Peak Soil: Why cellulosic ethanol, biofuels are unsustainable and a threat to America

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"The nation that destroys its soil destroys itself." - President Franklin D. Roosevelt

Peak Soil: Why Cellulosic ethanol and other Biofuels are
Not Sustainable and are a Threat to America's National Security

Editor's note: There are many serious problems with biofuels, especially on a massive scale, and it appears from this report that they cannot be surmounted. So let the truth of Alice Friedemann's meticulous and incisive diligence wash over you and rid you of any confusion or false hopes. The absurdity and destructiveness of large scale biofuels are a chance for people to eventually even reject the internal combustion engine and energy waste in general. One can also hazard from this report that bioplastics, as well, cannot make it in a big way.

The author looks ahead to post-petroleum living with considered conclusions: "Biofuels have yet to be proven viable, and mechanization may not be a great strategy in a world of declining energy." And, "…only a small amount of biomass (is) unspoken for" by today's essential economic and ecological activities. To top it off, she points out, "Crop production is reduced when residues are removed from the soil. Why would farmers want to sell their residues?" Here's an Oh- god-she-nailed-it zinger: "As prices of fertilizer inexorably rise due to natural gas depletion, it will be cheaper to return residues to the soil than to buy fertilizer." Looking further along than most of us, Alice has among her conclusions: "It's time to start increasing horse and oxen numbers, which will leave even less biomass for biorefineries." - JL

Part 1. The Dirt on Dirt.

Ethanol is an agribusiness get-rich-quick scheme that will bankrupt our topsoil.

Nineteenth century western farmers converted their corn into whiskey to make a profit (Rorabaugh 1979). Archer Daniels Midland, a large grain processor, came up with the same scheme in the 20th century. But ethanol was a product in search of a market, so ADM spent three decades relentlessly lobbying for ethanol to be used in gasoline. Today ADM makes record profits from ethanol sales and government subsidies (Barrionuevo 2006).

The Department of Energy hopes to have biomass supply 5% of the nation's power, 20% of transportation fuels, and 25% of chemicals by 2030. These combined goals are 30% of the current petroleum consumption (DOE Biomass Plan, DOE Feedstock Roadmap).

Fuels made from biomass are a lot like the nuclear powered airplanes the Air Force tried to build from 1946 to 1961, for billions of dollars. They never got off the ground. The idea was interesting -- atomic jets could fly for months without refueling. But the lead shielding to protect the crew and several months of food and water was too heavy for the plane to take off. The weight problem, the ease of shooting this behemoth down, and the consequences of a crash landing were so obvious, it’s amazing the project was ever funded, let alone kept going for 15 years.

Biomass fuels have equally obvious and predictable reasons for failure. Odum says that time explains why renewable energy provides such low energy yields compared to non-renewable fossil fuels. The more work left to nature, the higher the energy yield, but the longer the time required. Although coal and oil took millions of years to form into dense, concentrated solar power, all we had to do was extract and transport them (Odum 1996)

With every step required to transform a fuel into energy, there is less and less energy yield. For example, to make ethanol from corn grain, which is how all U.S. ethanol is made now, corn is first grown to develop hybrid seeds, which next season are planted, harvested, delivered, stored, and preprocessed to remove dirt. Dry-mill ethanol is milled, liquefied, heated, saccharified, fermented, evaporated, centrifuged, distilled, scrubbed, dried, stored, and transported to customers (McAloon 2000).

Fertile soil will be destroyed if crops and other "wastes" are removed to make cellulosic ethanol.

"We stand, in most places on earth, only six inches from desolation, for that is the thickness of the topsoil layer upon which the entire life of the planet depends" (Sampson 1981).

Loss of topsoil has been a major factor in the fall of civilizations (Sundquist 2005 Chapter 3, Lowdermilk 1953, Perlin 1991, Ponting 1993). You end up with a country like Iraq, formerly Mesopotamia, where 75% of the farm land became a salty desert.

Fuels from biomass are not sustainable, are ecologically destructive, have a net energy loss, and there isn’t enough biomass in America to make significant amounts of energy because essential inputs like water, land, fossil fuels, and phosphate ores are limited.

Soil Science 101 – There Is No "Waste" Biomass

Long before there was "Peak Oil", there was "Peak Soil". Iowa has some of the best topsoil in the world. In the past century, half of it’s been lost, from an average of 18 to 10 inches deep (Pate 2004, Klee 1991).

Productivity drops off sharply when topsoil reaches 6 inches or less, the average crop root zone depth (Sundquist 2005).

Crop productivity continually declines as topsoil is lost and residues are removed. (Al-Kaisi May 2001, Ball 2005, Blanco-Canqui 2006, BOA 1986, Calviño 2003, Franzleubbers 2006, Grandy 2006, Johnson 2004, Johnson 2005, Miranowski 1984, Power 1998, Sadras 2001, Troeh 2005, Wilhelm 2004).

On over half of America’s best crop land, the erosion rate is 27 times the natural rate, 11,000 pounds per acre (NCRS 2006). The natural, geological erosion rate is about 400 pounds of soil per acre per year (Troeh 2005). Some is due to farmers not being paid enough to conserve their land, but most is due to investors who farm for profit. Erosion control cuts into profits.

Erosion is happening ten to twenty times faster than the rate topsoil can be formed by natural processes (Pimentel 2006). That might make the average person concerned. But not the USDA -- they’ve defined erosion as the average soil loss that could occur without causing a decline in long term productivity.

Troeh (2005) believes that the tolerable soil loss (T) value is set too high, because it's based only on the upper layers -- how long it takes subsoil to be converted into topsoil. T ought to be based on deeper layers – the time for subsoil to develop from parent material or parent material from rock. If he’s right, erosion is even worse than NCRS figures.

Erosion removes the most fertile parts of the soil (USDA-ARS). When you feed the soil with fertilizer, you’re not feeding plants; you’re feeding the biota in the soil. Underground creatures and fungi break down fallen leaves and twigs into microscopic bits that plants can eat, and create tunnels air and water can infiltrate. In nature there are no elves feeding (fertilizing) the wild lands. When plants die, they’re recycled into basic elements and become a part of new plants. It’s a closed cycle. There is no bio-waste.

Soil creatures and fungi act as an immune system for plants against diseases, weeds, and insects – when this living community is harmed by agricultural chemicals and fertilizers, even more chemicals are needed in an increasing vicious cycle (Wolfe 2001).

There’s so much life in the soil, there can be 10 "biomass horses" underground for every horse grazing on an acre of pasture (Wardle 2004). If you dove into the soil and swam around, you’d be surrounded by miles of thin strands of mycorrhizal fungi that help plant roots absorb more nutrients and water, plus millions of creatures, most of them unknown. There'd be thousands of species in just a handful of earth –- springtails, bacteria, and worms digging airy subways. As you swam along, plant roots would tower above you like trees as you wove through underground skyscrapers.

Plants and creatures underground need to drink, eat, and breathe just as we do.   An ideal soil is half rock, and a quarter each water and air. When tractors plant and harvest, they crush the life out of the soil, as underground apartments collapse 9/11 style.   The tracks left by tractors in the soil are the erosion route for half of the soil that washes or blows away (Wilhelm 2004).

Corn Biofuel (i.e. butanol, ethanol, biodiesel) is especially harmful because:

Row crops such as corn and soy cause 50 times more soil erosion than sod crops [e.g., hay] (Sullivan 2004) or more (Al-Kaisi 2000), because the soil between the rows can wash or blow away. If corn is planted with last year's corn stalks left on the ground (no-till), erosion is less of a problem, but only about 20% of corn is grown no-till. Soy is usually grown no-till, but insignificant residues to harvest for fuel.

Corn uses more water, insecticide, and fertilizer than most crops (Pimentel 2003). Due to high corn prices, continuous corn (corn crop after corn crop) is increasing, rather than rotation of nitrogen fixing (fertilizer) and erosion control sod crops with corn.

The government has studied the effect of growing continuous corn, and found it increases eutrophication by 189%, global warming by 71%, and acidification by 6% (Powers 2005).

Farmers want to plant corn on highly-erodible, water protecting, or wildlife sustaining Conservation Reserve Program land. Farmers are paid not to grow crops on this land. But with high corn prices, farmers are now asking the Agricultural Department to release them from these contracts so they can plant corn on these low-producing, environmentally sensitive lands (Tomson 2007).

Crop residues are essential for soil nutrition, water retention, and soil carbon. Making cellulosic ethanol from corn residues -- the parts of the plant we don't eat (stalk, roots, and leaves) – removes water, carbon, and nutrients (Nelson, 2002, McAloon 2000, Sheehan, 2003).

These practices lead to lower crop production and ultimately deserts. Growing plants for fuel will accelerate the already unacceptable levels of topsoil erosion, soil carbon and nutrient depletion, soil compaction, water retention, water depletion, water pollution, air pollution, eutrophication, destruction of fisheries, siltation of dams and waterways, salination, loss of biodiversity, and damage to human health (Tegtmeier 2004).

Why are soil scientists absent from the biofuels debate?

I asked 35 soil scientists why topsoil wasn't part of the biofuels debate. These are just a few of the responses from the ten who replied to my off-the-record poll (no one wanted me to quote them, mostly due to fear of losing their jobs):

"I have no idea why soil scientists aren't questioning corn and cellulosic ethanol plans. Quite frankly I'm not sure that our society has had any sort of reasonable debate about this with all the facts laid out. When you see that even if all of the corn was converted to ethanol and that would not provide more than 20% of our current liquid fuel use, it certainly makes me wonder, even before considering the conversion efficiency, soil loss, water contamination, food price problems, etc."

"Biomass production is not sustainable. Only business men and women in the refinery business believe it is."

"Should we be using our best crop land to grow gasohol and contribute further to global warming? What will our children grow their food on?"

"As agricultural scientists, we are programmed to make farmers profitable, and therefore profits are at the top of the list, and not soil, family, or environmental sustainability".

"Government policy since WWII has been to encourage overproduction to keep food prices down (people with full bellies don't revolt or object too much). It's hard to make a living farming commodities when the selling price is always at or below the break even point. Farmers have had to get bigger and bigger to make ends meet since the margins keep getting thinner and thinner. We have sacrificed our family farms in the name of cheap food. When farmers stand to make few bucks (as with biofuels) agricultural scientists tend to look the other way".

"You are quite correct in your concern that soil science should be factored into decisions about biofuel production. Unfortunately, we soil scientists have missed the boat on the importance of soil management to the sustainability of biomass production, and the long-term impact for soil productivity."

This is not a new debate. Here's what scientists had to say decades ago:

Removing "crop residues…would rob organic matter that is vital to the maintenance of soil fertility and tilth, leading to disastrous soil erosion levels. Not considered is the importance of plant residues as a primary source of energy for soil microbial activity. The most prudent course, clearly, is to continue to recycle most crop residues back into the soil, where they are vital in keeping organic matter levels high enough to make the soil more open to air and water, more resistant to soil erosion, and more productive" (Sampson 1981).

"…Massive alcohol production from our farms is an immoral use of our soils since it rapidly promotes their wasting away. We must save these soils for an oil-less future" (Jackson 1980).

Natural Gas in Agriculture

When you take out more nutrients and organic matter from the soil than you put back in, you are "mining" the topsoil. The organic matter is especially important, since that's what prevents erosion, improves soil structure, health, water retention, and gives the next crop its nutrition. Modern agriculture only addresses the nutritional component by adding fossil-fuel based fertilizers, and because the soil is unhealthy from a lack of organic matter, copes with insects and disease with oil-based pesticides.

"Fertilizer energy" is 28% of the energy used in agriculture (Heller, 2000). Fertilizer uses natural gas both as a feedstock and the source of energy to create the high temperatures and pressures necessary to coax inert nitrogen out of the air (nitrogen is often the limiting factor in crop production). This is known as the Haber-Bosch process, and it's a big part of the green revolution that made it possible for the world's population to grow from half a billion to 6.5 billion today (Smil 2000, Fisher 2001).

Our national security is at risk as we become dependent on unstable foreign states to provide us with increasingly expensive fertilizer. Between 1995 and 2005 we increased our fertilizer imports by more than 148% for Anhydrous Ammonia, 93% for Urea (solid), and 349 % of other nitrogen fertilizers (USDA ERS). Removing crop residues will require large amounts of imported fertilizer from potential cartels, potentially so expensive farmers won't sell crops and residues for biofuels.

Improve national security and topsoil by returning residues to the land as fertilizer. We are vulnerable to high-priced fertilizer imports or "food for oil", which would greatly increase the cost of food for Americans.

Agriculture competes with homes and industry for fast depleting North American natural gas. Natural gas price increases have already caused over 280,000 job losses (Gerard 2006). Natural gas is also used for heating and cooking in over half our homes, generates 15% of electricity, and is a feedstock for thousands of products.

Return crop residues to the soil to provide organic fertilizer, don't increase the need for natural gas fertilizers by removing crop residues to make cellulosic biofuels.

Part 2. The Poop on Ethanol:
Energy Returned on Energy Invested (EROEI)

To understand the concept of EROEI, imagine a magician doing a variation on the rabbit-out-of-a-hat trick. He strides onstage with a rabbit, puts it into a top hat, and then spends the next five minutes pulling 100 more rabbits out. That is a pretty good return on investment!

Oil was like that in the beginning: one barrel of oil energy was required to get 100 more out, an Energy Returned on Energy Invested of 100:1.

When the biofuel magician tries to do the same trick decades later, he puts the rabbit into the hat, and pulls out only one pooping rabbit. The excrement is known as byproduct or coproduct in the ethanol industry.

Studies that show a positive energy gain for ethanol would have a negative return if the byproduct were left out (Farrell 2006). Here's where byproduct comes from: if you made ethanol from corn in your back yard, you'd dump a bushel of corn, two gallons of water, and yeast into your contraption. Out would come 18 pounds of ethanol, 18 pounds of CO_2, and 18 pounds of byproduct – the leftover corn solids.

Patzek and Pimentel believe you shouldn't include the energy contained in the byproduct, because you need to return it to the soil to improve nutrition and soil structure (Patzek June 2006). Giampetro believes the byproduct should be treated as a "serious waste disposal problem and … an energy cost", because if we supplied 10% of our energy from biomass, we'd generate 37 times more livestock feed than is used (Giampetro 1997).

It's even worse than he realized – Giampetro didn't know most of this "livestock feed" can't be fed to livestock because it's too energy and monetarily expensive to deliver – especially heavy wet distillers byproduct, which is short-lived, succumbing to mold and fungi after 4 to 10 days. Also, byproduct is a subset of what animals eat. Cattle are fed byproduct in 20% of their diet at most. Iowa's a big hog state, but commercial swine operations feed pigs a maximum of 5 to 10% byproduct (Trenkle 2006; Shurson 2003).

Worst of all, the EROEI of ethanol is 1.2:1 or 1.2 units of energy out for every unit of energy in, a gain of ".2". The "1" in "1.2" represents the liquid ethanol. What is the ".2" then? It's the rabbit feces – the byproduct. So you have no ethanol for your car, because the liquid "1" needs to be used to make more ethanol. That leaves you with just the ".2" --- a bucket of byproduct to feed your horse – you do have a horse, don't you? If horses are like cattle, then you can only use your byproduct for one-fifth of his diet, so you'll need four supplemental buckets of hay from your back yard to feed him. No doubt the byproduct could be used to make other things, but that would take energy.

Byproduct could be burned, but it takes a significant amount of energy to dry it out, and requires additional handling and equipment. More money can be made selling it wet to the cattle industry, which is hurting from the high price of corn. Byproduct should be put back into the ground to improve soil nutrition and structure for future generations, not sold for short-term profit and fed to cattle who aren't biologically adapted to eating corn.

The boundaries of what is included in EROEI calculations are kept as narrow as possible to reach positive results.

Researchers who find a positive EROEI for ethanol have not accounted for all of the energy inputs. For example, Shapouri admits the "energy used in the production of … farm machinery and equipment…, and cement, steel, and stainless steel used in the construction of ethanol plants, are not included". (Shapouri 2002). Or they assign overstated values of ethanol yield from corn (Patzek Dec 2006). Many, many, other inputs are left out.

Patzek and Pimentel have compelling evidence showing that about 30 percent more fossil energy is required to produce a gallon of ethanol than you get from it. Their papers are published in peer-reviewed journals where their data and methods are public, unlike many of the positive net energy results.

Infrastructure. Current EROEI figures don't take into account the delivery infrastructure that needs to be built. There are 850 million combustion engines in the world today. Just to replace half the 245 million cars and light trucks in the United States with E85 vehicles will take 12-15 years, It would take over $544 million dollars of delivery ethanol infrastructure (Reynolds 2002 case B1) and $5 to $34 billion to revamp 170,000 gas stations nationwide (Heinson 2007).

The EROEI of oil when we built most of the infrastructure in this country was about 100:1, and it's about 25:1 worldwide now. Even if you believe ethanol has a positive EROEI, you'd probably need at least an EROEI of at least 5 to maintain modern civilization (Hall 2003). A civilization based on ethanol's ".2" rabbit poop would only work for coprophagous (dung-eating) rabbits.

Of the four articles that showed a positive net energy for ethanol in Farrells 2006 Science article, three were not peer-reviewed. The only positive peer-reviewed article (Dias De Oliveira, 2005) states "The use of ethanol as a substitute for gasoline proved to be neither a sustainable nor an environmentally friendly option" and the "environmental impacts outweigh its benefits". Dias De Oliveria concluded there'd be a tremendous loss of biodiversity, and if all vehicles ran on E85 and their numbers grew by 4% per year, by 2048, the entire country, except for cities, would be covered with corn.

Part 3. Biofuel is a Grim Reaper.

The energy to remediate environmental damage is left out of EROEI calculations.

Global Warming

Soils contain twice the amount of carbon found in the atmosphere, and three times more carbon than is stored in all the Earth's vegetation (Jones 2006).

Climate change could increase soil loss by 33% to 274%, depending on the region (O'Neal 2005).

Intensive agriculture has already removed 20 to 50% of the original soil carbon, and some areas have lost 70%. To maintain soil C levels, no crop residues at all could be harvested under many tillage systems or on highly erodible lands, and none to a small percent on no-till, depending on crop production levels (Johnson 2006).

Deforestation of temperate hardwood forests, and conversion of range and wetlands to grow energy and food crops increases global warming. An average of 2.6 million acres of crop land were paved over or developed every year between 1982 and 2002 in the USA (NCRS 2004). The only new crop land is forest, range, or wetland.

Rainforest destruction is increasing global warming.   Energy farming is playing a huge role in deforestation, reducing biodiversity, water and water quality, and increasing soil erosion. Fires to clear land for palm oil plantations are destroying one of the last great remaining rainforests in Borneo, spewing so much carbon that Indonesia is third behind the United States and China in releasing greenhouse gases. Orangutans, rhinos, tigers and thousands of other species may be driven extinct (Monbiot 2005). Borneo palm oil plantation lands have grown 2,500% since 1984 (Barta 2006). Soybeans cause even more erosion than corn and suffer from all the same sustainability issues. The Amazon is being destroyed by farmers growing soybeans for food (National Geographic Jan 2007).and fuel (Olmstead 2006).

Biofuel from coal-burning biomass factories increases global warming (Farrell 2006). Driving a mile on ethanol from a coal-using biorefinery releases more CO2 than a mile on gasoline (Ward 2007). Coal in ethanol production is seen as a way to displace petroleum (Farrell 2006, Yacobucci 2006) and it’s already happening (Clayton 2006).

Current and future quantities of biofuels are too minisucle to affect global warming   (ScienceDaily 2007).

Surface Albedo. "How much the sun warms our climate depends on how much sunlight the land reflects (cooling us), versus how much it absorbs (heating us). A plausible 2% increase in the absorbed sunlight on a switch grass plantation could negate the climatic cooling benefit of the ethanol produced on it. We need to figure out now, not later, the full range of climatic consequences of growing cellulose crops" (Harte 2007).

Eutrophication.

Farm runoff of nitrogen fertilizers has contributed to the hypoxia (low oxygen) of rivers and lakes across the country and the dead zone in the Gulf of Mexico. Yet the cost of the lost shrimp and fisheries and increased cost of water treatment are not subtracted from the EROEI of ethanol.

Soil Erosion

Corn and soybeans have higher than average erosion rates. Eroded soil pollutes air, fills up reservoirs, and shortens the time dams can store water and generate electricity. Yet the energy of the hydropower lost to siltation, energy to remediate flood damage, energy to dredge dams, agricultural drainage ditches, harbors, and navigation channels, aren’t considered in EROEI calculations.

The majority of the best soil in the nation is rented and has the highest erosion rates. More than half the best farmland in the United States is rented: 65% in Iowa, 74% in Minnesota, 84% in Illinois, and 86% in Indiana. Owners seeking short-term profits have far less incentive than farmers who work their land to preserve soil and water. As you can see in the map below [check with us later or use link below], the dark areas, which represent the highest erosion rates, are the same areas with the highest percentage of rented farmland.

http://www.ers.usda.gov/Briefing/ConservationAndEnvironment/Gallery/sediment.htm

Water Pollution

Soil erosion is a serious source of water pollution, since it causes runoff of sediments, nutrients, salts, eutrophication, and chemicals that have had no chance to decompose into streams. This increases water treatment costs, increases health costs, kills fish with insecticides that work their way up the food chain (Troeh 2005).

Ethanol plants pollute water. They generate 13 liters of wastewater for every liter of ethanol produced (Pimentel March 2005)

Water depletion

Biofuel factories use a huge amount of water – four gallons for every gallon of ethanol produced. Despite 30 inches of rain per year in Iowa, there may not be enough water for corn ethanol factories as well as people and industry. Drought years will make matters worse (Cruse 2006).

Fifty percent of Americans rely on groundwater (Glennon 2002), and in many states, this groundwater is being depleted by agriculture faster than it is being recharged. This is already threatening current food supplies (Giampetro 1997). In some western irrigated corn acreage, groundwater is being mined at a rate 25% faster than the natural recharge of its aquifer (Pimentel 2003).

Biodiversity

Every acre of forest and wetland converted to crop land decreases soil biota, insect, bird, reptile, and mammal biodiversity.

Part 4. Biodiesel: Can we eat enough French Fries?

The idea we could run our economy on discarded fried food grease is very amusing. For starters, you'd need to feed 7 million heavy diesel trucks getting less than 8 mpg. Seems like we're all going to need to eat a lot more French Fries, but if anyone can pull it off, it would be Americans. Spin it as a patriotic duty and you'd see people out the door before the TV ad finished, the most popular government edict ever.

Scale. Where's the Soy? Biodiesel is not ready for prime time. Although John Deere is working on fuel additives and technologies to burn more than 5% accredited biodiesel (made to ASTM D6751 specifications – vegetable oil does not qualify), that is a long way off. 52 billion gallons of diesel fuel are consumed a year in the United States, but only 75 million gallons of biodiesel were produced – two-tenths of one percent of what's needed. To get the country to the point where gasoline was mixed with 5 percent biodiesel would require 64 percent of the soybean crop and 71,875 square miles of land (Borgman 2007), an area the size of the state of Washington. Soybeans cause even more erosion than corn.

Biodiesel shortens engine life. Currently, biodiesel concentrations higher than 5 percent can cause "water in the fuel due to storage problems, foreign material plugging filters…, fuel system seal and gasket failure, fuel gelling in cold weather, crankcase dilution, injection pump failure due to water ingestion, power loss, and, in some instances, can be detrimental to long engine life" (Borgman 2007). Biodiesel also has a short shelf life and it's hard to store – it easily absorbs moisture (water is a bane to combustion engines), oxidizes, and gets contaminated with microbes. It increases engine NOx emissions (ozone) and has thermal degradation at high temperatures (John Deere 2006).

On the cusp of energy descent, we can't even run the most vital aspect of our economy, agricultural machines, on "renewable" fuels. John Deere tractors can run on no more than 5% accredited biodiesel (Borgman 2007). Perhaps this is unintentionally wise – biofuels have yet to be proven viable, and mechanization may not be a great strategy in a world of declining energy.

Part 5. If we can't drink and drive, then burn baby burn.
Energy Crop Combustion

Wood is a crop, subject to the same issues as corn, and takes a lot longer to grow. Burning wood in your stove at home delivers far more energy than the logs would if converted to biofuels (Pimentel 2005). Wood was scarce in America when there were just 75 million people. Electricity from biomass combustion is not economic or sustainable.

Combustion pollution is expensive to control. Some biomass has absorbed heavy metals and other pollutants from sources like coal power plants, industry, and treated wood. Combustion can release chlorinated dioxins, benzofurans, polycyclic aromatic hydrocarbons, cadmium, mercury, arsenic, lead, nickel, and zinc.

Combustion contributes to global warming by adding nitrogen oxides and the carbon stored in plants back into the atmosphere, as well as removes agriculturally essential nitrogen and phosphate (Reijnders 2006)

EROEI in doubt. Combustion plants need to produce, transport, prepare, dry, burn, and control toxic emissions. Collection is energy intensive, requiring some combination of bunchers, skidders, whole-tree choppers, or tub grinders, and then hauling it to the biomass plant. There, the feedstock is chopped into similar sizes and placed on a conveyor belt to be fed to the plant. If biomass is co-fired with coal, it needs to be reduced in size, and the resulting fly ash may not be marketable to the concrete industry (Bain 2003). Any alkali or chlorine released in combustion gets deposited on the equipment, reducing overall plant efficiencies, as well as accelerating corrosion and erosion of plant components, requiring high replacement and maintenance energy.

Processing materials with different physical properties is energy intensive, requiring sorting, handling, drying, and chopping. It's hard to optimize the pyrolysis, gasification, and combustion processes if different combustible fuels are used. Urban waste requires a lot of sorting, since it often has material that must be removed, such as rocks, concrete and metal. The material that can be burned must also be sorted, since it varies from yard trimmings with high moisture content to chemically treated wood.

Biomass combustion competes with other industries that want this material for construction, mulch, compost, paper, and other profitable ventures, often driving the price of wood higher than a wood-burning biomass plant can afford. Much of the forest wood that could be burned is inaccessible due to a lack of roads.

Efficiency is lowered if material with a high water content is burned, like fresh wood. Different physical and chemical characteristics in fuel can lead to control problems (Badger 2002).   When wet fuel is burned, so much energy goes into vaporizing the water that very little energy emerges as heat, and drying takes time and energy.

Material is limited and expensive. California couldn't use crop residues due to low bulk density. In 2000, the viability of California biomass enterprise was in serious doubt because the energy to produce biomass was so high due to the small facilities and high cost of collecting and transporting material to the plants (Bain 2003).

Part 6. The problems with Cellulosic Ethanol could drive you to drink.

Many plants want animals to eat their seed and fruit to disperse them. Some seeds only germinate after going through an animal gut and coming out in ready-made fertilizer.   Seeds and fruits are easy to digest compared to the rest of the plant, that's why all of the commercial ethanol and biodiesel are made from the yummy parts of plants, the grain, rather than the stalks, leaves, and roots.

But plants don't want to be entirely devoured. They've spent hundreds of millions of years perfecting structures that can't easily be eaten. Be thankful plants figured this out, or everything would be mown down to bedrock.

If we ever did figure out how to break down cellulose in our back yard stills, it wouldn't be long before the 6.5 billion people on the planet destroyed the grasslands and forests of the world to power generators and motorbikes (Huber 2006)

Don Augenstein and John Benemann, who've been researching biofuels for over 30 years, are skeptical as well. According to them, "…severe barriers remain to ethanol from lignocellulose. The barriers look as daunting as they did 30 years ago".

Benemann says the EROEI can be easily determined to be about five times as much energy required to make cellulosic ethanol than the energy contained in the ethanol.

The success of cellulosic ethanol depends on finding or engineering organisms that can tolerate extremely high concentrations of ethanol. Augenstein argues that this creature would already exist if it were possible. Organisms have had a billion years of optimization through evolution to develop a tolerance to high ethanol levels (Benemann 2006). Someone making beer, wine, or moonshine would have already discovered this creature if it could exist.

The range of chemical and physical properties in biomass, even just corn stover (Ruth 2003, Sluiter 2000), is a challenge. It's hard to make cellulosic ethanol plants optimally efficient, because processes can't be tuned to such wide feedstock variation.

Where will the Billion Tons of Biomass for Cellulosic Fuels Come From?

The government believes there is a billion tons of biomass "waste" to make cellulosic biofuels, chemicals, and generate electricity with.

The United States lost 52 million acres of cropland between 1982 and 2002 (NCRS 2004). At that rate, all of the cropland will be gone in 140 years.

There isn't enough biomass to replace 30% of our petroleum use. The potential biomass energy is miniscule compared to the fossil fuel energy we consume every year, about 105 exa joules (EJ) in the USA. If you burned every living plant and its roots, you'd have 94 EJ of energy and we could all pretend we lived on Mars. Most of this 94 EJ of biomass is already being used for food and feed crops, and wood for paper and homes. Sparse vegetation and the 30 EJ in root systems are economically unavailable – leaving only a small amount of biomass unspoken for (Patzek June 2006).

Over 25% of the "waste" biomass is expected to come from 280 million tons of corn stover. Stover is what's left after the corn grain is harvested. Another 120 million tons will come from soy and cereal straw (DOE Feedstock Roadmap, DOE Biomass Plan).

There isn't enough no-till corn stover to harvest. The success of biofuels depends on corn residues. About 80% of farmers disk corn stover into the land after harvest. That renders it useless -- the crop residue is buried in mud and decomposing rapidly.

Only the 20 percent of farmers who farm no-till will have stover to sell. The DOE Billion Ton vision assumes all farmers are no-till, 75% of residues will be harvested, and fantasizes corn and wheat yields 50% higher than now are reached (DOE Billion Ton Vision 2005).

Many tons will never be available because farmers won't sell any, or much of their residue (certainly not 75%).

Many more tons will be lost due to drought, rain, or loss in storage.

Sustainable harvesting of plants is only 1/200th at best. Plants can only fix a tiny part of solar energy into plant matter every year -- about one-tenth to one-half of one percent new growth in temperate climates.

To prevent erosion, you could only harvest 51 million tons of corn and wheat residues, not 400 million tons (Nelson, 2002). Other factors, like soil structure, soil compression, water depletion, and environmental damage weren't considered. Fifty one million tons of residue could make about 3.8 billion gallons of ethanol, less than 1% of our energy needs.

Using corn stover is a problem, because corn, soy, and other row crops cause 50 times more soil erosion than sod crops (Sullivan 2004) or more (Al-Kaisi 2000), and corn also uses more water, insecticides and fertilizers than most crops (Pimentel 2003).

The amount of soy and cereal straw (wheat, oats, etc) is insignificant. It would be best to use cereal grain straw, because grains use far less water and cause far less erosion than row crops like corn and soybeans. But that isn't going to happen, because the green revolution fed billions more people by shortening grain height so that plant energy went into the edible seed, leaving little straw for biofuels. Often 90% of soybean and cereal straw is grown no-till, but the amount of cereal straw is insignificant and the soybean residues must remain on the field to prevent erosion

Energy Crops

Poor, erodible land. There aren't enough acres of land to grow significant amounts of energy crops. Potential energy crop land is usually poor quality or highly erodible land that shouldn't be harvested. Farmers are often paid not to farm this unproductive land. Many acres in switchgrass are being used for wildlife and recreation.

Few suitable bio-factory sites. Biorefineries can't be built just anywhere – very few sites could be found to build switchgrass plants in all of South Dakota (Wu 1998). Much of the state didn't have enough water or adequate drainage to build an ethanol factory. The sites had to be on main roads, near railroad and natural gas lines, out of floodplains, on parcels of at least 40 acres to provide storage for the residues, have electric power, and enough biomass nearby to supply the plant year round.

No energy crop farmers or investors. Farmers won't grow switchgrass until there's a switchgrass plant. Machines to harvest and transport switchgrass efficiently don't exist yet (Barrionuevo 2006). The capital to build switchgrass plants won't materialize until there are switchgrass farmers. Since "ethanol production using switchgrass required 50% more fossil energy than the ethanol fuel produced" (Pimentel 2005), investors for these plants will be hard to find.

Energy crops are subject to Liebig's law of the minimum too. Switchgrass may grow on marginal land, but it hasn't escaped the need for minerals and water. Studies have shown the more rainfall, the more switchgrass you get, and if you remove switchgrass, you're going to need to fertilize the land to replace the lost biomass, or you'll get continually lower yields of switchgrass every time you harvest the crop (Vogel 2002). Sugar cane has been touted as an "all you need is sunshine" plant. But according to the FAO, the nitrogen, phosphate, and potassium requirements of sugar cane are roughly similar to maize (FAO 2004).

Bioinvasive Potential. These fast-growing disease-resistant plants are potentially bioinvasive, another kudzu. Bioinvasion costs our country billions of dollars a year (Bright, 1998). Johnson grass was introduced as a forage grass and it's now an invasive weed in many states. Another fast-growing grass, Miscanthus, is now being proposed as a biofuel. It's been described as "Johnson grass on steroids" (Raghu 2006).

Sugar cane: too little to import. Brazil uses oil for 90% of their energy, and 17 times less oil (Jordan 2006). Brazilian ethanol production in 2003 was 3.3 billion gallons, about the same as the USA in 2004, or 1% of our transportation energy. Brazil uses 85% of their cane ethanol, leaving only 15% for export.

Sugar Cane: can't grow it here. Although we grow some sugar cane despite tremendous environmental damage (WWF) in Florida thanks to the sugar lobby, we're too far north to grow a significant amount of sugar cane or other fast growing C4 plants.

Wood ethanol is an energy sink. Ethanol production using wood biomass required 57% more fossil energy than the ethanol fuel produced (Pimentel 2005).

Wood is a nonrenewable resource. Old-growth forests had very dense wood, with a high energy content, but wood from fast-growing plantations is so low-density and low calorie it's not even good to burn in a fireplace. These plantations require energy to plant, fertilize, weed, thin, cut, and deliver. The trees are finally available for use after 20 to 90 years – too long for them to be considered a renewable fuel (Odum 1996). Nor do secondary forests always come back with the vigor of the preceding forest due to soil erosion, soil nutrition depletion, and mycorrhizae destruction (Luoma 1999).

There's not enough wood to fuel a civilization of 300 million people. Over half of North America was deforested by 1900, at a time when there were only 75 million people (Williams 2003). Most of this was from home use. In the 18th century the average Northeastern family used 10 to 20 cords per year. At least one acre of woods is required to sustainably harvest one cord of wood (Whitney 1994).

Energy crop limits. Energy crops may not be sustainable due to water, fertilizer, and harvesting impacts on the soil (DOE Biomass Roadmap 2005). Like all other monoculture crops, ultimately yields of energy crops will be reduced due to "pest problems, diseases, and soil degradation" (Giampetro, 1997).

Energy crop monoculture.   The "physical and chemical characteristics of feedstocks vary by source, by year, and by season, increasing processing costs" (DOE Feedstock Roadmap). That will encourage the development of genetically engineered biomass to minimize variation. Harvesting economies of scale will mean these crops will be grown in monoculture, just as food crops are. That's the wrong direction – to farm with less energy there'll need to be a return to rotation of diverse crops, and composted residues for soil nutrition, pest, and disease resistance.

A way around this would be to spend more on researching how cellulose digesting microbes tackle different herbaceous and woody biomass. The ideal energy crop would be a perennial, tall-grass prairie / herbivore ecosystem (Tilman 2006).

Farmers aren't Stupid: They won't sell their residues

Farmers are some of the smartest people on earth or they'd soon go out of business. They have to know everything from soil science to commodity futures.

Crop production is reduced when residues are removed from the soil. Why would farmers want to sell their residues?

Erosion, water, compression, nutrition. Harvesting of stover on the scale needed to fuel a cellulosic industry won't happen because farmers aren't stupid, especially the ones who work their own land. Although there is a wide range of opinion about the amount of residue that can be harvested safely without causing erosion, loss of soil nutrition, and soil structure, many farmers will want to be on the safe side, and stick with the studies showing that 20% (Nelson, 2002) to 30% (McAloon et al., 2000; Sheehan, 2003) at most can be harvested, not the 75% agribusiness claims is possible. Farmers also care about water quality (Lal 1998, Mann et al, 2002). And farmers will decide that permanent soil compression is not worth any price (Wilhelm 2004). As prices of fertilizer inexorably rise due to natural gas depletion, it will be cheaper to return residues to the soil than to buy fertilizer.

Residues are a headache. The further the farmer is from the biorefinery or railroad, the slimmer the profit, and the less likely a farmer will want the extra headache and cost of hiring and scheduling many different harvesting, collection, baling, and transportation contractors for corn stover.

Residues are used by other industries. Farm managers working for distant owners are more likely to sell crop residues since they're paid to generate profits, not preserve land. But even they will sell to the highest bidder, which might be the livestock or dairy industries, furfural factories, hydromulching companies, biocomposite manufacturers, pulp mills, or city dwellers faced with skyrocketing utility bills, since the high heating value of residue has twice the energy of the converted ethanol.

Investors aren't stupid either. If farmers can't supply enough crop residues to fuel the large biorefinery in their region, who will put up the capital to build one?

Can the biomass be harvested, baled, stored, and transported economically?

Harvesting. Sixteen ton tractors harvest corn and spit out stover. Many of these harvesters are contracted and will continue to collect corn in the limited harvest time, not stover. If tractors are still available, the land isn't wet, snow doesn't fall, and the stover is dry, three additional tractor runs will mow, rake, and bale the stover (Wilhelm 2004). This will triple the compaction damage to the soil (Troeh 2005), create more erosion-prone tire tracks, increase CO_2 emissions, add to labor costs, and put unwanted foreign matter into the bale (soil, rocks, baling wire, etc).

So biomass roadmaps call for a new type of tractor or attachment to harvest both corn and stover in one pass. But then the tractor would need to be much larger and heavier, which could cause decades-long or even permanent soil compaction. Farmers worry that mixing corn and stover might harm the quality of the grain. And on the cusp of energy descent, is it a good idea to build an even larger and more complex machine?

If the stover is harvested, the soil is now vulnerable to erosion if it rains, because there's no vegetation to protect the soil from the impact of falling raindrops. Rain also compacts the surface of the soil so that less water can enter, forcing more to run off, increasing erosion. Water landing on dense vegetation soaks into the soil, increasing plant growth and recharging underground aquifers. The more stover left on the land, the better.

Baling. The current technology to harvest residues is to put them into bales of hay. Hay is a dangerous commodity -- it can spontaneously combust, and once on fire, can't be extinguished, leading to fire loss and increased fire insurance costs. Somehow the bales have to be kept from combusting during the several months it takes to dry them from 50 to 15 percent moisture. A large, well drained, covered area is needed to vent fumes and dissipate heat. If the bales get wet they will compost (Atchison 2004).

Baling was developed for hay and has been adapted to corn stover with limited success. Biorefineries need at least half a million tons of biomass on hand to smooth supply bumps, much greater than any bale system has been designed for. Pelletization is not an option, it's too expensive. Other options need to be found. (DOE Feedstock Roadmap)

To get around the problems of exploding hay bales, wet stover could be collected. The moisture content needs to be around 60 percent, which means a lot of water will be transported, adding significantly to the delivery cost.

Storage. Stover needs to be stored with a moisture content of 15% or less, but it's typically 35-50%, and rain or snow during harvest will raise these levels even higher (DOE Feedstock Roadmap). If it's harvested wet anyhow, there'll be high or complete losses of biomass in storage (Atchison 2004).

Residues could be stored wet, as they are in ensilage, but a great deal of R&D are needed and to see if there are disease, pest, emission, runoff, groundwater contamination, dust, mold, or odor control problems. The amount of water required is unknown. The transit time must be short, or aerobic microbial activity will damage it. At the storage site, the wet biomass must be immediately washed, shredded, and transported to a drainage pad under a roof for storage, instead of baled when drier and left at the farm. The wet residues are heavy, making transportation costlier than for dry residues, perhaps uneconomical. It can freeze in the winter making it hard to handle. If the moisture is too low, air gets in, making aerobic fermentation possible, resulting in molds and spoilage.

Transportation. Although a 6,000 dry ton per day biorefinery would have 33% lower costs than a 2,000 ton factory, the price of gas and diesel limits the distance the biofuel refinery can be from farms, since the bales are large in volume but low in density, which limits how many bales can be loaded onto a truck and transported economically.

So the "economy of scale" achieved by a very large refinery has to be reduced to a 2,000 dry ton per day biorefinery. Even this smaller refinery would require 200 trucks per hour delivering biomass during harvest season (7 x 24), or 100 trucks per day if satellite sites for storage are used. This plant would need 90% of the no-till crop residues from the surrounding 7,000 square miles with half the farmers participating. Yet less than 20% of farmers practice no-till corn and not all of the farmland is planted in corn. When this biomass is delivered to the biorefinery, it will take up at least 100 acres of land stacked 25 feet high.

The average stover haul to the biorefinery would be 43 miles one way if these rosy assumptions all came true (Perlack 2002). If less than 30% of the stover is available, the average one-way trip becomes 100 miles and the biorefinery is economically impossible.

There is also a shortage of truck drivers, the rail system can't handle any new capacity, and trains are designed to operate between hubs, not intermodally (truck to train to truck). The existing transportation system has not changed much in 30 years, yet this congested, inadequate infrastructure somehow has to be used to transport huge amounts of ethanol, biomass, and byproducts (Haney 2006).

Cellulosic Biorefineries (see Appendix for more barriers)

There are over 60 barriers to be overcome in making cellulosic ethanol in Section III of the DOE "Roadmap for Agriculture Biomass Feedstock Supply in the United States" (DOE Feedstock Roadmap 2003). For example:

"Enzyme Biochemistry. Enzymes that exhibit high thermostability and substantial resistance to sugar end-product inhibition will be essential to fully realize enzyme-based sugar platform technology. The ability to develop such enzymes and consequently very low cost enzymatic hydrolysis technology requires increasing our understanding of the fundamental mechanisms underlying the biochemistry of enzymatic cellulose hydrolysis, including the impact of biomass structure on enzymatic cellulose decrystallization. Additional efforts aimed at understanding the role of cellulases and their interaction not only with cellulose but also the process environment is needed to affect further reductions in cellulase cost through improved production".

No wonder many of the issues with cellulosic ethanol aren't discussed – there's no way to express the problems in a sound bite.

It may not be possible to reduce the complex cellulose digesting strategies of bacteria and fungi into microorganisms or enzymes that can convert cellulose into ethanol in giant steel vats, especially given the huge physical and chemical variations in feedstock. The field of metagenomics is trying to create a chimera from snips of genetic material of cellulose-digesting bacteria and fungi. That would be the ultimate Swiss Army-knife microbe, able to convert cellulose to sugar and then sugar to ethanol.

There's also research to replicate termite gut cellulose breakdown. Termites depend on fascinating creatures called protists in their guts to digest wood. The protists in turn outsource the work to multiple kinds of bacteria living inside of them. This is done with energy (ATP) and architecture (membranes) in a system that evolved over millions of years. If the termite could fire the protists and work directly with the bacteria, that probably would have happened 50 million years ago. This process involves many kinds of bacteria, waste products, and other complexities that may not be reducible to an enzyme or a bacteria.

Finally, ethanol must be delivered. A motivation to develop cellulosic ethanol is the high delivery cost of corn grain ethanol from the Midwest to the coasts, since ethanol can't be delivered cheaply through pipelines, but must be transported by truck, rail, or barge (Yacobucci 2003).

The whole cellulosic ethanol enterprise falls apart if the energy returned is less than the energy invested or even one of the major stumbling blocks can't be overcome. If there isn't enough biomass, if the residues can't be stored without exploding or composting, if the oil to transport low-density residues to biorefineries or deliver the final product is too great, if no cheap enzymes or microbes are found to break down lignocellulose in wildly varying feedstocks, if the energy to clean up toxic byproducts is too expensive, or if organisms capable of tolerating high ethanol concentrations aren't found, if the barriers in Appendix A can't be overcome, then cellulosic fuels are not going to happen.

If the obstacles can be overcome, but we lose topsoil, deplete aquifers, poison the land, air, and water -- what kind of Faustian bargain is that?

Scientists have been trying to solve these issues for over thirty years now.

Nevertheless, this is worthy of research money, but not public funds for commercial refineries until the issues above have been solved. This is the best hope we have for replacing the half million products made from and with fossil fuels, and for liquid transportation fuels when population falls to pre-coal levels.

Part 7. Where do we go from here?

Subsidies and Politics

How come there are over 116 ethanol plants with 79 under construction and 200 more planned? The answer: subsidies and tax breaks.

Federal and state ethanol subsidies add up to 79 cents per liter (McCain 2003), with most of that going to agribusiness, not farmers. There is also a tax break of 5.3 cents per gallon for ethanol (Wall Street Journal 2002). An additional 51 cents per gallon goes mainly to the oil industry to get them to blend ethanol with gasoline.

In addition to the $8.4 billion per year subsidies for corn and ethanol production, the consumer pays an additional amount for any product with corn in it (Pollan 20005), beef, milk, and eggs, because corn diverted to ethanol raises the price of corn for the livestock industry.

Worst of all, the subsidies may never end, because Iowa plays a leading role in who's selected to be the next president. John McCain has softened his stand on ethanol (Birger 2006). All four senators in California and New York have pointed out that "ethanol subsidies are nothing but a way to funnel money to agribusiness and corn states at the expense of the rest of the country" (Washington Post 2002).

"Once we have a corn-based technology up and running the political system will protect it," said Lawrence J. Goldstein, a board member at the Energy Policy Research Foundation. "We cannot afford to have 15 billion gallons of corn-based ethanol in 2015, and that's exactly where we are headed" (Barrionuevo 2007).

Conclusion

Soil is the bedrock of civilization (Perlin 1991, Ponting 1993). Biofuels are not sustainable or renewable. Why would we destroy our topsoil, increase global warming, deplete and pollute groundwater, destroy fisheries, and use more energy than what's gained to make ethanol? Why would we do this to our children and grandchildren?

Perhaps it's a combination of pork barrel politics, an uninformed public, short-sighted greedy agribusiness corporations, jobs for the Midwest, politicians getting too large a percent of their campaign money from agribusiness (Lavelle 2007), elected leaders without science degrees, and desperation to provide liquid transportation fuels (Bucknell 1981, Hirsch 2005).

But this madness puts our national security at risk. Destruction of topsoil and collateral damage to water, fisheries, and food production will result in less food to eat or sell for petroleum and natural gas imports. Diversion of precious dwindling energy and money to impossible solutions is a threat to our nations' future.

Fix the unsustainable and destructive aspects of industrial agriculture. At least some good would come out of the ethanol fiasco if more attention were paid to how we grow our food. The effects of soil erosion on crop production have been hidden by mechanization and intensive use of fossil fuel fertilizers and chemicals on crops bred to tolerate them. As energy declines, crop yields will decline as well.

Jobs. Since part of what's driving the ethanol insanity is job creation, divert the subsidies and pork barrel money to erosion control and sustainable agriculture. Maybe Iowa will emerge from its makeover looking like Provence, France, and volunteers won't be needed to hand out free coffee at rest areas along I-80.

Continue to fund cellulosic ethanol research, focusing on how to make 500,000 fossil-fuel-based products (i.e. medicine, chemicals, plastics, etc) and fuel for when population declines to pre-fossil fuel carrying capacity. The feedstock should be from a perennial, tall-grass prairie herbivore ecosystem, not food crops. But don't waste taxpayer money to build demonstration or commercial plants until most of the research and sustainability barriers have been solved.

California should not adopt the E10 ethanol blend for global warming bill AB 32. Biofuels are at best neutral and at worst contribute to global warming. A better early action item would be to favor low-emission vehicle sales and require all new cars to have energy efficient tires.

Take away the E85 loophole that allows Detroit automakers to ignore CAFE standards and get away with selling even more gas guzzling vehicles (Consumer Reports 2006). Raise the CAFE standards higher immediately.

There are better, easier ways to stretch out petroleum than adding ethanol to it. Just keeping tires inflated properly would save more energy than all the ethanol produced today. Reducing the maximum speed limit to 55, consumer driving tips, truck stop electrification, and many other measures can save far more fuel in a shorter time than biofuels ever will, far less destructively. Better yet, Americans can bike or walk, which will save energy used in the health care system.

Let's stop the subsidies and see if ethanol can fly.

Reform our non-sustainable agricultural system

Give integrated pest management and organic agriculture research more funding

The National Resources Conservation Service (NCRS) and other conservation agencies have done a superb job of lowering the erosion rate since the dustbowl of the 1930's. Give these agencies a larger budget to further the effort.

To promote land stewardship, change taxes and zoning laws to favor small family farms. This will make possible the "social, economic, and environmental diversity necessary for agricultural and ecosystem stability" (Opie 2000).

Make the land grant universities follow the directive of the Hatch Act of 1887 to improve the lives of family farmers. Stop funding agricultural mechanization and petrochemical research and start funding how to fight pests and disease with diverse crops, crop rotations, and so on (Hightower 1978).

Don't allow construction of homes and businesses on prime farm land.
Integrate livestock into the crop rotation.

Teach family farmers and suburban homeowners how to maximize food production in limited space with Rodale and Biointensive techniques.

Since less than 1 percent of our elected leaders and their staff have scientific backgrounds, educate them in systems ecology, population ecology, soil, and climate science. So many of the important issues that face us need scientific understanding and judgment.

Divert funding from new airports, roads, and other future senseless infrastructure towards research in solar, wind, and cellulosic products. We're at the peak of scientific knowledge and our economic system hasn't been knocked flat yet by energy shortages – if we don't do the research now, it may never happen.

It's not unreasonable to expect farmers to conserve the soil, since the fate of civilization lies in their hands. But we need to pay farmers for far more than the cost of growing food so they can afford to conserve the land. In an oil-less future, healthy topsoil will be our most important resource.

Responsible politicians need to tell Americans why their love affair with the car can't continue. Leaders need to make the public understand that there are limits to growth, and an increasing population leads to the "Tragedy of the Commons". Even if it means they won't be re-elected. Arguing this amidst the church of development that prevails this is like walking into a Bible-belt church and telling the congregation God doesn't exist, but it must be done.

We are betting the farm on making cellulosic fuels work at a time when our energy and financial resources are diminishing. No matter how desperately we want to believe that human ingenuity will invent liquid or combustible fuels despite the laws of thermodynamics and how ecological systems actually work, the possibility of failure needs to be contemplated.

Living in the moment might be enlightenment for individuals, but for a nation, it's disastrous. Is there a Plan B if biofuels don't work? Coal is not an option. CO2 levels over 1,000 ppm could lead to the extinction of 95% of life on the planet (Lynas 2007, Ward 2006, Benton 2003).

Here we are, on the cusp of energy descent, with mechanized petrochemical farms. We import more farm products now than we sell abroad (Rohter 2004). Suburban sprawl destroys millions of acres of prime farm land as population grows every year. We've gone from 7 million family farms to 2 million much larger farms and destroyed a deeply satisfying rural way of life.

There need to be plans for de-mechanization of the farm economy if liquid fuels aren't found. There are less than four million horses, donkeys, and mules in America today. According to Bucknell, if the farm economy were de-mechanized, you'd need at least 31 million farm workers and 61 million horses. (Bucknell 1981)

The population of the United States has grown over 25 percent since Bucknell published Energy and the National Defense. To de-mechanize now, we'd need 39 million farm workers and 76 million horses. The horsepower represented by just farm tractors alone is equal to 400 million horses. It's time to start increasing horse and oxen numbers, which will leave even less biomass for biorefineries.

We need to transition from petroleum power to muscle power gracefully if we want to preserve democracy. Paul Roberts wonders whether the coming change will be "peaceful and orderly or chaotic and violent because we waited too long to begin planning for it" (Roberts 2004).

What is the carrying capacity of the nation? Is it 100 million (Pimentel 1991) or 250 million (Smil 2000)? Whatever carrying capacity is decided upon, pass legislation to drastically lower immigration and encourage one child families until America reaches this number. Or we can let resource wars, hunger, disease, extreme weather, rising oceans, and social chaos legislate the outcome.

Do you want to eat or drive? Even without growing food for biofuels, crop production per capita is going to go down as population keeps increasing, fossil fuel energy decreases, topsoil loss continues, and aquifers deplete, especially the Ogallala (Opie 2000). Where will the money come from to buy imported oil and natural gas if we don't have food to export?

There is no such thing as "waste" biomass. As we go down the energy ladder, plants will increasingly be needed to stabilize climate, provide food, medicine, shelter, furniture, heat, light, cooking fuel, clothing, etc.

Biofuels are a threat to the long-term national security of our nation. Is Dr. Strangelove in charge, with a plan to solve defense worries by creating a country that's such a salty polluted desert, no one would want to invade us? Why is Dr. Strangelove spending the last bits of energy in Uncle Sam's pocket on moonshine? Perhaps he's thinking that we're all going to need it, and the way things are going, he's probably right.

Appendix

Department of Energy Biofuel Roadmap Barriers

This is a partial summary of biofuel barriers from Department of Energy. Unless otherwise footnoted, the problems with biomass fuel production are from the Multi Year Program Plan DOE Biomass Plan or Roadmap for Agriculture Biomass Feedstock Supply in the United States. (DOE Biomass Plan, DOE Feedstock Roadmap).

Resource and Sustainability Barriers

1) Biomass feedstock will ultimately be limited by finite amounts of land and water

2) Biomass production may not be sustainable because of impacts on soil compaction, erosion, carbon, and nutrition.

3) Nor is it clear that perennial energy crops are sustainable, since not enough is known about their water and fertilizer needs, harvesting impacts on the soil, etc.

4) Farmers are concerned about the long-term effects on soil, crop productivity, and the return on investment when collecting residues.

5) The effects of biomass feedstock production on water flows and water quality are unknown

6) The risks of impact on biodiversity and public lands haven't been assessed.

Economic Barriers (or Investors Aren't Stupid)

1) Biomass can't compete economically with fossil fuels in transportation, chemicals, or electrical generation.

2) There aren't any credible data on price, location, quality and quantity of biomass.

3) Genetically-modified energy crops worry investors because they may create risks to native populations of related species and affect the value of the grain.

4) Biomass is inherently more expensive than fossil fuel refineries because

a) Biomass is of such low density that it can't be transported over large distances economically. Yet analysis has shown that biorefineries need to be large to be economically attractive – it will be difficult to find enough biomass close to the refinery to be delivered economically.

b) Biomass feedstock amounts are unpredictable since unknown quantities will be lost to extreme weather, sold to non-biofuel businesses, rot or combust in storage, or by used by farmers to improve their soil.

c) Ethanol can't be delivered in pipelines due to likely water contamination. Delivery by truck, barge, and rail is more expensive. Ethanol is a hazardous commodity which adds to its transportation cost and handling.

d) Biomass varies so widely in physical and chemical composition, size, shape, moisture levels, and density that it's difficult and expensive to supply, store, and process.

e) The capital and operating costs are high to bale, stack, palletize, and transport residues

f) Biomass is more geographically dispersed, and in much more ecologically sensitive areas than fossil resources.

g) The synthesis gas produced has potentially higher levels of tars and particulates than fossil fuels.

h) Biomass plants can't benefit from the same large-scale cost savings of oil refineries because biomass is too dispersed and of low density.

5) Consumers won't buy ethanol because it costs more than gasoline and contains 34% less energy per gallon. Consumer reports wrote they got the lowest fuel mileage in recent years from ethanol due to its low energy content compared to gasoline, effectively making ethanol $3.99 per gallon. Worse yet, automakers are getting fuel-economy credits for every E85 burning vehicle they sell, which lowers the overall mileage of auto fleets, which increases the amount of oil used and lessens energy independence. (Consumer Reports)

Equipment and Storage Barriers

1) There are no harvesting machines to harvest the wide range of residue from different crops, or to selectively harvest components of corn stover.

2) Current biomass harvesting and collection methods can't handle the many millions of tons of biomass that need to be collected.

3) How to store huge amounts of dry biomass hasn't been figured out.

4) No one knows how to store and handle vast quantities of different kinds of wet biomass. You can lose it all since it's prone to spoiling, rotting, and spontaneous combustion

Preprocessing Barriers

1) We don’t even know what the optimum properties of biomass to produce biofuels are, let alone have instruments to measure these unknown qualities.

2) Incoming biomass has impurities that have to be gotten out before grinding, compacting, and blending, or you may damage equipment and foul chemical and biological processes downstream.

3) Harvest season for crops can be so short that it will be difficult to find the time to harvest cellulosic biomass and pre-process and store a year of feedstock stably.

4) Cellulosic biomass needs to be pretreated so that it’s easier for enzymes to break down. Biomass has evolved for hundreds of millions of years to avoid chemical and biological degradation. How to overcome this reluctance isn’t well enough understood yet to design efficient and cost-effective pre-treatments.

5) Pretreatment reactors are made of expensive materials to resist acid and alkalis at high temperatures for long periods. Cheaper reactors or low acid/alkali biomass is needed.

6) To create value added products, ways to biologically, chemically, and mechanically split components off (fractionate) need to be figured out.

7) Corn mash needs to be thoroughly sterilized before microorganisms are added, or a bad batch may ensue. Bad batches pollute waterways if improperly disposed of. (Patzek Dec 2006).

Cellulosic Ethanol Showstoppers

1) The enzymes used in cellulosic biomass production are too expensive.

2) An enzyme that breaks down cellulose must be found that isn’t disabled by high heat or ethanol and other end-products, and other low cost enzymes for specific tasks in other processes are needed.
3) If these enzymes are found, then cheap methods to remove the
impurities generated are needed. Impurities like acids, phenols, alkalis, and salts inhibit fermentation and can poison chemical catalysts.

4) Catalysts for hydrogenation, hydrgenolysis, dehydration, upgrading pyrolysis oils, and oxidation steps are essential to succeeding in producing chemicals, materials, and transportation fuels. These catalysts must be cheap, long-lasting, work well in fouled environments, and be 90% selective.

5) Ethanol production needs major improvements in finding robust organisms that utilize all sugars efficiently in impure environments.

6) Key to making the process economic are cheap, efficient fermentation organisms that can produce chemicals and materials. Wald writes that the bacteria scientists are trying to tame come from the guts of termites, and they’re much harder to domesticate than yeast was. Nor have we yet convinced "them to multiply inside the unfamiliar confines of a 2,000-gallon stainless-steel tank" or "control their activity in the industrial-scale quantities needed" (Wald 2007).

7) Efficient aerobic fermentation organisms to lower capital fermentation costs.

8) Fermentation organisms that can make 95% pure fermentation products.

9) Cheap ways of removing impurities generated in fermentation and other steps are essential since the costs now are far too high.

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