Green Gold: Why cellulosic ethanol is a threat to farmers and the planet

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Cellulosic ethanol has everyone from John McCain to the Natural Resources Defense Council excited with the promise of greening the planet and the economy in one stroke. The U.S. Department of Energy is pouring money into cellulosic research, and politicians are talking about “advanced” and “second generation” biofuels as if it were the coming of our collective energy savior. Even companies making a fortune off corn ethanol see cellulosic as the future of fuel. The hype invites us to believe that those of us in industrialized countries won't have to change our patterns of consumption in order to solve the food and energy crises; that there is a quick technological fix to the food crisis, largely brought on by the use of food crops for vehicle fuel; that will also help us confront a changing climate. The irony of cellulosics however, is the unprecedented threat they pose to small farmers, the environment and our global carbon balance: the very things they pretend to protect.

Cellulosic 101

Though not the only “second generation” agro-fuel in development, cellulosic ethanol receives by far the most attention (and research dollars). Cellulose is the fibrous material that makes up the bulk of vascular plants. This fuel is made by distilling the sugars bound up in cellulose into alcohol for use mostly as a vehicle fuel. Most plants are about one third cellulose. Trees are around 50% cellulose, and cotton is nearly 90%. Cellulose is extremely difficult to break down; cows use four stomachs to turn the cellulose in grasses into sugars. Termites have over 200 microorganisms in their stomachs to help digest the cellulose in wood. So far no commercial cellulosic ethanol plants have achieved a positive net energy balance. Because so much energy goes into teasing the sugar out of biomass, cellulosic will never be viable without major breakthroughs in plant physiology. In other words, cellulosic ethanol *must* be genetically engineered in order to ever reach the market.

The Science Behind Cellulosic

The reason cellulosic ethanol is so difficult to produce is the same reason humans can't eat grass. Cellulose itself is a complex chain of sugars, bound in cell walls to two other compounds, lignin and hemi-cellulose. Lignin is the compound that gives plants their structure. It forms a sort of shield around cellulose, protecting it from pests and decay.

In processing cellulosic ethanol however, lignin is the first major hurdle. The lignin coats cellulose, making it difficult for enzymes to break it down into sugars. So before the separation of sugars can even begin, the three compounds must be broken up, typically with boiling, acids and/or steam. After this first step of separation, enzymes are added to decompose the cellulose into its component sugars; at present an inefficient and expensive process. The sugars are finally distilled into ethanol for fuel.

Overcoming the Impossible: Biotech to the Rescue

Industry proponents have essentially two major hurdles to overcome before cellulosic ethanol flows to consumers: achieving meaningful processing efficiency, and attaining yields high enough to make it worthwhile. In order to overcome the first hurdle, the biotech industry is both genetically engineering micro-organisms to break cellulose into sugars and manipulating the plant physiology to ease processing troubles.

So far, no single microorganism can catalyze cellulose into sugar. Biotech researchers are working on genetically engineering just one organism to either produce a super-powerful enzyme, or to digest cellulose by itself. A German research team recently genetically engineered the bacteria E. coli to synthesize ethanol.[i] This is potentially problematic because the E. coli was cultivated in the presence of antibiotics to track the uptake of new genetic material. The industrial use of such a process could easily result in the accidental unleashing of antibiotic resistant E. coli. These researchers thankfully concluded that E. coli was not the most efficient bacterial catalyst, but researchers for privately held biotech companies are engaging in similar research and have no obligation to publicly disclose their research and development.

Processing efficiency can also be addressed through genetic engineering of the plant itself. For example, the American GM forestry company, ArborGen, is conducting field trials in Brazil of GM trees with up to 20% less lignin in their wood[ii]. Trials of similarly altered Poplar are ongoing in Oregon. Genetically modified food-to-energy crops are already here, stirring up health and safety concerns wherever they are brought to market. Syngenta's Event 3272 fuel corn includes genetic material from a deep sea thermal vent organism to aid in processing. This organism was only recently discovered and hasn’t entered the human food supply yet.[iii]

The third way biotechnology is addressing the cellulose conundrum is by attempting to produce the greatest amount of biomass per acre possible to compensate for inefficiencies and satiate endless demand. Environmental groups herald the productive value of switchgrass, a perennial grass native to the Midwestern United States. But prominent cellulosics researcher Dr. Chris Sommerville contends that switchgrass will never be productive enough, and the weedy Miscanthus and other GM energy crops will take center stage.[iv] Current biotech pipeline products include inedible sugarcane and sorghum varieties and Poplar and Eucalyptus modified to produce biomass and grow quickly on short rotation. There are also attempts to engineer freeze and drought tolerance in already weedy species like Miscanthus and Eucalyptus.

The Cellulosic Pipeline: A partial look at what's to come

Proposed Energy Crops	Description	GE Traits in Development
Switchgrass	A tall grass native to the Midwestern United States	faster growing and higher yield
Miscanthus	A weedy, tall grass (up to ten feet), native to Asia	faster growing, drought tolerance higher yield
Poplar	A hardwood tree native to North America	reduced lignin content for processing ease, faster growing
Eucalyptus	Fast-growing tree native to Austrailia, weedy elsewhere	freeze tolerance, rapid growth,
Sorghum	A major staple grain	produces biomass instead of food
“Energycane”	A GE variety of sugarcane	genetically engineered to produce biomass instead of sugar
Pinus taeda (Loblolly Pine) Pinus radiata (Monterrey Pine)	Important industrial forestry species native to the Southeastern US and California, respectively (P. radiata is weedy in Chile)	faster growth to reduce time between harvests

A Publicly Funded Breakthrough

The barriers current cellulosic technology must still overcome ensure that it will take enormous public and private investment to get cellulosic fuels to the pump. A recent University of Iowa study found that without the largess offered by the 2007 Energy Act, cellulosic would never get off the ground.[v] Even with the Renewable Fuels Standard, the authors claim that the U.S. will fall drastically short of targets, producing around 4.5 billion of the mandated 21 billion gallons of "advanced biofuels" per year, and then only if the government triples the already enormous per gallon subsides to the ethanol industry.[vi] (From field to fuel, ethanol receives approximately $6.3-8.7 billion a year in subsides.[vii]) Asking taxpayers to launch cellulosic is illogical, (and a gift to industry) considering that a 3-4% increase in fuel economy would save the same amount of fuel the Iowa study predicts will be displaced by cellulosics.[viii] Even the USDA is backing away from the cellulosic hype. In September of last year USDA analysts said that although it holds "some longer-term promise" cellulosic is unlikely to be commercially viable before the 2005 Energy Policy Act benchmarks are met in 2013.[ix]

Cellulosics Will Worsen the Food Crisis

Far from alleviating the competition that is between food and fuel behind skyrocketing food prices, cellulosic crops will make it worse. Contrary to industry claims, at least some energy crops in development stand in direct competition with food crops. Some of the new cellulosic crops, like "Energycane," a sugarcane variety designed to produce biomass (for cellulosics) instead of sugar, obviously requires the same growing conditions as sugarcane. Switchgrass though touted as a crop for marginal and fallow lands, will soon be in direct competition with corn for acreage as demand for feedstock rises. Crops like high-biomass Sorghum will necessarily compete with its food-destined cousins for agricultural land. Regardless of whether the agro-fuel in question is corn or switchgrass, if it grows on land, it will drive up the price of food.

Where will all the land come from?

Leading cellulosics researcher Dr. Chris Sommerville contends that we could grow all of the world's transport fuel on 1% of its land area with energy crops like Miscanthus. Even if magically irrigation water and soil fertility were not an issue, such an undertaking would demand 10% of all the arable land in the world. This means that either 130 million acres of wildland must be converted to fuel crops, or the world will have to be 10% hungrier.

Agricultural Wastes for Fuel

Ethanol proponents claim that a significant portion of U.S. transportation fuels could be made from agricultural "waste" products alone. Cellulosic ethanol could theoretically be produced from corn stover, sugar cane bagasse and wood chips—all leftovers from industrial ag and forestry processing. But at what cost? A joint report by the USDA and the Department of Energy finds that reaching cellulosic targets would require removing nearly all agricultural residues and putting every acre of farmland under no-till practices.[x] Agricultural residues are turned back into the soil to increase organic matter and fertility. Without these residues, especially in corn, fields will require more nitrogen fertilizers, decreasing the overall energy efficiency and increasing the environmental footprint of those systems.[xi] Removing "waste" effectively mines the soil, increasing soil erosion, fertilizer runoff and nutrient loss.[xii] Removing organic matter from the soil also reduces water retention, making agriculture more vulnerable to drought. Similarly, removing dead and down wood, "forestry waste," reduced biodiversity and carbon storage in already stressed forests.[xiii]

What about Water?

Moreover, high intensity monocropping cannot exist in most places without irrigation. Global groundwater supplies are already drastically overtaxed. The Stockholm International Water Institute estimates that global agro-fuels production will demand as much water as it would take to grow food for the entire population of the planet by 2050.[xiv] The three largest grain producing countries in the world, the U.S., China, and India, are all drawing on groundwater supplies much faster than they can naturally be replaced. In the Indian State of Tamil Nadu 95% of small farmers have seen their wells dry up.[xv] China has already seen drastic reductions in the size of their wheat harvests due to lack of irrigation water, while in Beijing, expensive drilling technologies are being used to mine water tables that have fallen to more than 1000 meters beneath the surface.[xvi]

While industry proponents claim that cellulosic crops will use “little” irrigation, the exact amount of irrigation that crops like switchgrass or Miscanthus will demand is unknown. What is clear is that some irrigation will be required, especially in order to meet ever increasing demand for transportation fuels. Corn ethanol production alone will draw up to 120 billion gallons of water a year from the already overtaxed Ogalalla aquifer in the Midwestern United States.[xvii] Any additional draw on the aquifer is not only unsustainable in the long term, but will put large corporate farms in direct competition for water resources with smaller farmers with fewer resources to drill deeper and deeper wells. As in the state of Tamil Nadu, small farmers in the U.S. will certainly lose out to big agribusinesses. Any drawdown of groundwater resources to produce fuel crops will put food squarely in competition with fuel for water.

A Disaster for Small Farmers

Corporate land grabs for agro-fuels are already happening. In the Eastern Cape of South Africa where 500,000 hectares of communal farmland is being fenced and planted to canola for biodiesel. Locals have been forced to forgo their diverse food gardens and grazing lands, while Monsanto collects heavy subsidies for providing its chemicals and seeds “ to these corporate farmers.”[xviii] Aracruz Cellulose, a leading supplier of eucalyptus paper pulp and one of the new players in cellulosic ethanol, evicted 8,500 indigenous families from their land in the Brazilian state of Espirito Santo, converting 11,000 hectares to “Green Desert.”[xix] The plantations have dried up several rivers and streams, seriously threatening water supply to small farmers.[xx] If the technology to commercialize cellulosic from cellulosics becomes widely available, we can expect to see more small farmers pushed into forest edges and deserts or worse, to urban slums.

Moreover, the agro-fuels model is inherently industrial. Large quantities of uniform feedstock must be produced near a central processing facility. Price will largely be set by processors and volatile commodities markets. Just like any other green revolution technology, the winners will be the large corporate agribusinesses that have the capital and economies of scale to produce the enormous volumes it will take to make a profit. With corporate land takeovers for agro-fuels well under way, expecting peasant farmers to cash in on the agro-fuels boom is a pipe dream.

Environmental Solution or Environmental Nightmare?

The only way cellulosic energy crops will not compete with food for land and irrigation water is if natural landscapes are converted to industrial ones on an enormous scale. Industrial forestry is already responsible for poor water quality, razed landscapes, large-scale carbon emissions, and harsh boom and bust cycles that leave depressed towns and unemployed workers in their wake. Now the leaders of the industrial forestry industry are championing a new product—genetically engineered trees—as the green fuel of the future. Arborgen, a partnership between three industrial forestry corporations, aspires to be for forestry what Monsanto is to agriculture. The company is developing short-rotation, fast growing trees, trees with less lignin, which require the use of pesticides in forests, including eucalyptus, an already weedy species responsible for increased fire danger on the California Coast, that can withstand freezing temperatures. The new GE trees are engineered to be “short-rotation” meaning that every 7-10 years the stand of plantation trees would be clearcut.

More over, genetic pollution from these new crops is a certainty. All energy crops currently in development have close wild relatives, and many are wind pollinated. For example, tree pollen can travel 1200 miles in the wind, so the GE Poplar being tested in Oregon could conceivably contaminate forests as far away as Southern Alaska. Miscanthus and Euycapytus, both weedy species, are being genetically engineered with traits that make them weedier, (faster-growing, larger, drought and freeze tolerant), prompting scientists at a May 2008 UN meeting to voice concern about invasive species originating on agro-fuel plantations.[xxi]

The Carbon Question

One of the sexiest claims made about cellulosic ethanol is carbon neutrality. Proponents say that because plants sequester carbon from the atmosphere, plant-based fuels that use the whole plant (cellulosics) will sequester as much carbon as they emit. The carbon footprint of agro-fuels depends on how they are being farmed and processed. Processing efficiency is currently very low for cellulosics. While the race to genetically engineer microbes to efficiently convert cellulose to sugar is on, at the moment, it takes more energy to produce cellulosic ethanol than it yield.[xxii] Even if processing efficiency improves dramatically, cellulosic's climate footprint will not. Emissions from agriculture are responsible for 14% of global greenhouse gas emissions, not counting deforestation for agriculture, soil carbon loss, or peat degradation.[xxiii] Land transformation, largely due to expansion of agriculture, accounts for 18% of global GHG emissions, while transportation—the emissions agro-fuels would supposedly reduce—account for only 14%.[xxiv] The amount of greenhouse gas release has grown steadily in connection with the green revolution's increase in agricultural chemical use. Emissions of nitrous oxide, a greenhouse gas with 296 times the warming effects of carbon, are connected to synthetic nitrogen fertilizer application.[xxv] Emissions from agriculture are set to increase 30% by 2020, not including potential increases from agro-fuels production.[xxvi] Many of the GM agro-fuels traits like faster growth, shorter time until maturity, increased biomass, and stress resistant traits that will allow energy crops to grow on marginal land will drastically increase the use of nitrogen fertilizers. A recent study by Nobel Prize winning Physicist Paul Crutzen indicates that 3-5% of nitrogen applied as fertilizer is released into the atmosphere as nitrous oxide. In a life cycle analysis for corn ethanol, he concluded that no emissions benefits were to be had by replacing oil with corn ethanol.[xxvii] While the total nitrogen fertilizer demands of future energy crops are impossible to determine, these emissions have such a strong effect as to call into doubt the climate benefits of any fuel based on industrial agriculture.

Whether improvement of greenhouse gas emissions over fossil fuels will occur at depends on where crops are grown and how much nitrogen they demand. Even switchgrass, a native perennial in the United States, requires between 90-120lbs of nitrogen fertilizer per acre annually.[xxviii] The biodiesel boom is also causing some of the most rapid deforestation rates in history in Indonesia and other countries that export palm oil. Indonesia is the third largest producer of greenhouse gases in the world, largely because of expanding oil palm acreage.[xxix] Every ton of palm oil produced releases 33 tons of carbon dioxide into the atmosphere, more than 10 times petroleum, because of associated deforestation.[xxx] There is no reason to believe that cellulosic crops will be any better. In order for energy crops and food to coexist at all, production will have to expand into forests, prairies, and other carbon sinks.

Towards Meaningful Food and Energy Policy

Like the green revolution technologies before them, cellulosic crops will dispossess small farmers and do irreparable damage to the environment in the name of corporate greed. While cellulosic ethanol may be technically renewable, it is no more sustainable than whale blubber. Instead of moving the world toward a truly sustainable energy source, public investment in cellulosic only reinforces further environmental degradation. In terms of environmental or social change, it can be considered just another unnecessary subsidy to agribusiness and oil companies. The race to develop cellulosic ethanol will produce some very real winners and losers. Only this time the losers will be the very resources cellulosic is supposed to save.

A public call for a moratorium on agro-fuels, both in Europe and North America is gaining ground. The moratorium must include all agro-fuels, including cellulosics, and end public financing for this disaster in the making. We need meaningful energy policy in its place, a policy built on solar, wind, wave, micro-hydro power and a viable mass transportation system. We also need climate policy that supports small-scale, sustainable agriculture, takes into account greenhouse gas emissions and guarantees food sovereignty rather than increasing competition between food and fuel. It is time to stop pouring time, energy and money into the hollow promise of cellulosics' hollow promise.

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