to its objective analysis and discussion. My long-time colleagues Tom Blue, John Stewart, and Noel Stock made important contributions to this essay.

Many readers of this essay who have glossed over the above arithmetic will be wondering, "What's he trying to say here, does he mean that corn can actually contribute significant energy to the economy, and that in fact its ability to do so is actually increasing over time? Where's this guy coming from? What kind of academic study does he have to back his ideas up?"

In the summer of 1982, six years before the 1988 drought, I served on the Biomass Energy Panel of the Energy Research Advisory Board of the US Department of Energy, a panel chaired by Dr. David Pimentel of Cornell University. It was Pimentel who pioneered the concept of "embedded energy" and who calculated the "energy balance" of the country's major crops, and it was the Washington "gasohol" panels that first provided a public stage for his approach. Of the twelve persons on the 1982 Biomass Energy Panel, only three of us were not PhD's, and the majority of the panel very much liked Pimentel's idea of putting all plant materials on one single scale of BTUs. This method asks, "How many more BTUs do you get out of corn (or sorghum or squash, etc.) than you put in to produce the crop, including not only fertilizer but gasoline to drive the tractor, electricity to light the barn, etc.?" If it costs you more BTUs to produce something than you can get out of it as a fuel, then the idea of processing such a commodity, according to Pimentel, is a societal loss.

My complaint then, as now, is that "not all BTUs are equal." In other words, to process an item from a solid state to a liquid state can add significant societal value, regardless of the BTU balance. For instance, you cannot (presently) fill a car's gas tank with a bucket of solid chunks of coal. The *form* of energy has value in and of itself. You want a *liquid* form at a filling station. In the case of corn, you are essentially transforming the natural gas energy in nitrogen fertilizer and the solar energy from sun and rain into a liquid fuel that is useful for human transportation. Let me repeat: It is unquestionably true that energy is required to grow corn, just as Pimentel observed, but (again!) such energy is mainly from natural gas and from the sun—and the process of growing corn is becoming more and more efficient every year. There is a very positive and growing "energy balance" with corn, especially when you allow for the conversion of forms of energy and when you compare the options available for arriving at liquid fuels from all other sources, including petroleum. The conversion of petroleum to gasoline has a Net Energy Balance (NEB) of 0.81 (-19%) compared with corn to ethanol of 1.67 (+67%) according to a recent Congressional Research Service Report (Schnepf, 5-18-06).* Furthermore, a corn ethanol dry mill in Iowa or Minnesota constitutes an incremental but positive addition to the country's "motor fuel refining capacity," an addition that has been very difficult to achieve in the petroleum refining sector—due to the expense of these huge facilities and their difficulties in obtaining environmental permits.

The past few years of corn ethanol expansion, of course, have looked past the "energy balance" issue, mainly because of the sheer profitability of each new project. But this early profitability of the ethanol industry is nonetheless intimately connected to my calculations above. In other

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* The *Wall Street Journal's* editorial on January 27, 2007, "Very, Very Big Corn," used very, very different figures for the NEB comparison: "Even the most optimistic estimate says ethanol's net energy output is a marginal improvement of only 1.3 to one. For purposes of comparison, energy outputs from gasoline exceed inputs by an estimated 10 to one." No source is given for either side of this comparison by the *Journal*, which is an irksome privilege of America's very, very big media.

words, the "knowledge gains" in corn production over the past several decades have served to make "over-production" of the commodity its central problem, in terms of the paying demand for corn as an animal feed, and a cheap price per bushel its trademark. Why should it be any wonder, therefore, that as the price of crude oil nearly tripled in the past four years, while corn price remained unchanged ("dirt cheap"), that the world energy sector would discover agriculture? The green acres of the cornbelt lay waiting like an undrilled oil field.

Editorial writers too, especially since the President's State of the Union speech, have de-emphasized the "energy balance" criticism in favor of other targets which seem easier, including the idea that corn ethanol can not make its way in the market without subsidies. My first reaction to people who profess outrage at the existence of subsidies is to ask, "Where have you been all your life, in a closet? What aspect of modern American life since the 1930s is *not* affected by subsidies ('government transfers')?" Is it not a sheer matter of opinion, for example, whether the entire petroleum sector is "subsidized" by the multi-hundred billion dollar expense of the American military to keep peace in the Persian Gulf? To what other nation, by the way, does this peacekeeping job matter more, and what other nation is able? Should we think one day of China's taking over this duty? But if today the US spends $150 billion or more per year fighting in Iraq and the Gulf, doesn't the arithmetic say that this is a $1.00 per gallon expense "embedded" in the cost of our domestic use of nearly 150 billion gallons of gasoline? Should we not request a recalculation by Cornell University (and the *WSJ*) of all our fuel options that includes the costs of energy security?

Actually, the dollar sums involved in the world's relationship with the Middle East are much more staggering than just mentioned. Since 9-11 and the rise in crude oil price from the range of $25 per barrel to $70 and more, transfers of total dollars to OPEC have increased dramatically. OPEC revenue has gone from an average of $70 billion per quarter in 2000-2003 to an average of $280 billion per quarter in the years 2004-2006. This quadrupling in 2004-2006 has meant an aggregate increase in the financial flow to OPEC of $2,250 billion over the three-year period. In other words, the risks at stake in our crude oil buyer-seller relationship with the Middle East and North Africa are in the trillions of dollars, not merely in the billions or even tens or hundreds of billions.* Who then would want to argue that a 51 cent per gallon US excise tax credit to gasoline blenders for using ethanol (which across the current 6 billion gallons of ethanol comes to about $3 billion) is a "grievous distortion of the free market"? In a world economy now seriously distorted by state-sponsored and jihadist based terrorism, should we not be prepared to think more creatively about what may and what may not work to preserve the American way of life? Isn't the concept of an "acid test by the free market" more of a 19th century idea than a valid guide for the 21st?

This brings me to another emerging criticism of corn ethanol, the so-called food versus fuel debate, in which higher prices of corn due to ethanol fuel demand are seen as likely to run up the

* The transfer of trillions of dollars to "less developed" nations is not, of course, something which on humanitarian grounds we should always avoid, but the transfer in question to OPEC countries in the 2004-2006 may well have had more impact on the escalation of their inter-Islamic rivalries and on their expenditures for more and more sophisticated weaponry, including their development of nuclear options. If so, then the cumulative effect has been to increase the hazards and costs of future investment in crude oil and natural gas resources in these countries, supporting the view of a continued high range for energy prices.

price of American food. The first thing to observe here has to do still with subsidies, but in this case with farm subsidies per se, not with the ethanol excise tax credit. The federal government has transferred monies to the agricultural sector for over 70 years, and in the past two decades—again, the period in which corn yield has rapidly increased and corn price has remained cheap—it has not been unusual for federal crop price support programs to cost the taxpayer $10 billion per year or more. With the rise in today's market price of corn, exceeding the government "target prices," these agricultural subsidies will dwindle to the range of $2 billion, and will not recur unless and until the energy demand for crops disappears, or until crude oil price declines back to the $20 per barrel range, should that unlikely event ever happen. So the market price of corn has indeed risen, but the farm program subsidies are in effect being automatically de-activated, promising to more than offset the ethanol excise tax credit.

But despite this savings to the American taxpayer-consumer, we must repeat the question, could the rising price of corn push up on the price of food? Yes, without doubt it certainly could—especially on the price of meat, milk, and eggs. The principal market for corn has always been as feed for animals, both domestic and foreign, and so it will be animal feeders who first feel the impact of higher corn prices, and it will then be the public as these costs are passed on through the retail grocery and restaurant chain. The USDA's Chief Economist has recently acknowledged that food and meat prices may well increase by a significant percentage, but studies are still pending as to whether this means 5 or 10 percent or more. Barring unprecedented government intervention in the commodity markets, the job of corn price will continue to be allocating the corn supply among bidders from all three demand sectors—feed, fuel, and foreign exports. If fuel demand is backed by $70 plus crude oil (again), then its bid will be very strong.

Let us pause a moment here to reflect on "our way of life" in America, particularly on the intimate relationship between food and fuel. Is there anyone reading this essay today who can *walk* to the grocery store? Is it not true that virtually none of us can eat if we can't drive? How can you live in a suburb without a car? Even a person who *can* walk to a store or restaurant would find the shelves bare and the menus blank if it weren't for diesel trucks to deliver the meat and packaged food items from distant distribution centers, well outside the big city boundaries. Not even a Nebraska corn farmer is independent of this situation, as crop producers themselves must drive to town for groceries and fast food; one does not cook a dinner directly from corn, one feeds corn to animals and then drives them off in trucks to be slaughtered, packaged, and re-delivered in trucks to stores and restaurants hundreds of miles away.*

"Our way of life" in America, indeed the very core of our entire economy, requires driving, and lots of it. The problem is that for Americans to expect that both driving and eating (and eating well!) will forever be inexpensive, as though a kind of National Birthright, is now subject to the realities of where the world's remaining crude oil deposits are located and the cooperativeness (or not) of the owners of these deposits. In other words, geophysics and geopolitics together

* The vast majority of Americans must also drive for things other than food, for instance medical services, and here is a sector which exemplifies how the advanced organization of civilized life requires so much energy in very special forms. Consider the irradiation of tumors, the assessment of conditions with X-rays and other scanning machines, and laser eye surgery (perhaps the most concentrated form of energy of all). My phrase "our way of life" is meant to encompass all of this, and far from "scolding" us for driving so much (for having the highest "per capita energy use" in the world), I am actually in awe of our achievements.

make up a very inconvenient reality for those who expect us to continue indefinitely with cheap food and fuel across this wide continent.

I might personally prefer a public debate grounded in what to me are the global realities just mentioned, but I am sure that my wishes in this respect will be overwhelmed by (1) the temptation of many politicians to sensationalize the "ethanol threat to cheap food," and (2) the very loud cries already coming, and likely to increase, from the animal feeding sector—with whom I sympathize for being the ones to take the first "hit" from this unparalleled intersection of world energy and world agriculture. Despite the fact that I have mentioned my own personal involvement in the ethanol industry for over two decades, let me assure my readers that "never in my wildest" did I imagine crude oil in the $70s while corn remained in the $2s, and the sheer "gold rush" that this confrontation would produce. I cannot imagine any feeding company having had a strategic plan in place to cope with the forces now unfolding.*

It will not be the goal of this essay to "endorse" corn ethanol in either a political or business sense, or to defend whether it is good or bad for American agriculture and the public in general. What motivated me to write was frustration with the simplicity of the present editorial debate—the astonishing ignorance about the complexity and interrelatedness of the issues, the denial of what I see as the critical issues, and the outrageous criticism that "ethanol should be abandoned because it has no real chance of (totally) solving our energy problems." I agree point blank that ethanol is not a "total" answer. Who cannot calculate that converting the *entire* US corn crop would provide less than a fourth of US liquid fuel consumption? I recognize that the President and other national figures are enthusiastic about ethanol, but have they really declared it a "home run"? It seems to me that discussing ethanol in terms of "laying down a good bunt" is very, very appropriate—in the face of America's dependence on Middle Eastern crude oil. Our dependence, by the way, is much greater than the President seems willing to admit—it is not just our count of the barrels coming here directly from the Persian Gulf but the many more barrels which go to all the rest of the world, to nations who are our suppliers and our customers. We and the rest of the world are overwhelmingly dependent on Middle East oil.

Coming back to the editorials which irritate me, check out briefly the following alternatives to ethanol that have been offered if not as home runs at least as triples or doubles:

- **Tax gas**. As Charles Krauthammer of the *Washington Post* said on January 26, 2007, "Raise the price, and people change their habits. It's the essence of capitalism." In this alternative, the price of gasoline is raised not by enormous financial transfers to OPEC but deliberately by enormous transfers to our own federal government—for our bureaucrats to use or invest in what? If my assessment is correct that our way of life requires

* An associated question with the potential for food price rises in the United States is the likelihood of fuel ethanol pushing up on feedgrain prices all around the world. Generally speaking, the complaint of less developed countries has been that the farm subsidies of the US, Europe, and other advanced countries have acted to hold down on demand for their products, harming their own agricultural sectors—which in many cases are the largest parts of their economies. In other words, higher market price for their products is what the poorest countries have been asking for, to permit expanding their own crop production. One exception to this line of thought is Mexico, where certain types of corn are made directly into staple food tortillas, and which have already seen a doubling of market price. It should be noted as well in this connection that world hunger is associated more with wheat, rice, and other food grains than with corn and other feed grains, but that the food grain prices might rise as well, even though not being directly processed for fuel.

driving cars, then try to imagine how much Ford Motor Company would lose under such a tax remedy. I might agree that people ultimately need to "change their habits," but how is this to be accomplished without collapsing our entire economy? This "tax gas" alternative denies the intimate nature of the relation between motor fuel and the efficiency and achievements of all American economic activity.

- **Make cars more efficient**. Economist Robert J. Samuelson said on January 24, 2007, that a key alternative instead of biofuels was "tougher federal fuel economy standards to force auto companies to produce them." I am not an economist by formal education, but as I have been arguing plainly in the case of corn, the impact of efficiency is to lower the price of the commodity in question (in Samuelson's case, gasoline). When something is cheaper, people tend to use more of it. In other words, Samuelson may be right, but many economists take the other side of the equation: Providing people with more fuel-efficient cars may well mean that they just drive them farther, using the same volume of gasoline as before.
- **Drill for petroleum in the Arctic and the outer continental shelf**. This may make a positive contribution, but it seems much more like the same type of small step that I am using to characterize ethanol. Does anyone seriously believe that more oil from Alaska and the US Gulf is a complete answer?
- **Go (back to) nuclear**. For one thing, this is a much, much longer term "solution" than ethanol, and it requires envisioning entirely new ways of converting one form of energy (electricity) to some other form (hydrogen fuel cells?) which can supply Americans with the individual locomotion that freedom requires. As already mentioned, I am certainly in favor of energy *conversion* from one form to another, but in the near term I must concede that a corn ethanol dry mill has a tiny and entrepreneurially manageable scale compared to a nuclear power plant, or the grid work of dozens of them that would be required to constitute a "homerun." This nuclear alternative denies the reality of getting the nation's democratic representatives to agree on new laws and a master plan for carrying this out over many decades—and it also skips by the sore (but real) issue of "What about accidents?"

Let's move now to what I see as some of the real problems with ethanol, that may or may not keep us from making a bit of progress:

- **More smog**. According to an Associated Press story on January 30, 2007, "EPA Scientists to Propose Less Ethanol," the United States should "restrict the use of ethanol in an effort to improve air quality. Ethanol, an EPA official says, produces smog mainly when tailpipe and smokestack pollutants react with summer heat." I have no idea whether the "scientific evidence" justifies this EPA action or not, but it is potentially a tough issue. The chemistry is what it is, the pollution laws are what they are, and bureaucrats will interpret the regulations however they best see fit—and interested parties on both sides of the issue will seek relief or not from having Congress revise the rules. It is not possible to foresee how this problem may affect the ethanol alternative.
- **Worse mileage compared to gasoline**. I have been told that a rule of thumb for flex car drivers in Brazil is that ethanol price at the pump on any given day must be at least 30 percent lower than gasoline to make them switch. It is certainly true that the heat energy delivered by the combustion of ethanol is only about two-thirds that of gasoline. Again, I would say that chemistry rules this problem, but I would add that it is the chemistry of

oxidation (burning the fuel in air)—I have been shown evidence that other ways to "unpack" the energy stored in each molecule of ETOH may well provide more, not less, usable motive power than simple burning (and without smog!). But of course designing and delivering a whole new automotive engine is a project with at least as long a timeline as nuclear power plants, so the immediate reality is that ethanol price will surely suffer a "Brazilian discount" at the pump, once its production volume begins to significantly exceed the volume needed for Reformulated Gasoline (RFG), despite the existence of the 51 cent excise tax credit to blenders.

- **Getting rid of the by-product (DDG).** Calculations show that if corn ethanol production reaches 15 billion gallons (or about 10 percent of US motor fuel, the so-called "E-10" volume), this will be accompanied by the inadvertent production of about 40 million tons of Distillers Dried Grains (DDG). Proponents of ethanol argue that DDG will be fed to animals in place of whole corn, thus meaningfully reducing the need for what would be even larger corn harvests, and providing a stream of feed product sales for dry mills which will help keep down the price of ethanol. So far, so good, I would say—this is what is happening. But the volume of DDG is still manageable, as we are not even halfway to the E-10 target of 15 billion gallons. We have discovered that cattle in particular can be fed as much as 40 percent of their ration as DDG, instead of whole corn, but that the same is certainly not true for dairy, hogs, and poultry—whose limit for DDG inclusion may be closer to about 10 percent or so. The costs of drying DDG for long distance transportation are significant, and the rail capacity for doing this has tightened dramatically. It may well be that some portion of the DDG will need to be burned as fuel to power the dry mill, instead of being sold as animal feed to replace corn—a much lower price option.
- **Parallel mandate for biodiesel fuel along with ethanol.** Current energy legislation provides subsidies for diesel fuel made from soybean oil (and other sources of vegetable oil and animal fats), and the President's recent speech implied a substantial expansion of this biodiesel initiative. The problem is that the main crop which can be used for this purpose, soybeans, does not have the right chemical composition for such a new role. Soybeans are not an "energy crop" like corn, soybeans are a "protein crop." A 60 pound bushel of soybeans has only 11 pounds of soyoil, the remainder is protein meal and fiber.* For each 100 million gallons of biodiesel wanted from the soybean crop, we would get about 1.5 million tons of protein meal for animal feeds—and as our discussion of DDG has already pointed out, we have a surplus in this country (and the world) of protein meal. If the President's target of 4.5 billion gallons of biodiesel were to be reached using soybeans, we would thus have on our hands well over 60 million tons of additional soybean meal, for which there is no conceivable paying home. Does it make sense to think in terms of burning (oxidizing) *protein* molecules?
- **Transportation costs and "limits" in moving ethanol from cornbelt dry mills to gasoline blenders nationwide**. If there is one problem in which all the strands of my central thesis in this essay come together, it is here around the capacity of rail and truck to deliver the goods. So far in the corn ethanol expansion, all of the finished fuel ethanol is delivered to the country's 1,000 plus gasoline blenders by rail and truck, not by pipeline

* Corn has just the opposite chemical makeup from soybeans. Corn is about three-fourths energy (starch), and the rest protein, oil and fiber.

as is the case with gasoline. So what's the problem—just get more railcars, engines, and trucks, until the day comes when ethanol volume warrants its own pipelines! Here's the catch: railroads and highways are already very, very busy. I calculate that the goal of E-10 for the entire US (15 billion gallons of ethanol) would mean an increase in rail ton-miles of about 75 percent above what railroads now carry in their agricultural sector goods, and a similar 75 percent increase in ton-miles of agricultural trucking across the rural roads of America. Expanding the capacity of the rail network is very, very expensive—because all railroads go through the downtowns of cities (not around the city like an interstate highway by-pass), so rates per ton will need to increase to pay for these volumes of new surface transportation.

Let me depart from extending the list of problems for ethanol and emphasize this issue of railroad capacity and what I think it tells us about our degree of dependency on Middle Eastern crude oil. As I have been saying, it is the connection between the American way of life and surface transportation that is the main subject for debate. Ask yourself, "Why are railroads so busy today, operating at or above capacity?" Think about the last time you were stopped by a long train, what kind of train was it? Odds are it was either a coal train or a bi-modal train made up of container freight. So railroads are pushed by energy demands already, in the case of coal. But focus on the containers a minute: They contain manufactured goods from Asia which arrive on the country's west coast and must be transported all the way across the continent to the big population centers in the east. Here's the bigger conceptual point: The goods in these containers have energy embedded in them, lots of it. In a globalized economy, we have transferred our high energy-cost factory operations to China and the rest of Asia, where they use crude oil *from the Middle East* in the manufacture of goods that we purchase for our use in North America. It is foolhardy to argue that we can be "independent" from Middle Eastern oil merely by reducing the number of oil tankers landing at Houston, what about the embedded oil in our goods imported from Asia? How on earth can this aspect of our affairs have so far escaped serious attention?* We marvel about "globalization," but we have not stopped to grasp its genuine implications for our way of life.

Back to the conclusion of my list of the real problems with ethanol:

- **Weather and crop yield volatility**. There has not been another –25 percent corn yield decline from trend since 1988. There was a serious decline of 8 percent in the 1991 crop, due to flooding in the Upper Mississippi River region, and there was a worse decline of 10 percent in the 1995 crop, due to hot dry conditions across most of the cornbelt. The other years have seen an aggregate US corn yield fairly close to trend—with the feature that while some states may have been well below trend, others were above and compensated. But "better seeds" are not responsible for an absence of bad weather, rather it is simply an absence of bad weather. Seeds today have *more* drought resistance than previously, but they do not have *total* drought resistance, as evidenced by a 23 percent de-

* See Anthony Cordesman, *The Global Oil Market; Risks and Uncertainties* (Center for Strategic and International Studies, 2006), page 12: "The size of direct US imports of petroleum is only a partial measure of the United States' dependence on imports. The US economy is dependent on energy-intensive imports from Asia and other regions. The failure of the US Department of Energy and the Energy Information Administration to explicitly model such indirect imports and their steady growth is a long-standing and critical failure of US energy analysis and policy."

cline from trend for the state of Kansas and a 3.4 percent decline in the state of Iowa in this past year of 2006, offset by above yield performances elsewhere, leaving the aggregate US just barely above trend. The difference between the states is weather, not seeds, and weather has been generally okay, as we have said, since 1995. The *future* of cornbelt weather, however, is anyone's guess—it can only be predicted that we will again have a 1988 and / or a 1995, we just don't know when. When poor weather (even a –5 percent US crop) does occur, we can figure that the US corn ethanol industry and our entire food and feed agriculture (and food prices to be sure!) will be significantly stressed.

- **Parallel mandate for cellulosic ethanol along with ethanol from corn and other row crops.** I am not opposed to the cellulosic initiative, I really am not—but it will seem like I am. Of all the current ethanol rhetoric, the part that comes closest to teasing us with a "master stroke" is the part about cellulosics. The proponents say it avoids the food vs. fuel issue, because we do not use cellulose for food. They also say something like, "Give us just 75 million acres of land that produces ten tons of cellulosic biomass, and we will give you back enough liquid fuel to make a huge dent in OPEC." My question is, "Where indeed *is* this land on which it rains enough to produce 10 tons of something? The best land in Iowa currently does only 6 or 7 tons per acre of corn." The proponents respond, so far as I can gather, that they are thinking of genetically advanced grasses to be grown in the southeastern US, not the cornbelt—but if the subsidy for cellulosics is high enough, why wouldn't an Iowa farmer consider switchgrass, too? And yet it is precisely here that my cautions about surface transportation apply even stronger than with corn ethanol, perhaps by an order of magnitude more so. The harvesting of cellulosic crops is the gathering together of very light-weight, low density materials—and this requires far more truckloads for each ton to be delivered to processors than does corn. How to get around the density issue in the transportation of cellulosics baffles me, but I would not withhold my own tax dollar from proceeding to learn the processing chemistry that is needed. In other words, I have been quite wrong in my life about what will work and what won't, and I am willing to see what the cellulosic people come up with.

This willingness to see various approaches to "lay down a good bunt" is what I most endorse, particularly when someone can get to first base with manageable investments and technologies, and I think there is more than one ball park in which to play this game. I have tried to indicate that our dependency on Middle Eastern oil is dramatically stronger than any politician has yet been willing to admit to the public. It does appear, however, that this round of "We've got to pursue sources of alternative energy" is much more serious than the previous episodes under Nixon in 1973, Carter in 1979, and indeed all the other intervening Administrations.

Since I began this essay with a series of arithmetical calculations, let me test the reader and finish in the same fashion. I will not be suggesting a "master stroke," because that is what I most deplore, and what I personally had to learn to resist in starting my own small business. I will be suggesting instead a "master framework," a ball park, if you will, for bunts and even sharp singles to center field.

The total amount of solar energy reaching the earth each year from the sun is put at about 3,000 Q, where 1 Q is 1,000 quadrillion BTUs. The total estimated reserves of all fossil fuels is about

1,000 Q, of which, however, only about 100 Q is available from easy to reach crude oil, and this mainly now in the Middle East—the rest is in oil shale, tar sands, coal, and other forms. Now, here's the intriguing part: Each year, all of the world's peoples in all of the countries on earth, all of us together, including all of our needs for heating, cooling, manufacturing, and locomotion, consume about 0.5 Q. (You can look these figures up on the internet, or you can read about them in Max Singer's marvelous book, *Passage to a Human World* [Hudson Institute, 1987].)

What this means to me is that we live in an extremely energetic world and universe, and that it's up to us to figure out (1) how to tap these flows, (2) how to convert the dispersed forms of (plentiful) energy into concentrated forms which enable transportation and all the other activities of modern life, and (3) how to get along with each other while we do it. I am biased against Manhattan Projects* and in favor of smaller entrepreneurial adventures—and I think that "getting along" follows best on the heels of "getting honest" about the nature and scope of our problems.

* I was a child in grade school when this project eventuated in the two flashes of energy which killed over a hundred thousand people, and it seems wrong-headed to me to apply wartime bomb nomenclature to peace-time energy projects. In 1961, when I went to work in the nuclear weapons complex at the Sandia Laboratories in Albuquerque, the AEC had just declassified "Project Sherwood" with a color-printed hardbound book detailing all the technical schemes for pursuing controlled fusion. Talk about the availability of a zillion Q's! And yet, the political process of this country is such that we cannot allocate a few billion dollars a year for controlled fusion research, in preference apparently to spending hundreds of billions in the Persian Gulf—let alone the cost in human lives.

# NET ENERGY BALANCE (NEB) OF VARIOUS FUELS

| | Petroleum Gasoline | Corn Ethanol | Cellulosic Ethanol | Oilseed Biodiesel | Petroleum Diesel |
|---|---|---|---|---|---|
| NEB | 0.81 | 1.67* | 2.00 | 3.20 | 0.83 |
| Energy returned from a gallon of finished product more/less than energy used in the fuel's life cycle from source to user | -19% | 67% | 100% | 220% | -17% |
| Main Problems | Unstable feedstock supply, unwanted emissions | Limited current feedstock, unneeded feed byproduct, surface transportation | Limited current feedstock, no viable technology, surface transportation | Limited current feedstock, extreme feed byproduct glut | Unstable feedstock supply, unwanted emissions |

Note. The NEB is the ratio of the energy produced from a production process relative to the energy used in the production process. An output/input ratio of 1.00 implies that energy output equals energy inout.

*From Shapouri-USDA 2004, but Farrel-Science 2006 confirms a positive balance.
Principal form of energy used in the life-cycle process is natural gas (nitrogen fertilizer).

Source: Randy Schnepf, "Agriculture-Based Renewable Energy Production," May 18, 2006, Congressional Research Service.