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Communiqué

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Peak Soil + Peak Oil = Peak Spoils

In the name of moving "beyond petroleum," Big Oil, Gene Giants, governments, start-ups and others are forming partnerships that will extend corporate control over more resources in every part of the globe – while keeping the root causes of climate change intact. With grudging recognition that first-generation agrofuels are neither economical nor ecological, investors turn to other life-based technologies, including synthetic biology, for the next alternative fuel fix.

Issue: In OECD countries, massive government incentives and subsidies – estimated to be as high as US$15 billion/year – are stoking the agrofuels[1] boom and spurring unprecedented alliances that extend corporate power over a larger share of the world's resources.[2] Big Oil, Big Ag, Big Brains (and more) are teaming up to reap the only certain benefit of agrofuels – increased profits. In this *Communiqué*, ETC Group maps the new corporate alliances propelled by (and propelling) the scramble for bio-based fuels. We also include a new wave of corporate investors who are betting that synthetic biologists can turn microbes into fuel-producing factories.

Impact: With the agrofuels boom, the South's land and labor is once again being exploited to perpetuate unjust and unsustainable consumption patterns in the North. Fuel crops are competing with food crops – and small farmers and poor consumers are losing out. Because huge amounts of energy are required to grow these crops, first generation agrofuels (from crops like maize and rapeseed/canola) may actually *accelerate*, rather than *arrest*, climate change. The 2007/2008 UN Development Programme's *Human Development Report* warns that the consequences of climate change could be "apocalyptic" for some of the world's poorest people. In the face of catastrophic impacts from climate change, it is unacceptable to impose the added risks and burdens of agrofuels on the global South. The last thing the South needs is pressure to grow energy crops instead of food crops. Since agrofuels are neither ecologically nor economically efficient, biotech proponents are promoting a new generation of feedstocks and techniques to accelerate fuel production, including genetically engineered trees. These alternatives will present a slew of problems.

Financial Stakes: Energy crops are the fastest growing segment of the world agriculture market. According to industry estimates, the potential global market for liquid biofuels could expand from 11 billion gallons per annum in 2006 to 87 billion gallons in 2020.[3] The global agrofuels market was $20.5 billion in 2006, projected to grow to $80.9 billion in a decade. In OECD countries, start-ups and multinationals are divvying up the annual ~$15 billion in government incentives for alternative fuels.

Policy/Action: Across the globe, civil society organizations (CSOs) are demanding an end to the agrofuel boom. In the US and Europe, CSOs are calling for a moratorium on incentives for agrofuels, including the suspension of all targets, subsidies and financing through carbon trading mechanisms. The moratorium should be adopted by all governments. Entrenched structures that encourage unsustainable transport of commodities, people and products must be challenged. Governments failed to anticipate the negative social, economic and environmental impacts of first-generation agrofuels. Governments meeting in Rome at FAO's High-Level Conference on World Food Security and the Challenges of Bioenergy and Climate Change, 3-5 June 2008, should reject first-generation agrofuels and prevent the negative impacts of next-generation alternatives.

Background: According to agrofuels' boosters, there's virtually no end to the benefits of "energy crops." As a clean and green alternative to fossil fuels, they claim, agrofuels will create jobs, expand markets for farmers (especially in the global South), clean the air, combat global warming, promote energy independence, make agricultural "wasteland" productive, assure a worried public that governments are tackling climate change, demonstrate that corporations are thinking "green," and on and on.

Two recent reports – "Agrofuels: Towards a reality check in nine key areas" (June 2007) and GRAIN's special issue of *Seedling* on agrofuels (July 2007) – confirm that the touted benefits of agrofuels are merely green ghosts.[4]

Peak Soil[5] Rivals Peak Oil: In the name of "sustainable energy," thousands of indigenous and peasant communities have been forced – often violently – off their land to make room for energy crops. Land (including peatlands, which store an estimated 30% of all terrestrial carbon) is being burned and cleared to allow for crop monoculture plantations. These are "green deserts" (often planted with genetically-modified soy and maize), which destroy biodiversity and consume massive chemical inputs (fertilizers and pesticides).[6] Since both food and fuel are derived from the same plants, food prices spike along with the demand for energy crops. Climate change will exacerbate the South's food insecurity. Pressure to grow energy crops instead of food will be another added stress.

Even a report circulated at OECD's September 2007 Round Table recognizes the destructive nature of agrofuels. "Biofuels: Is the Cure Worse than the Disease?" warns: "The rush to energy crops threatens to cause food shortages and damage to biodiversity with limited benefits."[7] (Soon after the OECD discussions, lobbyists from the Renewable Fuels Association and the European Bioethanol Fuel Association demanded that OECD disavow the paper.)

Because of the unsustainable and downright counter-productive nature of agrofuels, civil society is pressuring governments to rollback mandated targets for agrofuel use.[8] Still, government incentives (including subsidies) to grow agrofuels are at an all-time high. According to the UN, energy crops are the fastest growing segment of the world agriculture market.[9] Global production of agrofuels has doubled over the last five years and is expected to double again in the next four.[10]

Agrofuels: The Really Inconvenient Truth

Supplementing fossil fuels with a small percentage of agrofuels, as governments (mostly in the North) have begun to mandate, *does nothing* to disrupt – in fact, *perpetuates* – the economic and social structures that encourage the transport of commodities, people and products all over the globe, every day. Agriculture is already a substantial contributor to carbon emissions – responsible for 14% of global emissions, the same percentage as transport – so we can't stop climate change by dramatically increasing energy crop production.[11] Even more to the point, agrofuels don't encourage changes in the North's voracious energy consumption – nor do they threaten the profits of Big Oil. According to projections, petroleum consumption will increase steadily, despite the agrofuel boom, and in 2030, crude oil will continue to be the dominant fuel type – accounting for 33% of global energy consumption, which is only a small decrease from its current share (38%).[12] Big Oil will move "beyond petroleum" into bio-based fuels to make up for any losses in market share.

Agrofuels1.0: Fermented sugars derived from "energy crops" (sugar cane, corn, soybean, rapeseed/canola and jatropha, for example) represent the first generation of petroleum alternatives. But after these first-generation agrofuels, the fuel family lineage is not clearly mapped out. It's unknown which technologies will be ready for market

first and how/if they will merge with other technologies under development. The corporate alliances shown in Table 2 reflect a wide range of techno-fixes beyond first generation agrofuels.

Fuel consumption is steadily increasing around the world, and global energy consumption is expected to increase by more than 50% by 2030.[13] Petroleum will remain king for the foreseeable future (see box above, "The Really Inconvenient Truth"). Rather than viewing agrofuels as a threat, Big Oil sees an opportunity to diversify. With the global agrofuels market at $20.5 billion in 2006 (projected to grow to $80.9 billion in a decade) and more than $10 billion in government incentives, oil companies are eager to reap the only certain benefit of agrofuels – increased corporate profits.[14] Table 1 shows how Big Oil is teaming up with Big Ag, Big Auto and "Big Brains" (Academia) to propel and profit from first-generation energy crops. Gene Giants are also teaming up to secure dominance in agrofuel crop seeds and intellectual property.

What's Coming Through the Pipeline?

The specter of peak oil has spurred a scramble for novel, bio-based energy sources (though little enthusiasm for curbing energy consumption). The range of potential fuel sources is wide – from algae to animal fat to microorganisms to genetically engineered eucalyptus trees, among many others. No one knows for sure which technologies will succeed in producing the most energy or the most profits. Oil giants like BP are diversifying their investments to be sure they've got a jump on whatever alternative(s) turn out to be most promising. But don't expect the most productive and/or least environmentally damaging options to be the ones that are most readily adopted: Powerful governments and corporations will work together to determine the winners – the technologies that best serve their interests.

Down the Road: Cellulosic Fuel First-generation agrofuels are simply too inefficient to represent more than a drop in the global oil drum (even though they may cause plenty of damage to people and the planet). Therefore, the pursuit of more efficient fuel-production technologies continues. The alternative currently producing the most hype (if hardly any energy) is cellulosic fuels. The vision of cellulosic fuel turns every plant, living or dead, and every plant part into fuel feedstock – not just those plant parts with sugars that are easily extracted and then fermented. The dramatic increase in potential fuel sources from plant "biomass" is the main attraction of cellulosic fuel, which George W. Bush highlighted in his 2007 State of the Union address. The U.S. president said, "We must continue investing in new methods of producing [fuel] – using everything from wood chips to grasses, to agricultural wastes."[15]

"The old joke is you can make anything from lignin except money." – Andy Aden, senior researcher at the National Renewable Energy Laboratory in Golden, Colorado (US), commenting on the difficulty of converting high lignin biomass to fuel[16]

With the promise of cellulosic fuel, corporations are seeing an even deeper shade of green. But there are technical barriers to achieving the vision. Wood chips, grasses, corncobs and trees aren't attractive agrofuel feedstocks today for the same reason they aren't good (human) food sources: They are difficult to break down and turn into energy. Only certain microbial enzymes (some of which exist in the guts of ruminants) can digest and process the *cellulose* and *hemicellulose* found within these plant cells. Another hurdle is high *lignin* content. Lignin, present to some degree in almost all plants, is responsible for water transport and plays a major role in a plant's ability to sequester carbon. But it's indigestible to enzymes and can be broken down only by certain bacteria and fungi. In general, the higher the lignin content, the

more rigid the plant and the harder it is for enzymes to get at the cellulose and hemicellulose to break them down.

Though a cheap and efficient way to produce cellulosic fuel has yet to be developed, companies and governments are focusing plenty of R & D energy on it, with the US and China taking the lead. According to UK-based New Energy Finance, a market research firm, venture capitalists invested $235 million in cellulosic fuel development in 2006.[17] In 2006, China's central government announced it would spend $5 billion over the next ten years to expand ethanol capacity, with a focus on cellulosic ethanol.[18] The U.S. Department of Energy's (DOE) Biomass Program administered by the Office of Energy Efficiency has a robust $224 million budget for 2007. The DOE will invest $385 million in six cellulosic ethanol plants over four years (2007-2010) and will collaborate with industry to develop enzymes for converting cellulosic biomass into biofuels.

Industry and governments are pursuing two paths to achieve more cost-effective cellulosic fuel (eventually, however, the two paths may intersect). One avenue is to re-engineer plant biomass so that it can be more easily converted to fuel:

Genetic engineering lignin content in trees: Despite concerns from scientists and protests from civil society, biotech companies are attempting to genetically engineer trees with reduced lignin content to create a more efficient fuel feedstock. Arborgen, headquartered in the southeastern U.S., is leading the GM tree effort. As a first step, the company is playing a key role in an international consortium to sequence the eucalyptus tree genome. Eucalyptus is currently the most valuable tree for producing fiber and paper and could become equally important as a low-lignin agrofuel feedstock.[19] In August 2007, Arborgen announced that it had acquired the nursery and seed orchard businesses of three companies – International Paper and MeadWestvaco in the US, and Rubicon Limited in New Zealand and Australia.[20] According to Arborgen, these acquisitions "add world-leading production, sales and distribution operations" to its main business of "purpose grown trees."[21] Arborgen is positioning itself to control the entire supply chain from tree to tank.

The other approach is to use *synthetic biology* to re-engineer the enzymes, fungi and bacteria that break down the biomass and produce the fuel. In October 2007 Genencor, Inc., a division of Danisco – a multinational food ingredient and sugar producer – began selling an enzyme cocktail that the company says is formulated to break down cellulose and hemicellulose for fuel.[22] Novozymes A/S, a Danish biotech company also focusing on enzymes, is collaborating with the Brazilian sugar cane industry's technical center (Centro de Tecnologia Canavieira) to develop ethanol from bagasse – a by-product of sugar production from sugar cane.[23]

Other researchers in the field of synthetic biology aim to turn microbial cells into "living chemical factories" to induce them to manufacture substances they would not produce naturally. A Genencor-DuPont research collaboration, for example, resulted in an engineered *E. coli* bacterium that produces an industrially useful chemical called 1,3-propanediol (used in coatings, adhesives, solvents and antifreeze).[24] It was achieved by altering the bacterium's *metabolic pathways*. Inside a cell, a series of chemical reactions takes place – triggered and regulated by enzymes. The chemical reactions occur sequentially: Imagine a line of dominoes standing on end – knocking down a domino at one end of the line can trigger changes along its entire length. The series of chemical reactions that maintain cell *metabolism* – which regulates how the cell uses and stores energy – is often called a "cascade." Visual representations of metabolic pathways (along which the chemical reactions take place) are based on electronic circuitry diagrams, giving a sense

of their complexity and interconnectedness. Scientists have figured out how to manipulate these pathways to change which chemical reactions take place, altering which chemicals are produced. Theoretically, with enough targeted manipulation, any chemical substance could be produced in this way, so it's not surprising that bioproduction of fuel is the focus of much current synthetic biology research.

> ***Synthetic Biology*** *– The design and construction of new biological parts, devices and systems that do not exist in the natural world and also the redesign of existing biological systems to perform specific tasks.*

California-based Amyris Biotechnologies announced in September 2007 that the company had amassed $70 million in venture capital funding to produce bio-gasoline, bio-diesel and bio-jet fuel via synthetic biology's cellular factories.[25] Three years earlier, the company gained glowing press coverage when the Gates Foundation gave Amyris almost $43 million for a project to manipulate *E. coli's* metabolic pathways to produce artemisinic acid. Artemisinic acid is a chemical precursor to artemisinin, a known malaria treatment that is normally extracted from a plant called *Artemisia annua*, or sweet wormword. With microbe-sourced artemisinin, *Artemisia annua*, which is currently in high demand, would no longer be needed.[26] Successful scale-up of synthetic artemisinin for a low-cost malaria treatment has yet to happen.

Amyris's biofuel work involves the same technology as the artemisinin project: A microbe's metabolic pathways are altered so that it produces a high-demand, industrially-useful substance. Amyris's fuels are produced through fermentation, and fermentation requires sugar. Currently, the company's feedstock of choice is sugar cane, but it could potentially be corn or any other cellulosic source. Amyris claims that it has altered microbial metabolic pathways so that microbes efficiently ferment the sugar to produce a hydrocarbon fuel like petroleum rather than the usual, alcohol-based ethanol. The company says the advantage is that the current infrastructure – including car engines and fuel pipelines – can remain unchanged. In effect, the company's synthetic fuel technology shifts the demand from one substance with negative environmental impacts in limited supply (i.e., petroleum) to another substance with different negative environmental impacts in limited supply (i.e., synthetic fuel derived from plant cellulose). Amyris's synthetic fuel will require massive quantities of sugar cane or other cellulose-laden plant matter, which means that it offers no solution to Peak Soil even if it could, theoretically, address the problem of Peak Oil. Amyris is currently negotiating with retail giant Costco and with Virgin Fuels, Sir Richard Branson's company formed in 2006, to sell its synthetic fuel.[27]

> "The biofuels industry today is like the Wild West during the Gold Rush…." – Doug Cameron, Chief Scientific Officer, Khosla Ventures

Amyris is just one in a crowd of California-based synthetic biology companies trying to convert biomass to fuel by altering microbial metabolic pathways involved in fermentation. Solazyme, a new company focusing on the metabolic pathways of marine microbes, is looking for corporate and academic R&D partners to apply its technology to fuel production.[28] LS9, founded in 2005 by venture capital firms Khosla Ventures and Flagship Ventures, is another synthetic biology company hoping to produce fuels from a variety of plant feedstocks, which would be compatible with the existing liquid fuel infrastructure. Khosla Ventures is investing in more than a dozen bio-based fuel companies,[29] including Gevo, Inc., yet another California synthetic biology company. Gevo wants to turn plant biomass into butanol and isobutanol, alcohol-based fuels that yield slightly more energy than ethanol. Gevo has backing from

the Virgin Green Fund, an investing firm affiliated with Virgin Fuels.

Other companies are exploring different techniques to get living organisms to produce fuel. BP is leading the way, forming partnerships with genomics companies, synthetic biology companies and public sector researchers promising novel fuels using novel bioproduction technologies. Synthetic Genomics, Inc., the private company founded by genomics giant J. Craig Venter, announced in June 2007 that BP had made an equity investment in the company to sequence the genomes of naturally occurring microbial communities that live in oil, natural gas, coal and shale.[30] The goal is to apply what's learned from studying oil-metabolizing microbes to design new organisms that may be able to produce a fuel such as hydrogen or other chemicals.[31] The financial details of BP's investment were not disclosed.

Moving Beyond First-Generation Agrofuels: Making IT Happen

Cellulosic ethanol via genetic engineering and synthetic biology won't amount to much without a big helping hand from Information Technologies (IT). For example, the role played by genomics, which is heavily dependent on bioinformatics – the management and analysis of biological data – will be crucial to the development of GM crops for second-generation biofuels. IT companies are becoming more visibly and directly involved in biofuels research. In 2006, Microsoft offered a half-million dollars to support research projects aimed at addressing "computational challenges in synthetic biology."[32] J. Craig Venter, CEO of Synthetic Genomics, Inc., claims it may be possible to create novel organisms to produce fuel directly. He's enthusiastic about using the world's most powerful computers – like Google's – to "characterize all the genes on the planet."[33] But are we ready for the likes of a BP / Google / Monsanto merger? BPoogleMon?

Synthetic Biology Red Flags

Advocates of the synthetic biology approach insist that turning microbes into factories is the key to cheap biofuels, pharmaceuticals and other industrial chemicals. Craig Venter recently told *New Scientist* that, within twenty years, he expects synthetic biology "to become the standard for making anything."[34] And that could be the problem. Made-to-order organisms could just as likely become bioweapons factories as fuel and medicine factories. But the danger is not only bio-terror; it is also "bio-error"– synthetic biology accidents that cause unintended harm to human health and the environment.[35] Experience with agricultural biotechnology has shown that a promise of precise control is not enough to contain genetically modified organisms once they're in farmers' fields. Synthetic biology's living organisms, systems and devices will be just as difficult to contain and control.

In 2006, 38 civil society organizations sent an open letter to the synthetic biology community, expressing concern over the absence of societal debate concerning the socio-economic, health and environmental implications, and the absence of regulatory oversight.[36] There are enormous complexities involved with the creation of novel life forms: How could their accidental release into the environment be prevented or the effects of their intentional release be evaluated? Who will control them, and how? How will research be regulated? Should we engineer life in this way when the environmental and human safety questions are so vast? Who should decide?

Table 2 shows alliances formed to pursue diverse projects beyond first-generation agrofuels. Some collaborators aim to produce cellulosic fuel using engineered feedstocks, but others are pursuing different avenues, for example, using algae as the potential green grail or engineered microorganisms that can process or produce fuels.

What's wrong with cellulosic fuel?
Governments and companies assume they will overcome the technical barriers to commercializing cellulosic fuel – perhaps within the next decade – but what are the implications, if they eventually capture the holy grail? What happens when *all* plant matter becomes a potential feedstock for fuel? Who will decide what qualifies as agricultural waste?

If the vision of cellulosic fuel is realized and the demand for plant biomass dramatically increases, it raises a host of environmental and social concerns. Helena Paul of EcoNexus, Almuth Ernsting of Biofuelwatch and science writer Alice Friedemann, among others, have outlined the most pressing environmental issues:[37]

- Increase in biomass production from land that is designated as "waste " or "marginal" will result in vast increases in pesticide- and herbicide-use.

- Removing crop residues from fields will cause decreases in soil productivity and consequent increases in the use of nitrate fertilizers, resulting in greater nitrous oxide emissions.

- Removing crop residues from fields will increase soil erosion and decrease runoff abatement.[38]

- Removal of dead and dying trees from forests will increase biodiversity losses and decrease forest carbon-sequestration capacity.

- Many plants identified as good candidates for second-generation agrofuels are harmful to the environment as invasive species (e.g., miscanthus, switch grass, reed canary grass).

- High risk of gene flow from reduced-lignin GM trees to natural forests with unknown impacts on the environment and biodiversity.

In 2008, ETC Group will publish a critique of the "sugar economy" vision, in which fuels and other industrial chemicals are produced through fermentation, particularly as it relates to synthetic biology.

Note: The lists of alliances are not exhaustive. New agrofuel partnerships are forged daily.

Table 1: Alliances Propelling First-Generation Agrofuels		
Who	**What**	**How much?**
Oil, Agribusiness, Auto		
BP—DuPont—British Sugar • BP is the world's 4 largest corporation • DuPont owns Pioneer Hi-Bred, the world's 2nd largest seed company • British Sugar is a subsidiary of Associated British Foods Plc	Ethanol from wheat feedstock	$400 million; BP and British Sugar each own 45%; DuPont owns 10%; 420 million litres/year (2009)
BP—D1 Fuel Crops Ltd. • D1 Oils (UK) produces inedible vegetable oils from "earth to engine" – seed, planting, processing	1 million hectares to be planted with jatropha over next 4 years in Southeast Asia, Central and South America and India	$160 million over 5 years; 50/50 joint venture; 2 million tons of jatropha oil/year for agrofuel (expected)
Ergon Biofuels—Bunge • Ergon Biofuels, subsidiary of Ergon, owner of 3 petroleum refineries in U.S. • Bunge is a Fortune 500 (F500) multinational agribusiness & food co.	Corn ethanol using ~21 million bushels of corn/year	50/50 joint venture; $100 million ethanol production facility to produce 60 million gallons/year
Ashland—Cargill • Ashland is a multinational, transportation, chemical and petroleum company • Cargill is a multinational grain and oilseed processor	First product will be propylene glycol from glycerin, a by-product of biodiesel	$80-100 million joint venture to produce bio-based chemicals
ConocoPhillips—Tyson • Tyson Foods is a F500 company and one of the world's largest meat producers • ConocoPhillips is the world's 9th largest corporation	Beef, poultry and pork by-product fat for transportation diesel fuel	~$100 million invested by ConocoPhillips; Tyson's investment undisclosed (<$100 million); 175 million gallons/year by 2009
Syntroleum—Tyson • Syntroleum (US) produces synthetic fuel	Beef, poultry and pork by-product fat for fuel in the diesel, jet and military markets	$150 million plant will be built in 2008 to produce ~75 million gallons/year starting 2010
Petrobras—Itochu • Petrobras (Brazil) is a multinational F500 oil company • Itochu (Japan) is a F500 trading company – trades oil, food, textiles and more	Petrobras and Itochu signed a memorandum of understanding (MOU), June 2007, focusing on the production potential of bioethanol, biodiesel and bioelectricity from sugar cane with aim of exporting to Japan and other international markets.	
DaimlerChrysler—United Nations Environment Programme (UNEP) • DaimlerChrysler is world's 8th largest corporation	The partnership aims to promote biodiesel from jatropha planted in Gujarat (northwest India) and to develop second-generation biofuels using a biomass-to-liquid process.	
Syngenta—Harneshwar Agro Products Power and Yeast Ltd. (India) • Syngenta is the world's third largest seed company • Harneshwar is a 12,000-member farmer cooperative based in Indapur, India	Harneshwar built and operates a facility to process tropical sugar beets into agrofuel. The facility was specifically designed to process Syngenta's proprietary sugar beet, which has been field-tested in India for five years. Syngenta says it took more than a decade of breeding to develop the variety.	

Table 1 (contd.): Alliances Propelling First-Generation Agrofuels		
Boeing—NASA—Tecbio • Tecbio (Brazil), founded 2001, engineering firm developing biodiesel refineries • NASA – US National Aeronautics and Space Administration • Boeing – largest manufacturer of commercial jetliners and military aircraft combined; operates NASA's Space Shuttle and International Space Station	Collaboration to produce an aviation fuel, a biodiesel from babassu palm kernel oil. The babassu palm grows in the northeast of Brazil. Two pilot projects are underway for local populations to collect and harvest babassu nuts to be used for agrofuel and other products.	
Big Oil & Big Brains: Industry—University Partnerships		
BP—Univ. of California-Berkeley—Lawrence Berkeley National Lab—Univ. of Illinois, Urbana/Champaign • The atomic bomb was developed at Lawrence Berkeley National Lab	Primary mission is to promote the biofuels industry; research will involve genetic engineering, synthetic biology	$500 million over 10 years (BP has separate projects at Berkeley, Stanford, Princeton, California Institute of Technology and Arizona State University)
ExxonMobil—Stanford University (US) • ExxonMobil is the world's 2nd largest corporation	Research includes genetic engineering agrofuel crops and engineering *E. coli* to increase biodiesel yields from feedstocks.	ExxonMobil will invest $100 million in Stanford's Global Climate and Energy Project over 10 years; General Electric and Toyota will invest $50 million each; Schlumberger (an oilfield services company) will invest $25 million.
Gene Giants x 2		
Monsanto—Cargill have formed a joint venture called **Renessen** • Monsanto is the world's largest seed company	Renessen markets genetically engineered (herbicide tolerant) soybean and corn called Mavera to be used for both animal feed and fuel.	
Monsanto—BASF • BASF is a F500 chemical and agricultural biotechnology company	Monsanto & BASF announced in March 2007 they will invest up to $1.5 billion in a collaboration devoted to developing high yield and stress-tolerant traits in corn, soy, cotton and canola, partly to meet demand for agrofuel crops.	

Table 2: Alliances to move beyond first-generation agrofuels		
Who?	**What?**	**How Much?**
BP—Univ. of California-Berkeley—Lawrence Berkeley National Lab—Univ. of Illinois, Urbana/Champaign (This partnership also appears in Table 1.)	Primary mission is to promote the biofuels industry; research will involve genetic engineering, synthetic biology	$500 million over 10 years (BP has separate projects at Berkeley, Stanford, Princeton, California Institute of Technology and Arizona State University)
Mascoma Corporation—Royal Nedalco • Mascoma produces fuels from cellulosic biomass using proprietary microorganisms and enzymes • Royal Nedalco is a subsidiary of Dutch sugar giant Cosun and produces plant-derived ethanol (ethyl alcohol)	Joint development agreement to commercialize ethanol production from lignocellulosic biomass. Nedalco licensed its yeast-based fermentation technology to Mascoma. The two companies will collaborate on joint research programs to produce fuel from straw and wood chips	
UOP—DARPA—Cargill—Arizona State University—Sandia National Lab—Southwest Research Institute • UOP, an oil processing technology company, is owned by Honeywell, a F500 defense and aerospace company • DARPA – Defense Advanced Research Projects Agency of US govt. • Sandia, US govt.-owned lab, of the Dept. of Energy's National Nuclear Security Administration, operated by Lockheed Martin, a F500 company	Collaboration for technology R&D to convert vegetable and algal oils to military jet fuels	DARPA has invested $6.7 million
Univ. of California-Irvine—CODA Genomics	$1.67 million collaboration to boost ethanol production by re-engineering a yeast to produce enzymes that allow it to digest biomass	
Lawrence Berkeley National Laboratory—Univ. of California-Berkeley—Univ. of California-Davis—Stanford University—Sandia National Laboratory	Joint Bioenergy Institute to develop cellulosic ethanol technologies using plant biotech and synthetic biology	$125 million from the US Department of Energy over 5 years
Chevron Corporation—Univ. of California-Davis	R&D to produce fuel from farm and forest residues, urban wastes and energy crops	$25 million over 5 years, 2006-2011
Chevron Corporation—National Renewable Energy Laboratory (NREL, US Department of Energy)	One project in five-year bio-fuels research collaboration. Chevron and NREL scientists will attempt to identify and develop algae strains that can be harvested and processed into jet fuel. Chevron Technology Ventures is funding the project.	
BP—Mendel Biotechnology Mendel Biotech, a privately-held company, has a long-term partnership with **Monsanto**; Monsanto has exclusive royalty-bearing licenses to Mendel technology in certain crops; Mendel and Monsanto extensively exchange proprietary information	Five-year research program to develop feedstocks for the production of cellulosic agrofuels. BP became a shareholder of Mendel with representation on Mendel's Board.	

Table 2: Alliances to move beyond first-generation agrofuels	
BP—Synthetic Genomics, Inc.	Long-term R&D plan for sequencing and re-engineering microorganisms found in fossil fuel deposits to speed up the hydrocarbon formation process, create biofuels, etc. BP made equity investment in Synthetic Genomics. Details not disclosed.
Synthetic Genomics, Inc.—Asiatic Centre for Genome Technology (ACGT) • Synthetic Genomics (US) is developing novel organisms to create fuel directly ACGT is a subsidiary of Asiatic Development Berhard, an oil palm plantation company	Multi-year, R&D joint venture to sequence and analyze the oil palm genome; ACGT and its parent company's chairman and chief executive, Tan Sri Lim Kok Thay, made equity investments in Synthetic Genomics as part of the deal. Financial details not disclosed.
Agrivida—Codon Devices, Inc. • Agrivida is an agricultural biotechnology company (US), a spin-off from Massachusetts Institute of Technology • Codon Devices (US) is a synthetic biology company, specializing in gene synthesis	A development agreement in which Codon Devices will produce "optimized enzymes" for Agrivida to incorporate into genetically engineered corn. The goal is for the enzymes to degrade the entire mass of plant material into small sugars that can then be readily converted to ethanol.
Shell—CHOREN Industries • Shell is US affiliate of Royal DutchShell, the world's 3rd largest corporation • CHOREN Industries (Germany) works with Volkswagen and DaimlerChrysler to commercialize its "SunDiesel," a biomass-to-liquid synthetic fuel	Partnership to produce wood chips to liquid fuel. A plant in Freiberg, Germany is slated to begin production in late 2007
Royal Dutch Shell—Codexis • Codexis (US) Codexis develops enzymes for use as biocatalysts in chemical manufacturing processes including pharmaceuticals and industrial chemicals	Collaboration began in 2006 and expanded in 2007 for five years of research to develop enzymes to improve conversion of non-food feedstocks to biofuels; Shell made equity investment in Codexis and took a seat on its Board of Directors.
US Department of Energy Joint Genome Institute—California Institute of Technology—Verenium Corp.—the National Biodiversity Institute of Costa Rica (INBio)—IBM's Thomas J. Watson Research Center • Cambridge (US)-based Verenium Corp. is the product of merger of Diversa, an industrial biotech and bioprospecting company, and Celunol Corp., a bioenergy company specializing in cellulosic fuel.	Collaboration to sequence and analyze the genomes of specialized microbes in termite guts that break down the cell walls of plant material (e.g., wood). The goal is to identify the microbes' metabolic pathways and then synthesize the enzymes discovered through the research collaboration in order to produce cellulosic fuels.
Novozymes A/S—China Resources Alcohol Corporation (CRAC)—SunOpta • SunOpta, headquartered in Ontario, Canada, is a food company with a BioProcess Group focused on biomass to fuel conversion • State-owned CRAC is the second-largest ethanol producer in China • Novozymes is a Danish biotech firm	Three-year Joint Development Agreement to produce cellulosic ethanol in ZhaoDong City, China (2006). CRAC supplies the facility; SunOpta supplies the conversion technology and Novozymes supplies the enzymes used in the conversion process.

Table 2: Alliances to move beyond first-generation agrofuels	
Novozymes A/S—Xergi A/S • Novozymes and Xergi are Danish biotech firms • Novozymes also collaborates with POET Energy (U.S.), which has received $80 million grant from US Department of Energy for cellulosic ethanol	Partnership to develop microorganisms and technologies to harvest components in manure to produce both fuel and "optimized" fertilizer
Novozymes A/S—Centro de Tecnologia Canavieira (Brazil)	Research collaboration to develop bioethanol from bagasse – a residual product of sugar production from sugar cane. Novozymes will contribute enzyme technology.
Khosla Ventures—Gevo, Inc., LS9, Inc., Amyris Biotechnologies, KiOR (joint venture with Dutch agrofuels start-up BIOeCon), Mascoma, Verenium Corp., etc.	Khosla Ventures, founded in 2004 by Vinod Khosla, a founder of Sun Microsystems, has invested "tens of millions of dollars" of venture capital in private cellulosic fuel companies[39]

Sources: ETC Group, company web sites, *Biofuel Review*

ENDNOTES:

[1] CSOs have argued that *agrofuel* is a more accurate term than *biofuel* to refer to fuel derived from industrially grown agricultural crops. See, for example, the editorial in GRAIN's Agrofuels special issue of *Seedling* (July 2007). ETC Group agrees. The term *biofuel* could regain relevance in the future if companies succeed in applying synthetic biology to create novel microorganisms capable of producing fuel.

[2] The $15 billion estimate comes from Martin Wolf, "Biofuels: a tale of special interests and subsidies," *Financial Times*, 30 October 2007.

[3] The estimates come from BP-DuPont joint market research, as cited in Bio-Era report, *Genome Synthesis and Design Futures: Implications for the U.S. Economy*, February 2007, p. 93.

[4] The reports are available on the Internet:
"Agrofuels: Towards a reality check in nine key areas" was prepared for the 12th meeting of the Convention on Biological Diversity's Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) and is available here: http://www.econexus.info/
GRAIN's Agrofuels special issue of *Seedling* is available here: http://www.grain.org/seedling/?type=68.

[5] The term *Peak Soil* is taken from Alice Friedemann, "Peak Soil: Why cellulosic ethanol, biofuels are unsustainable and a threat to America," 10 April 2007. On the Internet: http://www.energybulletin.net/28610.html

[6] In a recent *Chemical and Engineering News* article with the ominous title, "A Great Time to Make Fertilizers" (May 14, 2007, p. 30), William Storck reports that due to the increased corn plantings in North America to meet demand for corn ethanol, the region's four biggest fertilizer companies – Mosaic, Terra Industries, Agrium and PotashCorp – all posted first-quarter sales (2007) significantly higher than the same period in 2006, from 19% (Mosaic) to 34% (PotashCorp) higher. Industrial agriculture and deforestation are already substantial contributors to greenhouse gases in the atmosphere; as they expand to satisfy the craving for agrofuels, their emissions will go up, too, exacerbating global warming. According to the *Stern Review on the Economics of Climate Change* (UK, 2006), land use (e.g., deforestation) accounts for 18% of all carbon emissions; agriculture accounts for 14%, the same percentage as transport. (See executive summary [long], p. iv.

[7] Richard Doornbosch and Ronald Steenblik, *Biofuels: Is the Cure Worse than the Disease?* OECD Round Table on Sustainable Development, Paris, 11-12 September 2007. Shortly after its release, lobbyists from the Renewable Fuels Association and the European Bioethanol Fuel Association demanded that OECD disavow the paper. See http://biopact.com/2007/09/euus-biofuel-organisations-urge-oecd-to.html.
[8] See, for example, http://www.econexus.info/biofuels.html
[9] UN-Energy, *Sustainable Bioenergy: A Framework for Decision Makers*, May 2007, p. 6.
[10] *Ibid.*, p. 5.
[11] According to the *Stern Review on the Economics of Climate Change* (UK, 2006), land use (e.g., deforestation) accounts for 18% of all carbon emissions; agriculture accounts for 14%, the same percentage as transport. See executive summary (long), p. iv, available on the Internet: http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/sternreview_summary.cfm.
[12] US Department of Energy press release, "Strong Growth in World Energy Demand is Projected Through 2030," June 20, 2006, on the Internet: http://www.eia.doe.gov/neic/press/press271.html. See Figure 2.
[13] DOE, International Energy Outlook 2007, Figure 8, available on the Internet: http://www.eia.doe.gov/oiaf/ieo/index.html.
[14] Global market figures are from Clean Edge, "Clean Energy Trends 2007," 6 March 2007, on the Internet: http://www.cleanedge.com/charts-2007CETrends.php
[15] A transcript of George W. Bush's speech is available here: http://www.whitehouse.gov/news/releases/2007/01/20070123-2.html.
[16] As quoted in Joel K. Bourne, Jr., "Green Dreams," *National Geographic*, October 2007, p. 53.
[17] New Energy Finance, *Cleaning Up 2007: Growth in VC/PE Investment in Clean Energy Technologies, Companies & Projects*, 23 Aug 2007, p. 11 of Executive Summary, available on the Internet: www.newenergyfinance.com.
[18] Anon., "SunOpta, Novozymes and China Resources Alcohol to Develop Cellulosic Ethanol in China," 25 June 2006, available on the Internet: http://www.greencarcongress.com/2006/06/sunopta_novozym.html.
[19] See Arborgen news release, http://www.arborgen.com/cms/upload/EucaGen%20Release.FINAL.7.3.07.pdf.
[20] See Arborgen news release: http://www.arborgen.com/media_release_082307.pdf.
[21] *Ibid.*
[22] Genencor's product is called Accellerase 1000. See: http://www.genencor.com/cms/connect/genencor/products_and_services/agri_processing/renewable_fuels/new_products_ethanol/cellulosic_ethanol_en.htm.
[23] See Novozymes's news release, 13 September 2007: http://www.novozymes.com/en/MainStructure/Press+Room/PressRelease/2007/2nd+generation+biofuel.htm.
[24] Bio-Era report, *Genome Synthesis and Design Futures: Implications for the U.S. Economy*, February 2007, p. 85.
[25] See Amyris Biotechnologies news release, http://www.amyrisbiotech.com/news_091907.html.
[26] For more information on Amyris and the synthetic artemisinin project, see ETC Group, *Extreme Genetic Engineering: An Introduction to Synthetic Biology*, January 2007, pp. 52-55.
[27] Jason Pontin, "First, Cure Malaria. Next, Global Warming," *New York Times*, June 3, 2007.
[28] See Solazyme's web site, http://www.solazyme.com/partnering.shtml.
[29] See Khosla Ventures' web site, http:// www.khoslaventures.com Click on "renewable portfolio" to see Powerpoint slide of companies.
[30] See Synthetic Genomics news release, http://www.syntheticgenomics.com/press/2007-06-13.htm.
[31] On using synthetic biology to create microorganisms that can produce fuel, see ETC Group *News Release*, "Patenting Pandora's Bug: Goodbye, Dolly...Hello, Synthia! J. Craig Venter Institute Seeks Monopoly Patents on the World's First-Ever Human-Made Life Form," 7 June 2007, and attached backgrounder. On the Internet: http://www.etcgroup.org/en/materials/publications.html?pub_id=631.
[32]See http://research.microsoft.com/ur/us/fundingopps/RFPs/eScience_RFP_2006.aspx.
[33] David Vise and Mark Malseed, *The Google Story*, New York: Delta Trade Paperbacks, September 2006, p. 285.
[34] Peter Aldhous interview with J. Craig Venter, *New Scientist*, Issue #2626, 20 October 2007, pp. 56-57.
[35] See ETC Group *News Release*, "Patenting Pandora's Bug: Goodbye, Dolly...Hello, Synthia! J. Craig Venter Institute Seeks Monopoly Patents on the World's First-Ever Human-Made Life Form," 7 June 2007, and attached backgrounder. On the Internet: http://www.etcgroup.org/en/materials/publications.html?pub_id=631. See also, ETC Group news release, "Extreme Monopoly: Venter's Team Makes Vast Patent Grab on Synthetic Genomics," 8 December 2007, available on the Internet: http://www.etcgroup.org/en/materials/publications.html?pub_id=665.
[36] The open letter is available, dated 19 May 2006, is available here: http://www.etcgroup.org/en/materials/publications.html?pub_id=8.

[37] Helena Paul and Almuth Ernsting, "Second Generation Biofuels: An Unproven Future Technology with Unknown Risks," available on the Internet: http://www.biofuelwatch.org.uk/inf_paper_2g-bfs.pdf. See also: "Agrofuels: Towards a reality check in nine key areas," June 2007, pp. 13-16, available on the Internet: http://www.econexus.info/. See Alice Friedemann, "Peak Soil: Why cellulosic ethanol, biofuels are unsustainable and a threat to America," 10 April 2007. On the Internet: http://www.energybulletin.net/28610.html.

[38] The US Department of Agriculture's Agricultural Research Service is conducting a five-year project to study the impact of residue removal for biofuel production on soil. See: http://www.ars.usda.gov/research/projects/projects.htm?accn_no=410653.

[39] Norm Alster, "On the Ethanol Bandwagon, Big Names and Big Risks," *New York Times*, 26 March 2006.

ETC Group is an international civil society organization based in Canada. We are dedicated to the conservation and sustainable advancement of cultural and ecological diversity and human rights. ETC Group supports socially responsible development of technologies useful to the poor and marginalized and we address international governance issues affecting the international community. We also monitor the ownership and control of technologies and the consolidation of corporate power.

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