RESISTANCE Number 60
OILWATCH NETWORK BULLETIN
March 2996

BIOFUELS

Dear friends and colleagues:

This issue of “Resistance” will be devoted to analyse the problematic of biofuels. The articles included in this bulletin are part of the publication “Which Energy? 2006 energy report from the Institute of Science in Society. Mae-Wan Ho, Peter Bunyard, Peter Saunders, Elizabeth Bravo and Rhea Gala.

Oilwatch Secretariat
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CONTENT

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1. WHAT ARE BIOFUELS?

Biofuels are fuels derived from crop plants, and include biomass that's directly burned, biodiesel from plant seed-oil, and ethanol (or methanol) from fermenting grain, grass, straw or wood. Biofuels have gained favour with environmental groups as renewable energy sources that are "carbon neutral", in that they do not add any greenhouse gas into the atmosphere; burning them simply returns to the atmosphere the carbon dioxide that the plants take out when they were growing in the field.

However, they take up valuable land that should be used for growing food, especially in poor Third World countries. Realistic estimates show that making biofuels from energy crops requires more fossil fuel energy than they yield, and they do not substantially reduce greenhouse gas emissions when all the inputs are accounted for.

Furthermore, they cause irreparable damages to the soil and the environment.

Biofuels can also be produced from wood chips, crop residues and other agricultural and industrial wastes, which do not compete for land with food crops, but the environmental impacts are still substantial.

Source: ISIS. 2006
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2. BIOFUELS FOR OIL ADDICTS CURE WORSE THAN THE ADDICTION?
MAE-WAN HO

Bioethanol and biodiesel from energy crops compete for land that grows food and return less energy than the fossil fuel energy used in producing them; they are also damaging to the environment and disastrous for the economy

"We must break our addiction to oil", President George W. Bush said in his State of the Union address, but he wasn't advising people to give up their cars or to use less oil, say by improving the gas mileage of cars. Instead, he launched the "Advanced Energy Initiative" that would increase federal budget by 22 percent for research into clean fuel technologies; including biofuels derived from plants as substitutes for oil to power the country's cars.

Successive US presidents have promoted ethanol from corn as a subsidised fuel additive. President Bush said US scientists are now working out how to make ethanol from wood chips, stalks, or switch grass "practical and competitive within six years", which would replace more than 70 percent of oil imports from "unstable parts of the world" – the Middle East - by 2025.*2* Currently 60 percent of the oil consumed in the US is imported, up from 53 percent since George W. Bush came to power.

BIOFUELS FROM ENERGY CROPS CANNOT SUBSTITUTE FOR CURRENT FOSSIL FUEL USE

Biofuels from energy crops cannot substitute for current fossil fuel use. The major constraints are land surface available for growing the crops, crop yield, and energy conversion efficiency, although economics also plays a large role.

Growing crops for burning - biomass - should be the cheapest kind of biofuel both in energy and financial terms, as it requires minimum processing after harvest.

Crop scientists at Virginia Tech, David Parrish and John Fike, reviewed the biology and agronomy of switchgrass, the most researched and favoured biofuel crop.*3* Switchgrass is a perennial native to the USA, and has been extensively grown for fodder soon after the Europeans arrived. It is prolific, does not require much nitrogen fertiliser, and is considered the most sustainable, or the least environmentally damaging biofuel crop. But the review concluded that, "even at maximum output, such systems could not provide the energy currently being derived from fossil fuels."

Substituting switchgrass for coal is estimated to reduce greenhouse gas emissions by about 1.7 ton CO_2 per ton switchgrass. The prices that growers receive for biomass, however, must be sufficiently favourable. Thus, about 8 m ha would be available if the price reached $33 per ton at the farm gate, increasing to about 17 m ha at $44 per ton. The market price paid for woodchip biomass in Virginia in 2004 averaged about $33 per ton *delivered*, and the price for hay (all kinds) is about $95 per ton.

One estimate placed the delivery costs of switchgrass at $63 per ton. Adding the costs of processing, such as pressing into pellets or cubes for handling within a power plant, would bring the user's costs to about $83 per ton. One ton of switchgrass produces 17-18 GJ of energy when burned, compared with 27-30 GJ for coal; and coal prices are $55 per ton.

Switchgrass for energy is not at all economically competitive, unless substantial subsidy is available. *The same applies, all the more so, to other energy crops*.

David Pimentel, a professor of crops science at Cornell University New York and Tad Patzek, a professor of chemical engineering at University of California Berkeley, reviewed the energy balance and economics of producing biomass, ethanol or biodiesel from corn, switchgrass, wood, soybeans and sunflower using the now generally accepted lifecycle analysis. Although there is much controversy over the energy balance of ethanol and biodiesel, the energy balance of biomass yield is generally less subject to dispute, and is therefore a useful starting point (see Table 1).

As can be seen, switchgrass has the most favourable output/input energy ratio of 14.52, followed by wheat at 12.88, and oilseed rape at 9.21, if the straw is included. Switchgrass is hence the most promising energy crop, whether as biomass for burning or to make other fuels downstream, such as ethanol.

A quick calculation*3* showed that even if all the farmland in the United States were converted to growing switchgrass, it would not produce enough ethanol for the country's fossil fuel use. Switchgrass takes several years to mature. The yield ranges from 0 for complete failure of the crop to take hold to 20 ton or more per ha, a lot depending on the rainfall. A yield of 15 tonne /ha is optimistic; and would provide some 250 GJ/ha of raw chemical energy a year. If that energy could be converted with 70 percent efficiency into electricity, ethanol, methanol etc., it would take about 460 m ha to produce the 80EJ (ExaJoule = 1018J) fossil fuel energy used in the USA each year. The total farmland in the USA is 380 m ha, of which 175 m ha is harvested cropland.

Clearly, energy crops are a bad option, and may become obsolete as ethanol can now be made from wood chips, crop residues and other agricultural wastes, and industrial wastes, though even that is not sustainable.

TABLE 1. ENERGY BALANCE FOR BIOMASS YIELD OF MAJOR ENERGY CROPS

Crop	Yield (t/ha)	Energy Input (GJ)	Biomass Energy(GJ)	Output/Input
Maize [4]	8.655	33.978	130.459	3.84
Switchgr. [4]	10.000	11.535	167.480	14.52
Soybean [4]	2.668	15.685	40.216	2.56
Sunflower [5]	1.500	25.620	19.470	0.76
Oilseed rape [4]	4.080a	12.159	54.346	4.47
	8.080b	12.417	114.346	9.21
Wheat [5]	8.960a	12.562	74.189	5.91
	15.460b	13.328	171.689	12.88

a grain only, b grain & straw

DO YOU GET MORE ENERGY OUT OF BIOFUEL THAN THE FOSSIL FUEL ENERGY YOU PUT IN?

There is a huge debate over the energy balance of making ethanol or biodiesel out of energy crops, with David Pimentel and Tad Patzek presenting negative energy balance for *all* crops based on current processing methods,*4* i.e., it takes more fossil energy input to produce the equivalent energy in biofuel.

Thus for each unit of energy spent in fossil fuel, the return is 0.778 unit of energy in maize ethanol, 0.688 unit in switchgrass ethanol, 0.636 unit in wood ethanol, and worst of all, 0.534 unit in soybean biodiesel.

Their paper has provoked a strong riposte from several US government departments,*6* accusing Pimentel and Patzek of using obsolete figures, of not counting the energy content of by-products such as the seedcake (residue left after oil is extracted) that can be used as animal feed, and of including energy used for building processing plants, farm machinery, and labour, not usually included in such assessments.
For their part, Pimentel and Patzek, along with many other scientists like me, are critical of estimates that produce positive energy balance precisely because they leave out necessary energy investments. In fact, neither Pimentel and Patzek nor their critics have included the costs of waste treatment and disposal or the environmental impacts of intensive bioenergy crop cultivation such as depletion of soil and environmental pollution from fertilisers and pesticides.

To apportion processing-energy to coproducts according to their bulk composition in the seed may appear unexceptionable. Only 18 percent of the soybean is oil that makes biodiesel, while the rest is soybean cake used as animal feed. However, as the seedcake is produced as soon as the oil is extracted, it is simply creative accounting to attribute 82 percent of the downstream processing energy for biodiesel - which is quite substantial - to the animal feed.

ENERGY BALANCE OF ETHANOL FROM CORN

Sure enough, a new study*7* comparing six estimates of energy balance of corn ethanol did find that "net energy calculations are most sensitive to assumptions about coproduct allocation".

The analyses, carried out by researchers at the University of California Berkeley, and published in the journal *Science* in January 2006 included the estimate produced by Pimentel and Patzek. The researchers developed a 'model' to allow them to compare the data and assumptions across the estimates. Pimentel and Patzek's negative energy balance stood out in including energy used for building processing plants, farm machinery, and labour, and for not giving credit for co-products.

Removing those "incommensurate" factors nevertheless resulted in only a modest positive energy balance of just over 3 MJ/litre to 8 MJ/litre ethanol in the analyses that gave positive energy balance, which translates to 1.13 to 1.34 for energy output/energy input (there being 23.4 MJ in one litre of ethanol), while the reduction in greenhouse gas emissions averaged about 13 percent.

The researchers have devised a way of presenting energy balance in terms of "petroleum input" - expressed as MJ petrol/MJ ethanol – that puts a very positive gloss on the figures and is very misleading. It essentially adds one hundred percent energy credit to the ethanol because it assumes that the ethanol substitutes 100 percent for fossil fuel use.

The researchers then used the "best data" from the six analyses to "create" three cases with their model (hence all hypothetical): *Ethanol Today*, that claims to include typical values for the current US corn ethanol industry; *CO*2 *Intensive*, based on plans to ship Nebraska corn to a lignite-powered ethanol 24 plant in North Dakota, and *Cellulosic*, which assumes that production of ethanol from switchgrass cellulose becomes economic, an admitted "preliminary estimate of a rapidly evolving technology".

For the three cases, the researchers found a positive energy balance: a whopping 23 MJ/litre ethanol for *Cellulosic*, 5 MJ/litre for *Ethanol Today*, and 1.2 MJ/litre for *CO*2 *Intensive*; the corresponding output/input energy ratios are 1.98, 1.21, and 1.05 respectively. *Cellulosic* is the clear winner in terms of energy balance, and also by a long shot in net greenhouse gas emission saved, which is 89 percent; the corresponding values for *Ethanol Today* and *CO*2 *Intensive* are 17 percent and about 2 percent respectively.

These analyses show that current production methods, represented by *Ethanol Today* and *CO*2 *Intensive*, offer but a small positive energy balance and little if any savings in greenhouse gas emissions, *even with the most favourable assumptions built in*.

BAD ECONOMICS OF ETHANOL FROM CORN

Ethanol constitutes 99 percent of all biofuels in the United States;8 3.4 billion gallons of ethanol were produced in 2004 and blended into gasoline, amounting to about 2 percent of all gasoline sold by volume and 1.3 percent of its energy content.

Ethanol use is set to expand as the federal government has introduced a $0.51 tax credit per gallon of ethanol and issued a new mandate for 7.5 billion gallons of "renewable fuel" to be used in gasoline by 2012, which is included in the recently passed Energy Policy Act (EPACT 2005).*7*
Pimentel and Patzek4 have shown not only that the energy return is substantially negative, the economics is worse. About 50 percent of the cost of producing ethanol is for the corn feedstock itself ($0.28/litre). Ethanol costs a lot more to produce than it is worth on the market, and without federal and state subsidies amounting to some $3 billion per year, corn ethanol production in the US would cease.

Senator McCain reports that total ethanol subsidies amount to $0.79/litre; adding the production costs would bring the cost to $1.24/litre. Ethanol has only 66 percent as much energy per litre as gasoline; so corn ethanol costs $1.88/litre, or $7.12 per gallonequivalent of gasoline, compared to the current cost of producing gasoline, which is $.33/litre.

Federal and state subsidies for ethanol production that total $0.79/litre mainly end up in the pocket of large corporations, with a maximum of $0.02 per bushel, or 0.2 cent/litre ethanol going to the farmer.

The total costs to the consumer in subsidizing ethanol and corn production is estimated at $8.4 billion/yr, because producing the required corn feedstock increases corn prices. One estimate is that ethanol production adds more than $1 billion to the cost of beef production.

Clearly ethanol from corn is neither sustainable nor economical, and a lot of effort has been devoted to finding alternative feedstock.

WORSE ENERGY YIELDS AS ACCOUNTING GETS MORE REALISTIC

In a detailed rebuttal to the *Science* paper showing a positive energy balance in ethanol production from corn, Patzek*9* exposed the major flaws in energy

accounting used, which greatly inflated the energy return. These include:
• Failure to account for the energy in corn grains as energy input
• Assuming an impossibly high yield of corn ethanol at variance with real data available
• Assigning away undue energy costs in ethanol production, in particular, distillation, to coproducts such as fermentation residues that have nothing to do with ethanol production.

In addition, the ethanol industry routinely inflates the ethanol yield by counting as ethanol the 5 percent of gasoline added to corn ethanol as denaturant; by taking the amount of fermentable starch to be the total extractable starch, although not all of the latter is fermentable; and by taking the weight of wet corn (average 18 percent moisture) as dry corn.

When the energy accounting done by different authors is reanalysed on the same set of realistic data, energy yields come out remarkably uniform.

The output/input ratio varies between 0.245 and 0.310. In other words, *the energy balance is strongly negative: for every unit used in making corn ethanol, one gets at most 0.3 unit of energy back. It takes at least 9 times more fossil fuel energy to produce ethanol from corn at the refinery gate than gasoline or diesel fuel from crude oil*.

As Patzek points out, the 7.5 billion gallons of ethanol mandated by the 2005 Energy Bill by 2012 could be compensated by an increase of car mileage by just one mile per gallon, excluding gas-guzzling SUVs and light trucks.

The economic consequences of excessive corn production have been devastating. The price of corn in Iowa, the largest corn producer, declined 10-fold between 1949 and 2005 as corn yields have tripled.

Today, Iowa farmers earn a third for the corn they sell compared to 1949, while their production costs increased manifold, because they burn methane and diesel to produce corn. The price of methane has increased several-fold in the last three years. "Corn crop subsidies supplemented the market corn price by up to 50 percent between 1995 and 2004." Patzek writes, predicting more concentration of industrial corn production in gigantic farms operated by large agribusiness corporations, and real farmers will only rent the land.

An industrial raw material at rock-bottom price can now be processed into ethanol at a significant profit, further enhanced by a federal subsidy of 50 cents per gallon ethanol, plus state and local community subsidies.

Patzek concludes: "the United States has already wasted a lot of time, money, and natural resources….. pursuing a mirage of an energy scheme that cannot possibly replace fossil fuels…The only real solution is to limit the rate of use of

these fossil fuels. Everything else will lead to an eventual national disaster."
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3. ETHANOL FROM CELLULOSE BIOMASS *NOT* SUSTAINABLE NOR ENVIRONMENTALLY BENIGN.

Mae-Wan Ho

CELLULOSIC ETHANOL THE 'GREEN GOLD'

One main limit to getting ethanol out of plant material is that most of the sugar substrate, apart from the starch in corn kernels and other grain, is unavailable for fermentation by bacteria and other microbes. It is locked away in cellulose, the fibrous materials that make up 75 to 85 percent of the plant, the rest being lignin, the woody material.

However, a cocktail of enzymes called cellulases are able to break down cellulose into sugar units, which can then be fermented by microbes into ethanol (see Box). That means grass, straw, and other crop residues can also be turned into ethanol. That has been hailed as the 'green gold' that could replace imported 'black gold' crude oil,*1* and is widely seen to have the potential of substantially reducing our consumption of fossil fuel.

"It is at least as likely as hydrogen to be an energy carrier of choice for a sustainable transportation sector," the National Resources Defense Council (NRDC) and the Union of Concerned Scientists said in a joint statement.

Shell Oil predicted the global market for biofuels such as 'cellulosic ethanol' would grow to exceed $10 billion by 2012.
A study funded by the Energy Foundation and the National Commission on Energy Policy concluded that "biofuels coupled with vehicle efficiency and smart growth could reduce the oil dependency of our transportation sector by twothirds by 2050 in a sustainable way." 'Smart growth' is a planning term which means growth that maximise sustainable development of cities in transport and other energy savings.

Cellulosic ethanol can be produced from a wide variety of feedstocks including agricultural plant wastes (corn stover, cereal straws, sugarcane bargasse), plant wastes from industrial processes (sawdust, paper pulp) as well as energy crops such as switchgrass.

Lee Lynd, engineering professor at Dartmouth, has been working with the Gorham Paper Mill to convert paper sludge to ethanol. Lynd said, "This is genuinely a negative cost feedstock. And it is already pretreated, eliminating a step in the conversion process."

The company Masada Oxynol is planning a facility in Middletown, New York, to process municipal solid waste into ethanol. After recovering recyclables, acid hydrolysis will be used to convert cellulosic materials into sugars. "The facility will provide both economic and environmental value," said David Webster, Executive Vice President of Masada. The process reduces or eliminates landfills. By-products of the process include gypsum, lignin and fly ash. The lignin will be recovered for burning to make the plant selfsufficient in energy, the fly ash can be put back into the soil as fertiliser.

BRINGING PRODUCTION COSTS DOWN

The cellulases needed for breaking down cellulose so far have come from fungi, in particular from

Trichoderma reesei. NREL scientists have investigated other sources, such as the bacterium *Acdiothermus cellulolyticus*, which they found in the hot springs of Yellowstone National Park. But bacterial exoglucanases are not usually as good as the fungal ones, though they tolerate high temperatures. A next step is to combine high temperature tolerance with the efficiency of the fungal enzyme. NREL and DOE have contracted the world's largest enzyme companies, Genecor International and Novozymes to reduce the cost of producing cellulases down to a range of $.10-$.20 per gallon of ethanol, and they have succeeded..*1*

A further improvement involves the simultaneous action of enzyme and fermenting microbes, so that as the sugars are produced by the cellulases, the microbes ferment the glucose to ethanol.*3* Iogen Corporation based in Ottawa, Canada*4* was the first to develop the enzyme process for getting ethanol from cellulose. It has built the world's first and only demonstration scale facility to convert cellulose biomass to ethanol. The facility processes 40 tons of wheat straw per day, and Iogen became the first company to commercialise cellulosic ethanol in April 2004. The primary consumer so far has been the Canadian government, which along with the US government (particularly the DOE's NREL) has invested millions of dollars into helping commercialise cellulosic ethanol

HOW CELLULASES MAKE CELLULOSE A FEEDSTOCK FOR ETHANOL

The cellulose crystal unit consists of thousands of strands, each strand made up of hundreds of glucose units linked up together. The cellulose is wrapped in a sheath of hemicellulose and lignin, which protects the cellulose from being broken down. Hemicellulose is easier to break down than cellulose.*2* A combination of mild heat, pressure and acidic (or basic) conditions will break the hemicellulose into its component mixture of sugars, mainly xylose.

Scientists in the National Renewable Energy Laboratory (NREL) of the Department of Energy (DOE) used dilute sulphuric acid to hydrolyse (break down by reacting with water) the hemicellulose/lignin sheath, exposing the cellulose.

To hydrolyse cellulose chemically requires higher temperature and pressure and stronger acid conditions, involving rather expensive processing equipment; which is why they have looked to enzymes, *cellulases*, to do the trick.

Although humans cannot digest cellulose, cattle, termites, beaver, and mushrooms can. Some bacteria, fungi and insects produce cellulases themselves, other animals play host to bacteria that produce cellulases in their digestive tracts.

Most cellulases are complexes of three enzymes working together to hydrolyse cellulose. First, an *endoglucanase* breaks one of the chains within the cellulose crystal structure, then, an *exoglucanase* attaches to one of the loose ends, pulls the cellulose chain out of the crystal structure, and works its way down the chain, breaking off units of cellobiose (two glucose units joined together). Finally, a betaglucosidase splits the cellobiose into two glucose molecules, which can then be fermented into ethanol.

CELLULOSIC ETHANOL SUSTAINABLE?

A preliminary life-cycle analysis of cellulosic ethanol showed it reduces greenhouse gas emission by 89 percent over reformulated gasoline. By contrast sugar-fermented ethanol reduced GHG emissions by an average of 13 percent.*5*

The energy yield appeared better than anything else, with a ratio of output over input of 1.98, which means that for every unit of energy input almost 2 units energy of cellulosic ethanol is produced; although this is very likely to be inflated due to flawed accounting
Procedures.

Can the US agricultural systems support largescale cellulosic ethanol production? Is there sufficient land? Can biomass be supplied without impacting the cost of agricultural land, competing with food production and harming the environment?

The answer to these questions ranges from no to a qualified yes, contingent upon R&D efforts, technological innovation and government policy.*1*

One estimate says that for producing 50 billion gallons ethanol per year from cellulosic biomass, the waste stream would supply only 40 to 50 percent of the feedstock, the rest has to come from energy crops such as corn and switch grass, without large impacts on the agricultural system.

But beyond that level, there would be implications for the cost of cropland and competition with food crops.

The US is set to consume 290 billion gallons of gasoline a year in cars and trucks by 2050.

Increasing vehicle efficiencies to 50 mpg or better and instituting smart growth policies could reduce consumption to 108 billion gallons by 2050.

According to the NRDC report, *Growing Energy*,[6] the number of gallons of ethanol currently produced per dry US ton of biomass is 50 US gallons, or 208.93 litre/metric tonne (which compares poorly with 371.75 l/tonne from corn grain[7]). That needs to improve to 117 gallons per dry ton (488.89 l/tonne), the equivalent of 77 gallons of gasoline.

If yield improvements of switch grass predicted at 12.4 dry tons per acre (27.77tonne/ha) could be realised - which is more than twice the current average of 5 dry tons per acre - then an estimated 114 million acres dedicated to switchgrass could provide sufficient biomass to produce 165 billion gallons ethanol by 2050 (equivalent to 108 billion gallons of gasoline).

This would take up 26.4 percent of US total harvested cropland, or 12.2 percent of total farmland, and would almost certainly impact on food production.

A big idea for making biofuels economical and efficient is to develop biorefineries, analogous to petrol refineries, where crude oil is converted into fuels and co-products such as fertilisers and plastics. In the case of a biorefinery, the plant biomass feedstock will produce diverse products such as animal feed, fuels, chemicals, polymers, lubricants, adhesives, fertilisers and power.

John Sheehan of NREL has been using process simulation software to look at biorefinery design. "Scale is a huge issue," said Sheehan. He has discovered that biorefineries need to process 5 000 to 10 000 tons of biomass per day to be economically viable. "Below 2 000 tons per day, capital costs skyrocket."

A study from the US DOE and USDA published April 20058 concluded that forestland and cropland have the potential to provide a 7-fold increase in the amount of biomass currently consumed by bioenergy and biobased products - in excess of 1.3 billion dry tons - which is sufficient to satisfy more than one-third of the current demand for transport fuels.

More than 25 percent would come from extensively managed forestlands and about 75 percent from intensively managed croplands. The majority primary resources would be logging residues and fuel treatments (to reduce fire hazards) from forestland, and crop residues and perennial crops from agricultural land.

This estimate is based, among other things, on (optimistic) projections of substantial crops yield increases, especially a 50 percent yield boost in the major bioenergy corn crop, and 60 m acres of perennial bioenergy crop (such as switchgrass) planted on 'idle' cropland including 8 m acres previously planted with soybean crop.

It is clear that unless fuel consumption is substantially reduced from current levels, biofuels from energy crops cannot replace fossil fuel without impacting on food production.

FURTHER DEVELOPMENTS

A further constraint in getting ethanol from plant 27 biomass is that many of the non-glucose sugars contained in hemicellulose, such as xylose, are not fermented into alcohol by the usual microbes.

Cellulose makes up 40-50 percent dry weight of biomass, and hemicellulose 20-35 percent.

Lonnie Ingram, Professor of microbiology at University of Florida Institute of Food and Agricultural sciences made headline news[9] because his research team has genetically engineered a strain of *E. coli* bacterium to produce ethanol from xylose.[10] It has been commercialised with help from the US DOE. The company, BC International Corp., based in Dedham, Mass., holds exclusive rights to use and license the engineered bacterium.

The *E. coli* was engineered by transferring into it the genes needed to ferment sugars – pyruvate decarboxylase and alcohol dehydrogenase – from the bacterium *Zymomonas mobilis*, and fermented xylose with a yield of ethanol at 95 percent of the theoretical.[11]

Greg Luli, vice-president of research for BC International said the firm plans to build a 30 million gallon biomass to ethanol plant in Jennings Louisiana, expected to be operational by the end of 2006.[9] Waste from the sugarcane industry in Louisiana will be the plant's main feedstock.

Parallel developments are taking place in Europe. A pilot plant was announced by the Swedish company Etek Etholtekhnik AB to produce 400-500 litres of ethanol a day from a feedstock input of 2 tonnes of dry biomass.[12] The plant is designed for a two-step dilute acid hydrolysis process and a combination with enzyme hydrolysis.

The feedstock is softwood, but other biomass like hardwood and annual corps such as straw and reed canary grass will also be tested.
The pilot plant is to be located in Ornskildsvik in northern Sweden, close to an existing sulphite pulp ethanol plant. Three Universities in the region – Umeå University, Mid Sweden University and The Technical University of Lulea - own the plant.

STILL UNECONOMICAL AND UNSUSTAINABLE

One problem with the technology of fermenting xylose with bacteria, summed up by a group of professors at Massachusetts Institute of Technology (MIT) in a White Paper submitted to the MIT Council on Energy*13* is that a rather dilute ethanol solution is produced, at most 5-6 percent, compared with the 12 percent for cornstarch fermented with yeast.

Lonnie Ingram's xylosefermenting *E. coli* yields a 4.5 percent solution of ethanol.*14* The reason is that certain compounds accumulate during the fermentation of sugarmixtures from biomass that inhibit microbial growth.

In other words, the bacteria produce beer, not wine; and the extra water required in the fermentation process plus the extra energy needed to distil the ethanol will make it uneconomical and unsustainable.

The MIT professors also questioned whether the idea of a biorefinery to make use of byproducts from fermentation is economically feasible. They propose to use biotechnology to create microbes that can overcome the growth inhibition to improve the yield and productivity of ethanol from biomass.

If they do, they had better make sure the genetically engineered bacterium does not escape into the environment, and this applies to all other genetically engineered bacteria that make ethanol from cellulose biomass.

Some years ago, soil scientist Elaine Ingham and her graduate student Michael Holmes tested a genetically engineered bacterium *Klebsiella planticola* that produced ethanol from wood debris and found it killed *all* the wheat plants in every microcosm tested.*15,16*

ENVIRONMENTAL IMPACTS OF ETHANOL

Is ethanol really cleaner and greener than gasoline? In a Senate Hearing on The National Sustainable Fuels and Chemicals Act 1999, the NRDC gave evidence*17* that combustion products of ethanol include formaldehyde and acetaldehyde, both known carcinogens; and that increased use of ethanol may also increase atmospheric levels of peroxyacetylnitrate (PAN).

They referred to a University of California report on health effects of oxygenates including ethanol*18* (chemicals containing oxygen added to fuels to make them burn more efficiently), which stated that using ethanol would result in increased atmospheric concentrations of acetaldehyde and PAN.

Acetaldehyde has been listed as a Toxic Air Contaminant in California based on evidence of carcinogenicity and while PAN is "genotoxic [causes genetic damage] and produces respiratory and eye irritation and may produce lung damage."

The NRDC pointed out that increased use of ethanol in fuel might lead to an increase in ethanol exposure via inhalation, which could result in the range of known toxicities associated with ingested ethanol. They also warned of emissions of nitric oxides and volatile organic compounds that are ozone precursors.

Recently, Cal Hodge of A Second Opinion Inc. reported that ozone levels in the atmosphere increased in California in 2003 associated with the switch to 10 percent ethanol from methyl tertiary butyl ether in gasoline a year ago.*19*

The ozone exceedances in California's South Coast Air Basin were twice those of the previous three years, while the maximum ozone concentration was up by 22 percent. This increase in ozone was indeed correlated with increase in emissions of nitrogen oxides and volatile organic compounds, which escaped the notice of the US Environmental Protection Agency (EPA).

The EPA gave ethanol in gasoline a clean bill of health using a flawed model for the tests that did not take into account the fact that ethanol tends to produce more nitrogen oxides, that it tends to permeate through the seals in automotive fuel systems and to degrade driveability thereby increasing exhaust emissions. He called for "banning, not expanding" the use of ethanol in US gasoline.

BIODIESEL HAS GREATER ENVIRONMENTAL IMPACTS THAN DIESEL

• Increases inorganic raw materials, the mineral feedstock for making fertilisers, by 100 percent
• Increases non-radioactive wastes, primarily gypsum, a by-product of phosphate fertiliser, by 98 percent
• Inreases radioactive wastes due to electricity supplied by nuclear power plants by 90 percent
• Increases eutrophication from fertiliser run-offs by 75 percent
• Increases photochemical oxidants due to volatile organic compounds released during the production of biodiesel, especially hexane in solvent-based oil extraction, by nearly 70 percent
• Increases water use (in the esterification process for creating biodiesel) by 30 percent
• Increases acidication from nitrogen and sulphur oxides and ammonia released during the growth of rapeseed crop, also from nitrogen oxides emissions from burning biodisel, by 15 percent.
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4. BIODIESEL BOOM IN EUROPE?

Mae-Wan Ho

OVERLY OPTIMISTIC ASSESSMENT IN US DOE REPORT

The US had plans to make biodiesel out of soybeans at least since 1998, when a glowing assessment of its energy balance was provided in a report sponsored by the Department of Agriculture and the Department of Energy.*1*

It claimed that, "Biodiesel yields 3.2 units of fuel product energy for every unit of fossil energy consumed in its life cycle" and that it reduces net emissions of CO_2 by 78.45 percent compared to petroleum diesel.

These estimates were overly optimistic, and out of line with other analyses. But this report may have had undue influence over the subsequent development of biodiesel around the world.

Biodiesel is Europe's dominant renewable fuel.*2* It is widely welcomed by environmental groups as a renewable energy that burns more cleanly than diesel. A comprehensive study by the US Environment Protection Agency*3* showed that biodiesel burns with much less hydrocarbons, carbon monoxide and particulate matter in the exhaust, although there was an increase in nitrogen oxides.

EUROPE EMBRACING BIOFUELS

As part of a range of measures to reduce greenhouse gas emissions, the EU is encouraging the use of biofuels.*2*

The current (2003) EU Biofuels Directive requires 2 percent of the energy for transport to come from renewable sources, including both biodiesel and bioethanol, rising to 5.75 percent by the end of 2010, and 20 percent by 2020.

Transport fuels account for around a quarter of EU's greenhouse gas emissions and demand for diesel and petrol is fast rising. In 2004, 270 m tonnes of fossil fuels were consumed compared with 180 m tonnes in 1985, and by 2020, fuel consumption will reach 325 m tonnes.

Tax exemptions and national targets introduced across Europe are driving the biodiesel market. Germany has the highest consumption of biodiesel at 1.1 m tonnes in 2004.

UK's reduction of duty on biodiesel by 20 pence a litre in July 2002 has encouraged investment, though UK consumed only 0.3 m tonnes of biodiesel in 2004.

A new EU draft paper*4* released 8 February 2006 outlines a series of measures to promote biofuels in the EU and developing countries.

The current voluntary target to have biofuels make up 5.75 percent share of transport fuels by 2010 looks likely to be missed. The EU draft paper admitted that some aspects of biofuels are unsustainable, such as allowing farmers to grow sugar beet for ethanol on set-aside land, or to convert wine into ethanol. Set-aside land is also being used to grow oilseed rape for biodiesel.

Europe has dominated the biodiesel industry to-date with 90 percent of global production.

The EU produced 2.4 m tonnes of biofuels in 2004, amounting to 0.8 percent of EU petrol and diesel consumption. Ethanol made up 0.5 m tonnes and biodiesel 1.9 m tonnes. Rapeseed oil is the main biodiesel feedstock, constituting just over 20 percent of EU25 total oilseed production.*5*

A special aid for energy crops was introduced by the 2003 Common Agricultural Policy reform that pays a premium of 45 euros per ha with a maximum guaranteed area of 1.5 million hectares as the budgetary ceiling.

Biodiesel manufacture appears straightforward starting from oil.*6* It is a chemical process of *trans-esterification* in which fat or vegetable oil is reacted with a simple alcohol such as methanol in the presence of sodium hydroxide as catalyst. The methanol splits the fatty acids from the oil to form methyl esters (biodiesel) and glycerine.

The glycerine is separated from the fuel and removed as a marketable by-product (for making soap, for example), while the biodiesel is washed with water and dried.

Biodiesel can also be produced from waste cooking oils.

LIFE CYCLE ANALYSIS IGNORES EXTERNAL COSTS

A study carried out in Australia showed that while biodiesel produced from waste cooking oils reduces carbon emissions by 90 percent, biodiesel made from rapeseed oil would save only 50 percent of carbon dioxide emissions compared with using diesel.*7*

The UK's biodiesel industry group commissioned a study that found producing biodiesel from oilseed rape "strongly energy positive",*8* with an output/input energy ratio of 1.78 where straw was left in the field; where straw was burned as fuel and oilseed rape meal used as a fertiliser, the ratio was even better at 3.71.

But these favourable estimates were arrived at by a combination of dubious measures, such as inflating the yield of oilseed to 4.08 t/ha when UK's 2004 average national yield was only 2.9 t/ha,*9* assigning illegitimate energy credits to coproducts, leaving out legitimate energy embodied in buildings required for processing and in farming implements and machinery, and ignoring many external environmental costs.

Research conducted at the Flemish Institute for Technological Research, sponsored by the Belgian Office for Scientific, Technical, and Cultural Affairs and the European Commission, told a very different story, as revealed in a paper presented at an international conference sponsored by the US EPA in 2000.*10* It stated:

"..biodiesel fuel causes more health and environmental problems because it created more particulate pollution, released more pollutants that promote ozone formation, generated more waste and caused more eutrophication." Hence, "The benefits biodiesel fuel offers in terms of reducing greenhouse gas emissions do not justify its use in light of the other environmental damage it causes…"

These conclusions created some consternation in the biodiesel community.

But as Jon Van Gerpen of Iowa State University explained,*10* that is because most life cycle assessments ignored external costs, on which little has been published. He confirmed that while biodiesel reduces the impact on the environment by 55 percent in saving fossil fuel use, and reduces greenhouse gas emissions by 40 percent, it has greater impacts than diesel in seven other categories of environmental impacts not normally included in the life cycle assessment.

While not contesting the scientific validity of the analysis provided in the report for biodiesel production from oilseed rape in Belgium, van Gerpen concluded it could not be extrapolated to biodiesel production from soybean in the US, where, he claimed, those environmental impacts would be minimal, though others would disagree with him.

Rapeseed is indeed a relatively expensive crop to grow, requiring frequent rotation and extensive use of expensive fossil-fuel fertilisers, with major environmental concerns. It is estimated that the cost of producing biodiesel is twice that of conventional diesel.*2* And just to meet the 5.75 percent target, more than 9 percent of the EU's agricultural area will be needed.

OUTSOURCING BIODIESEL

The cost of biodiesel is reduced substantially if energy crops are produced overseas.*11*

The UKbased company D1 Oils is developing huge plantations of jatropha trees (*Jatropha Curcas*), a non-edible oil crop, all over the third world. But this approach will do nothing to improve energy supply security for Europe. *2*

Not only that, it would wreak havoc on food production in third world countries, already reeling from the globalised food trade.

British Petroleum has announced*12* it will fund a US$9.4 million project by The Energy and Resources Institute in Andhra Pradesh to produce biodiesel from jatropha. The project, expected to take 10 years, would involve cultivating jatropha on about 8 000 ha currently designated as "wasteland", and install all the equipment necessary for crushing the seed, extracting oil and processing to produce 9 million litres of biodiesel per annum.

Part of the project will include a full environmental and social impact assessment of elements of the supply chain and life cycle analysis of greenhouse gas emissions.

"Because jatropha is drought resistant and can grow on marginal land, it offers the possibility of an economically, socially and environmentally sustainable contribution to energy security challenges in India," said Phil New, senior vice president of BP's fuels management group.

"Recent developments have made green fuels economically attractive in view of the resource potential of this option and the environmental benefits associated with it, along with employment generation and empowerment of the rural population," TERI Director General, Dr RK Pachauri, said.

The big question is what constitutes "marginal" and "wasteland", and who really benefits from the biodiesel produced, let alone the environmental costs that have not been factored in.
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5. THE NEW BIOFUELS REPUBLICS

Elizabeth Bravo and Mae-Wan Ho

THE NEXT EUROPEAN COLONISATION HAS BEGUN

The end of cheap oil and the impending fuel crisis have convinced the European Union and the United States to seriously tackle their long-standing and worsening "addiction to oil", not by kicking the habit, but by guzzling biofuels instead.

These "carbon neutral" fuels - biodiesel or bioethanol - make even committed environmentalists feel good about getting into their SUVs, as they do not contribute to carbon emissions.

Burning biofuels simply sends back into the atmosphere carbon dioxide that the plants took out when they were growing in the field. The snag is that there simply isn't sufficient arable land on which to grow all the biofuel crops needed to satisfy the voracious appetites of the industrialised nations.

So, the next phase of colonisation has begun. The industrialised countries are looking to the Third World to feed their addiction: the land is there for the taking as is cheap labour, and the environmental damages of large plantations, biofuels extraction and refining can all be outsourced, exactly as they were in the extraction of crude oil.

Brazil is already currently the main supplier of ethanol to the United Kingdom,*1* and is looking to greatly increasing its exports elsewhere.

Companies dedicated to biodiesel have set their sights on countries in Latin America, Africa, Asia and the Pacific, where they can also obtain raw material at competitive prices.

UK-based DI Oils predicted in 2004 that the world market for biodiesel would grow by 14.5 percent annually to 2.79 million tonnes by 2010.*3* The Asia Pacific operations of the company, based in Manila, will provide the Philippine Coconut Authority with the opportunity to meet the surge in biodiesel demand from Japan, China, Korea, Taiwan and Australia.

DI Oils has fastened on jatropha, a fastgrowing, high-yielding tree that can be planted in semi-tropical areas on "wasteland and irrigated with sewerage water".*4*

According to its CEO, the company already has plantations totalling 267 000 Ha in Ghana, Madagascar, South Africa, India and the Philippines, and intends to expand to 9 million ha.*5*

The Indian government announced a national biodiesel purchase policy in October 2005 that would enable farmers and biodiesel producers to get a support price of Rs 25 per litre for jatropha oil,*6* and intends to bring one million ha of land under jatropha cultivation to supply blended diesel within the next few years.

Biodiesel has also provided a much needed outlet for the glut of genetically modified (GM) crops that consumers are rejecting worldwide.

President Lula of Brazil has declared that GM soya is to be used for biofuels and "good soya" for human consumption.*7*

Argentina also has plans to transform GM soya into biodiesel.*8*

The biodiesel industry says that for processing biofuels, large refining plants have to be constructed close to agricultural areas or forests, where the raw material is grown. The biodiesel will then have to be transported to filling stations in the same way as oil.

The oil industry will want to maintain control over the distribution of fuels, and will enter into an agreement with these new companies,[9] as in many cases the supply chain can be very complex.

EVERYBODY WINS?

Biodiesel is projected as a business in which everybody wins. The European emissions of CO_2 decreases, and Third World countries increase their exports and improve the quality of life of their rural populations.

The reality is something else. It is said that during the growth of the crop, the plants absorb CO_2 from the atmosphere. This is true of what was growing before the plantation was established. As the industry has plans of expanding exponentially, it is likely that they will begin to occupy primary or secondary forested areas, as has already happened with the soya plantations.[10]

Soya plantations have displaced the forests of El Chaco in Argentina and the forests in Pantanal, Atlantic and Chaco areas in Paraguay. Even more dramatically much of the Amazon, Pantanal, and Atlantic forests in Brazil have all been cut down for soya.

The net CO_2 balance is therefore strongly negative. Additionally, other greenhouse gases are generated as a product of the crop itself, and the processing, refining, transport and distribution of the fuel. It looks increasingly likely that biofuels are a net contributor of CO_2 and other greenhouse gases into the atmosphere. As regards the benefits to the producers of the biofuel crops, these can be extremely negative.

First, the destruction of forest and other original vegetation has already happened; and if these crops were to expand as intended, they could threaten food security and food sovereignty of the local populations, because farmers would stop producing food crops for the population and instead concentrate on producing "clean fuels" for Europe.

The production of soya in Argentina could increase to 100 million tonnes,[11] which involves a huge environmental and social cost to the Argentinean people, such as the displacement of rural populations, growing deforestation and desertification of soils and hence greater hunger and social inequity.

Large-scale agriculture, such as is needed to comply with the demand for biofuels, is highly dependent on oil derivatives such as fertilisers and pesticides, which, apart from producing CO_2 emissions, are highly polluting.

The predictions for Brazil are alarming, as this country could become the world leader in the substitution of fossil fuels with biofuels, with all the impacts this entails. In Brazil, ethanol has been obtained so far from sugarcane, but the expansion of soya is happening as Brazil is experiencing a boom in exporting sugarcane ethanol.

Sugarcane and soya plantations may well compete for land, making it almost inevitable that more forests will be cut down to accommodate the growth in both.

Recently, the Spanish government of Zapatero announced that Repsol will install a biodiesel plant in León.*12* It is predicted that the raw material will be obtained from oily crops and will come from regions where labour and land are cheap and where GM crops are permitted, i.e., the Southern Hemisphere.
In other words, the poor developing nations will be forced to feed the voracious appetites of rich countries for biofuels at the expense of their own hungry masses and suffer the devastation of their natural forests and biodiversity.

ETHANOL IN BRAZIL*2*

Brazil's national ethanol programme (ProAlcool) began in response to the oil crisis of the 1970s, and ethanol now accounts for 40 percent of Brazil's driving fuel. The country's 'flex fuel' car fleet is the only one in the world that can use 100 percent of either ethanol or gasoline. Brazil's ethanol production was 15.9 billion litres in 2005, second only to the United States, and more than a third of the global production.

Until recently, Brazilian ethanol has been produced for domestic consumption. But in 2004, exports more than doubled to 2.6 billion litres. In 2005, the futures market for sugar rose by 62 percent on the back of rising international demand for ethanol. Brazil is exporting to US, India, Venezuela, Nigeria, China and Europe. It is negotiating with Japan to export ethanol to it after Japan authorized the substitution of up to 3 percent of gasoline with ethanol to help meet its Kyoto Treaty commitments.

Already the logistics of distribution, rather than productive capacity, is limiting the expansion of Brazil's ethanol exports, and creating a demand for building ports with storage tanks and loading facilities, and improving railway and pipeline links between the ports and sugar-producing regions. A new ethanol port in Santos will increase Brazil's export capacity to 5.6 billion litres by the end of 2006.

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7. PADRE NUESTRO MAÍZ
Werner Ovalle López

Yo tengo manos de maíz. En ellas
reside un hálito terrestre,
y palpitan misterios arcillosos

con humedad de vegetales peces.

Yo tengo frente de maíz. Yo sueño
la paz del surco iluminado y verde,
coronado de cañas verticales
como lineales templos de azúcar y de fiebre.

Yo tengo frente de maíz. Yo pienso
con las venas acústicas y fuertes
como un resucitado intemporal
que escondiera su voz en los claveles.

Yo tengo labios de maíz. Yo canto
sin la fría corola de la muerte
y predico las alas de la harina
con una gran serenidad silvestre.

Yo tengo sueños de maíz. Yo vivo;
hombre de ayer, de hoy, hombre de siempre......
.....Nuestro atavismo vegetal es único:
Maíz de amor, substancia de las sienes.