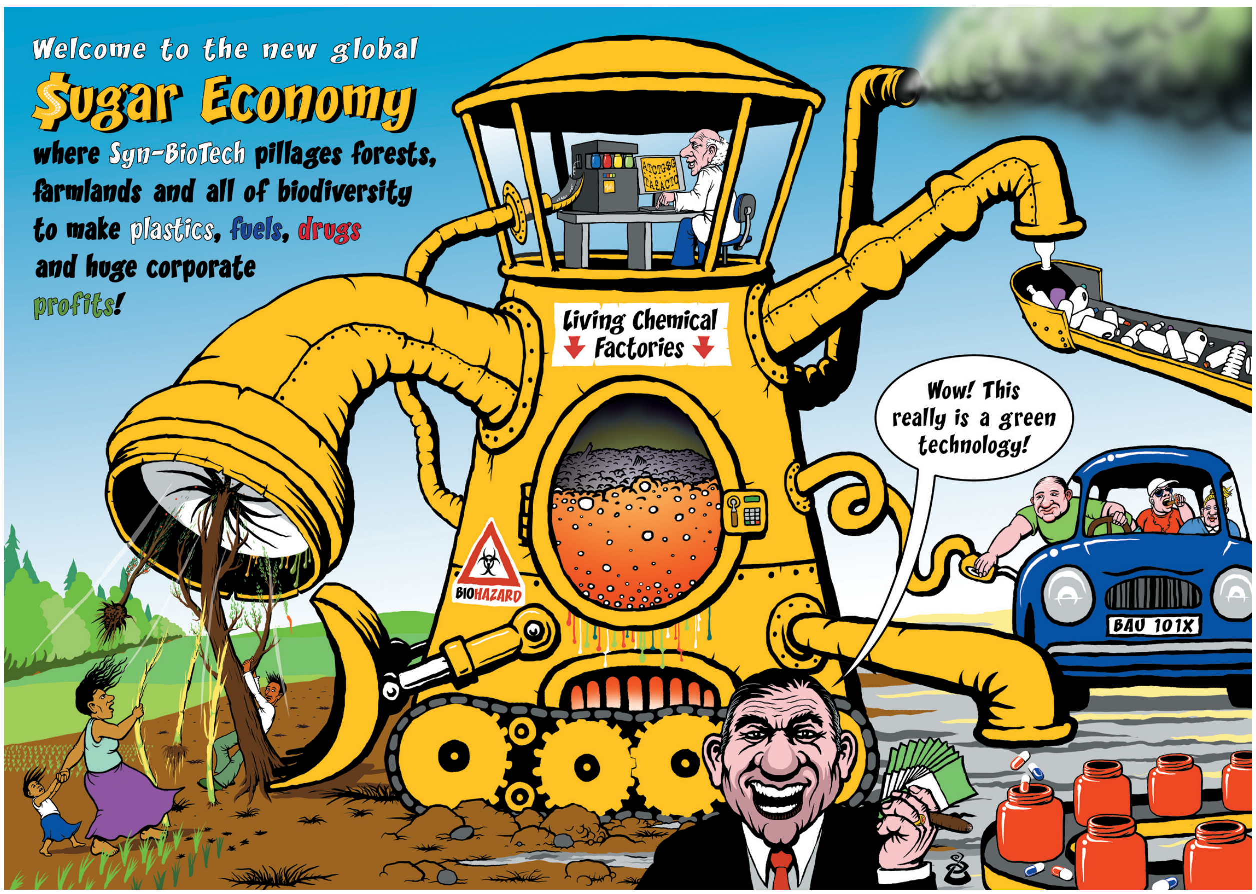
Commodifying Nature's Last Straw?

Extreme Genetic Engineering and the Post-Petroleum Sugar Economy



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Peak oil, skyrocketing fuel costs and climate crisis are driving corporate enthusiasm for a "biological engineering revolution" that some predict will dramatically transform industrial production of food, energy, materials, medicine and all of nature. Advocates of converging technologies promise a greener, cleaner post-petroleum future where the production of economically important compounds depends not on fossil fuels – but on biological manufacturing platforms fueled by plant sugars. It may sound sweet and clean, but the so-called "sugar economy" will also be the catalyst for a corporate grab on all plant matter – and destruction of biodiversity on a massive scale.

The future bio-economy will rely on "extreme genetic engineering" – a suite of technologies that are still in early stages of development: cheap and fast gene sequencing; made-to-order biological parts; genome engineering and design; nano-scale materials fabrication and operating systems. The common denominator is that all these technologies – biotech, nanotech, synthetic biology – involve engineering of living organisms at the nano-scale. This technology convergence is driving a convergence of corporate power. New bioengineering technologies are attracting billions of dollars in corporate funding from energy, chemical and agribusiness giants – including DuPont, BP, Shell, Chevron, Cargill – among others.

The 21st century's bio-based future is called the "sugar economy," or the "carbohydrate economy," because industrial production will be based on biological feedstocks (agricultural crops, grasses, forest residues, plant oils, algae, etc.) whose sugars are extracted, fermented and converted into high-value chemicals, polymers or other molecular building blocks. The director of Cargill's industrial bio-products division explains: "With advances in biotechnology, any chemical made from the carbon in oil could be made from the carbon found in plants."[1]

Biological engineering has the potential to affect virtually every sector of the economy that relies on fossil fuels – not only transportation fuels, but also plastics, paints, cosmetics, adhesives, carpets, textiles and thousands more consumer products. Advocates assure us that the "food vs. fuel" debate will be irrelevant in the future sugar economy, because feedstocks will come from cheap and plentiful "cellulosic biomass"– plant matter composed of cellulose fibers (including crop residues such as rice straw, corn stalks, wheat straw; wood chips; and dedicated "energy crops" such as switchgrass, fast-growing trees, algae, even municipal waste). The giant stumbling block is that it currently requires a lot of energy to break down some biological feedstocks into sugar, and traditional chemistry has failed to provide an economical process. Proponents insist that "next generation" feedstocks will use old and new biotechnologies, as well as break-through fermentation technologies, to succeed where chemistry failed.

> *"Biology can make certain things better than traditional chemistry can."*
>
> *– Charles O. Holliday, Jr., CEO, DuPont*

What is the sugar economy?

Syn Bio enthusiasts envision a post-petroleum era in which industrial production is fueled by sugars extracted from biological feedstocks (biomass). The biotech industry's bioeconomy vision includes a network of biorefineries, where extracted plant sugars are fermented in vats filled with genetically engineered – and one day, fully synthetic – microbes. The microbes function as "living chemical factories," converting sugars into high-value molecules – the building blocks for fuels, energy, plastic, chemicals and more. Theoretically, any product made from petrochemicals could also be made from sugar using this biological manufacturing approach.

What is biomass?
Material derived from living or recently living biological organisms. Sources of biomass include all plants and trees, as well as by-products such as organic waste from livestock, food processing and garbage.

Converging Technologies Crystallize Corporate Power

Eschewing fossil fuels as the planet's economic fulcrum won't happen overnight. It's too soon to tell if sugar-coated visions of the carbohydrate economy are mostly technological hype and hubris, or if bio-based production processes can compete with their petrochemical counterparts. Some of the world's largest corporations are beginning to shift some production away from petrochemicals to bio-based processes. The quest for the sugar economy is fueling high-dollar deals in the university-industry complex, most notably the $500 million alliance between BP and University of California Berkeley.[2] We're also seeing unprecedented corporate alliances involving synthetic biology start-ups and some of the world's largest corporations – including Big Oil, Big Pharma, chemical firms, agribusiness giants, automobile manufacturers, forest product companies and more (see table). For example:

► Agribusiness giant **Archer Daniels Midland Co**. and **Metabolix** formed a joint venture (Telles Co.) to commercialize bioplastics made from corn sugar. The company's biorefinery will produce 110 million pounds of plastic resin per year starting in late 2008.

► **DuPont** partnered with sugar giant **Tate & Lyle** (recently sold to agribusiness giant **Bunge**) and **Genencor** to develop a commercial bio-based product – a fiber called "Sorona."

► **BP** is partnering with **Mendel Biotechnologies** to develop genetically engineered perennial grass for fuel.

► **ConocoPhillips** and **Archer Daniels Midland** forged an alliance on cellulosic biofuel production.

► **BP** has a joint venture with **DuPont** to develop biobutanol.

► **Shell** is equity investor in cellulosic ethanol producer **Iogen**.

► **General Motors** and **Marathon Oil** are equity investors in **Mascoma**, a company that is engineering microbes to break down biomass and digest sugars.

► **Codexis** is developing biocatalytic chemical processes to reduce manufacturing costs of pharmaceuticals, transportation fuels, and industrial chemicals. **Shell**, **Merck**, **Schering-Plough**, **Bristol-Myers Squibb**, and **Pfizer** are among its corporate partners.

► **BP** is an equity investor in **Synthetic Genomics**, a synbio company that aims to commercialize synthetic genomic processes for alternative energy.

► **Chevron** and **Weyerhaeuser** have a 50-50 joint venture to develop technology for converting cellulose-based biomass into biofuels.

► **Chevron** has an agreement with synthetic biology startup **Solazyme** to develop an industrial process to transform algae into diesel fuel.

► France's Industrial Innovation Agency is financing a €90 million initiative to develop biomaterials from renewable sources.

► The U.S. Department of Energy is investing $385 million in six commercial-scale cellulosic ethanol biorefineries. Corporate partners include: **Cargill**, **Dow**, **DuPont**, **Shell**, **Iogen**, among others.

Today's industrial bio-economy focuses primarily on agrofuels (biofuels) – especially ethanol and biodiesel. *Nature Biotechnology's* Emily Waltz explains: "The market for fuels swamps that of chemical and material markets, and the prospect of commanding just a piece of it is a draw that many entrepreneurs, governments and investors cannot resist."[3] Since the 1970s, 70% of all U.S. government funding for R&D in biomass has gone to biofuels.[4] In the U.S., energy applications account for 94% of fossil fuel consumption; petrochemicals account for the rest.

> *"... any chemical made from the carbon in oil could be made from the carbon found in plants."*
>
> – John Stoppert, Cargill

Bio-Economic Research Associates (Cambridge, MA) predicts that bio-based chemical processes could capture more than $70 billion in revenues by 2010 – more than 10% of the global chemical industry total. (One analyst predicts that the market for bio-plastics will expand from $1 billion in 2007 to over $10 billion by 2020.[6]) The biofuels sector could reach $40 billion by 2010 and $110-150 billion by 2020. Revenues from vaccines developed with next generation DNA technologies could reach $20 billion by 2010.[7]

Another Late Lesson from Early Warnings

Recent experience with industrial agrofuels offers a modern day parable about the dangers of techno-fixes that are promoted as green and sustainable solutions to peak oil and climate change. By mid-2008, even some OECD countries were admitting that industrial agrofuels have been a tragic boondoggle that can't be remotely described as a socially or ecologically sustainable response to climate change.[8] Not only are industrial agrofuels driving the world's poorest farmers off their land and into deeper poverty, [9] they are the single greatest factor contributing to soaring food prices[10] and have pushed over 30 million additional people (so far) from subsistence to hunger.[11] Recent scientific papers conclude that industrial agrofuels are not arresting climate change but *accelerating* it.[12]

Synthetic Biology to the Rescue?

But techno-optimists aren't worried – because there are plenty more techno-fixes on the launching pad. Venture capitalists, corporate titans and the U.S. Department of Energy are betting that advances in synthetic biology will overcome the technological bottlenecks that threaten to delay the sugar economy. Synthetic biology, they tell us, will enable next generation cellulosic feedstocks to be far more efficient and sustainable, and won't compete with land and resources that are used to grow conventional food crops.

Today, synthetic biologists are pursuing a variety of methods to efficiently extract sugars from biomass feedstocks. For example, they are trying to use synthetic microbes to break down cellulosic biomass, and they are also converting microbial cells into "living chemical factories" that manufacture new bio-based products.

Jump-started by U.S. government subsidies,[14] venture capitalists and corporations are supporting R&D (in-house) as well as alliances with synthetic biology start-ups (see table, page 5).

Amyris Biotechnologies, a California-based synthetic biology start-up, aims to engineer new metabolic pathways in microbes so they will produce novel or rare compounds. Although best known for its high-profile efforts to coax engineered cells to produce an anti-malarial compound, the company's primary goal is to modify the genetic pathways of yeast so that it efficiently ferments sugars to produce longer chain molecules of gasoline, diesel and jet fuel. In 2007, Amyris raised $70 million in venture capital to develop synthetic fuel technology.[15] In April 2008 Amyris announced a joint venture with Brazil's Crystalsev to commercialize "advanced renewable fuels" made from sugarcane in 2010 – including diesel, jet fuel and gasoline.[16] In the longer term, Amyris wants to create new production pathways in engineered microbes to churn out pharmaceuticals, flavors, fragrances and nutraceuticals.

What is Synthetic Biology?

Inspired by the convergence of molecular biology, computing and engineering, synthetic biology refers to the creation of designer organisms built from synthetic DNA. Scientists have already used synthetic DNA to construct working viruses and re-engineer existing microbes; they are also attempting to build human-made life forms that perform specific tasks.

In September 2008 California-based synthetic biology company, Solazyme, Inc., announced that it has successfully produced the world's first microbial-derived jet fuel by engineering algae to produce oil in fermentation tanks.[17] The company describes it as the first step towards achieving fuel alternatives on a large scale, and claims that its production process can employ a variety of non-food feedstocks, including cellulosic materials such as agricultural residues and high-productivity grasses (bagasse and switchgrass).

DuPont already manufactures a sugar-based biomaterial via engineered microbes.[18] Using a proprietary process developed through partnerships with Genentech and Tate & Lyle, the company engineers the cellular machinery of an *E. coli* bacterium so that it can ferment corn sugar to produce the main ingredient in the company's Sorona fiber, 1,3-propanediol (trademarked name Bio-PDO).[19] Dupont's goal is to one day produce Bio-PDO from cellulosic plant material instead of milled corn. DuPont predicts that Sorona, which can be turned into anything from underwear to carpeting, will eventually replace nylon. Although Sorona fiber is neither compostable nor biodegradable, DuPont boasts that it's environmentally friendly because its production requires 40 percent less energy and reduces greenhouse gas emissions by 20 percent compared to petroleum-based propanediol. But it takes six million bushels of corn to produce 100 million pounds of Bio-PDO – the estimated annual output of DuPont's Tennessee-based (USA) bio-refinery.[20] And that's just one example of one biorefinery producing just one bio-based material for a single year. In other words, synthetic biology's state-of-the-art, sugar-dependent biorefineries will create a massive demand for agricultural feedstocks. According to biotech industry estimates, a minimum of 500,000 acres of cropland (that is, the crop residues or "wastes" from that area) would be required to sustain a

> *"[Synthetic organisms] will replace the petrochemical industry, most food, clean energy and bioremediation."*
> – J. Craig Venter, CEO, Synthetic Genomics, Inc.[13]

moderately-sized, commercial-scale biorefinery.[21]

Synthetic biology's grand vision of a post-petroleum era depends on biomass – whether derived from "energy crops," trees (including GE trees), agricultural "wastes," crop residues or algae. If the vision of a sugar economy advances, will *all* plant matter become a potential feedstock? Who decides what qualifies as agricultural waste or residue? *Whose* land will grow the feedstocks? An article in the February 2008 issue of *Nature* suggests that synthetic biology approaches "might be tailored to **marginal lands** where the soil wouldn't support food crops." (emphasis added)[22] The implications, especially for marginalized farming communities and poor people in the South, are profound. At a May 2006 meeting of synthetic biologists, Nobel laureate Dr. Steven Chu pointed out that there is "quite a bit" of arable land suitable for rain-fed energy crops, and that Latin America and Sub-Saharan Africa are areas best suited for biomass generation. Failing to learn from the first-generation agrofuel train wreck, *The Economist* naively suggests that "there's plenty of biomass to go around" and that "the world's hitherto impoverished tropics may find themselves in the middle of an unexpected and welcome industrial revolution."[23]

In the name of moving "beyond petroleum" we're seeing a new convergence of corporate power that is poised to appropriate and further commodify biological resources in every part of the globe - while keeping the root causes of climate change intact.

Advocates of synthetic biology and the bio-based sugar economy assume that unlimited supplies of cellulosic biomass will be available. But can massive quantities of biomass be harvested sustainably without eroding/degrading soils, destroying biodiversity, increasing food insecurity and displacing marginalized peoples? Can synthetic microbes work predictably? Can they be safely contained and controlled? No one knows the answers to these questions, but that's not curbing corporate enthusiasm. In the current social and economic context, the global grab for next generation cellulosic feedstocks threatens to repeat the mistakes of first-generation agrofuels on a more massive scale.

The pattern is familiar. Once again, land, labour and biological resources in the global South are in danger of being exploited to satisfy the North's voracious consumption and reckless waste. In the name of moving "beyond petroleum" we're seeing a new convergence of corporate power that is poised to appropriate and further commodify biological resources in every part of the globe – while keeping the root causes of climate change intact.[24]

An upcoming report by ETC Group and the Global Justice Ecology Project will examine the far-reaching implications of the sugar economy, especially for marginalized communities in the global South.

Artwork by Stig. 

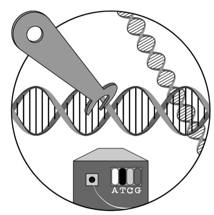
Publication design by Deborah S. Wechsler, Wordsmith Services.

Breaking the Biomass Bank: Limits to (plant) Growth

"Almost all of the arable land on Earth would need to be covered with the fastest-growing known energy crops, such as switchgrass, to produce the amount of energy currently consumed from fossil fuels annually." – U.S. Department of Energy, 2005[25]

The earth's plant biomass is rapidly dwindling. Forests and grasslands, in particular, are disappearing at an alarming rate. Researchers estimate that humans already consume almost a quarter of global biomass (24%). Of that amount, more than half (53%) is harvested for food, fuel, heating and lumber. 40% is lost through land use changes and 7% is burned in human induced fires.[26]

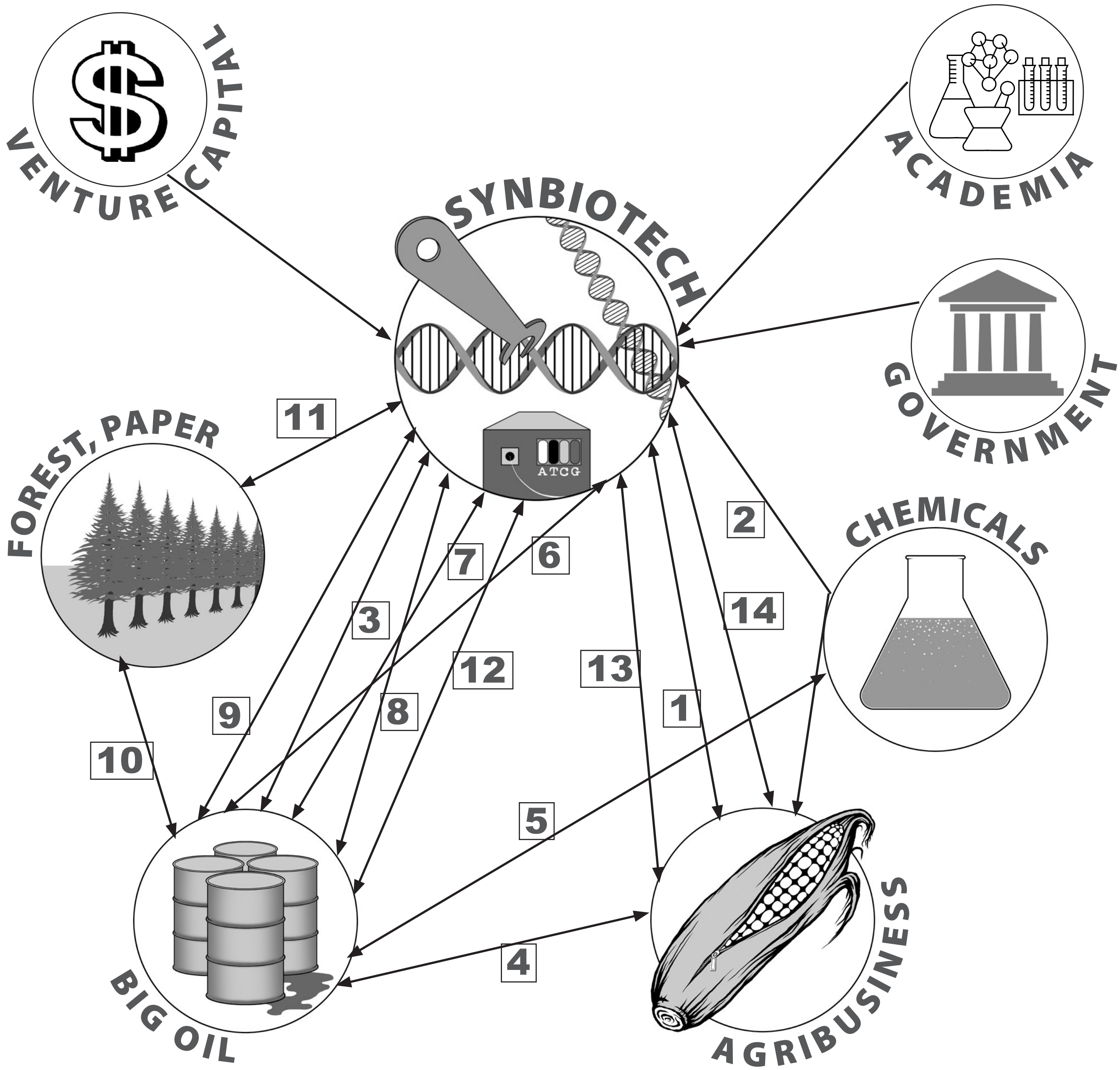
The United States currently consumes 190 million dry tonnes of biomass annually for energy, and the government wants to increase that figure to one billion tonnes. Researchers conclude that the goal is technically feasible, but only by increasing yields of energy crops by 50% and by removing large quantities (~75%) of agricultural residues from cropland. Impacts of increased residue removal will include impoverished soils (requiring more industrial fertilizers) and dangerous increases in soil erosion.[27]



Synthetic Biology Players and Corporate Partners

COMPANY	CORPORATE PARTNERS/INVESTORS	COMPANY FOCUS
Amyris Biotechnology Emeryville, CA, USA	Partnership with CrystalSev (one of Brazil's largest sugar and ethanol manufacturer); Sanofi-Aventis; Khosla Ventures; Kleiner Perkins Caufield & Byers; TPG Ventures (TPGV); Amyris CEO is John Melo, previously president of U.S. Fuels Operations for BP	Using synthetic biology to commercialize biofuels, pharmaceuticals, fine chemicals, and nutraceuticals.
Athenix Research Triangle Park, NC, USA	Syngenta; Monsanto; Iowa Corn Promotion Board	Developing genes and enzymes to enable processes to release sugars from biological feedstocks.
Codexis Redwood City, CA, USA	Shell; Merck; Schering-Plough; Bristol-Myers Squibb; Pfizer; Chevron; Maxygen; Pequot Ventures; CMEA Ventures; Bio*One Capital	Developing biocatalytic chemical processes to reduce manufacturing costs of pharmaceuticals, transportation fuels, and industrial chemicals.
Coskata Warrenville, IL, USA	General Motors; ICM	Biology-based renewable energy company. Using proprietary microorganisms and bioreactor designs, aims to produce ethanol for under US$1.00 per gallon.
Genencor (Danisco subsidiary) Rochester, NY, USA	Goodyear Tire & Rubber; DuPont; Procter & Gamble; Cargill; Dow; Eastman Chemical	Engineering protein (enzyme) products for industrial applications (i.e., grain processing, cleaning, textiles, biofuels).
Genomatica San Diego, CA, USA	Iceland Genomic Ventures; Mohr Davidow Ventures (MDV); Alloy Ventures; Draper Fisher Jurvetson	Engineering microorganisms to make an industrial chemical used in plastic, rubber and fiber products.
Gevo Englewood, CO, USA	Virgin Group; Khosla Ventures; Burrill & Company; Malaysian Life Sciences Capital Fund	Developing large-scale production of advanced biofuels, including butanol (higher-energy biofuel than ethanol).
LS9 S. San Francisco, CA, USA	Diversa; Khosla Ventures; Flagship Ventures, Lightspeed Ventures Partners	Using synthetic biology to develop petroleum and other oil-based industrial products.
Mascoma Boston, MA, USA	General Motors and Marathon Oil are equity investors; Khosla Ventures; Kleiner Perkins Caufield & Byers, Pinnacle Ventures; Vantage Point Venture Partners, U.S. Dept. of Energy	Employing engineered microbes to break down biomass and digest sugars.
Metabolix Cambridge, MA, USA	Archer Daniels Midland; U.S. Department of Energy	Developing proprietary platform technology for co-producing plastics, chemicals and energy from switchgrass, oilseeds and sugarcane.
Novozymes (Novo Nordisk Foundation) Bagsvaerd, Denmark	Center for Sustainable and Green Chemistry and Dept. of Chemical Engineering at The Technical University of Denmark (DTU); Danish National Advanced Technology Foundation; Department of Energy's National Renewable Energy Laboratory (NREL)	Engineering enzyme genes using a technique called artificial evolution for industrial applications.
Solazyme S. San Francisco, CA, USA	Chevron; Imperium Renewables, Inc.,;Blue Crest Capital Finance, L.P.	Engineering marine microbes to create renewable energy, industrial chemicals.
Synthetic Genomics La Jolla, CA, USA	BP; Asiatic Centre for Genome Technology (ACGT, Malaysia) subsidiary of the Genting Group; Biotech-onomy LLC; Draper Fisher Jurvetson; Desarrollo Consolidado de Negocios; Meteor Group LLC	Using synthetic genomic processes and naturally occurring processes for alternative energy.
Verenium Cambridge, MA, USA	Marubeni Corp.;Tsukishima Kikai Co.; BASF; Dupont; Danisco; Cargill; Bunge; Syngenta	Created by 2007 merger of Diversa & Celunol. Developing cellulosic ethanol.

SynbioTech's Sugar Economy Is Crystallizing Corporate Power



Sample Alliances

1. ADM + Metabolix
2. DuPont + Tate & Lyle + Genencor
3. BP + Mendel Biotechnologies
4. ADM + ConocoPhillips
5. BP + DuPont
6. General Motors + Marathon Oil + Mascoma
7. Shell + Codexis
8. BP + Synthetic Genomics
9. Chevron + Solazyme
10. Chevron + Weyerhaeuser
11. International Paper / MeadWestvaco / Rubicon Limited + Arborgen
12. Royal Dutch Shell + Codexis
13. Royal Nedalco + Mascoma
14. Crystalsev + Amyris

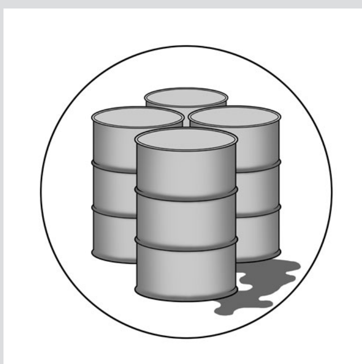
Leading Commercial Gene Synthesis Companies

Company
GeneArt (Germany)
Blue Heron Biotech (USA)
DNA 2.0 (USA)
GenScript (USA)
Integrated DNA Technologies (USA)
Bio S&T (Canada)
Epoch Biolabs (USA)
Bio Basic, Inc. (Canada)
BaseClear (Netherlands)

Source: ETC Group

Note: Synthetic DNA is the raw material for creating artificial life. Our list includes the leading companies involved in commercial gene synthesis (companies that specialize in synthesizing long pieces of double-stranded DNA). Only one, GeneArt, is publicly traded.

Petroleum Refining: Top 10

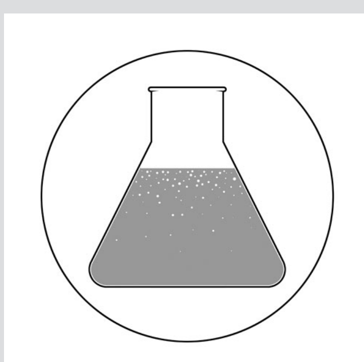


Company	2007 Revenues (US$ millions)
1. ExxonMobil (USA)	372,824
2. Royal Dutch Shell (Netherlands)	355,782
3. BP (UK)	291,438
4. Chevron (USA)	210,783
5. Total (France)	187,280
6. ConocoPhillips (USA)	178,558
7. China Petroleum & Chemical (China)	159,260
8. China National Petroleum (China)	129,798
9. ENI (Italy)	120,565
10. Valero Energy (USA)	96,758

Source: CNN/Global Fortune 500 2008

The world's 39 largest petroleum refiners had combined revenues of $3.3 trillion ($3,293,847 million) in 2007. The top 10 petroleum companies account for 64% of the revenues earned by the 39 largest refiners.

Chemical Industry: Top 10



Company	2007 Chemical Revenues (US$ millions)
1. BASF (Germany)	65,037
2. Dow Chemical (USA)	53,513
3. Shell (UK)	45,911
4. Ineos Group (UK)	37,686
5. ExxonMobil (USA)	36,826
6. China Petroleum & Chemical (China)	30,676
7. SABIC (Saudi Arabia)	29,276
8. DuPont (USA)	29,218
9. Total (France)	28,786
10. Formosa Plastics Group (Taiwan)	26,541

Source: *Chemical & Engineering News*, 28 July 2008 .

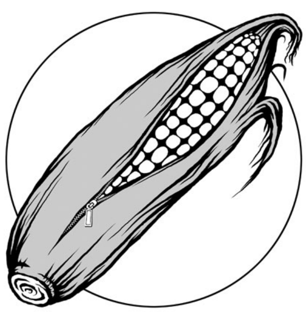
Forest, Paper & Packaging Corporations: Top 10

Company	2007 Revenues (U.S. millions $)
1. International Paper (USA)	21,890
2. Stora Enso (Finland)	18,322
3. Kimberly-Clark (USA)	18,266
4. Svenska Cellulosa (Sweden)	15,675
5. Weyerhaeuser (USA)	13,949
6. UPM (Finland)	13,748
7. Oji Paper (Japan)	10,758
8. Metsaliitto (Finland)	10,507
9. Nippon Unipac (Japan)	9,990
10. Smurfit Kappa (Ireland)	9,963

Source: PricewaterhouseCoopers, 2008

Sales of the top 100 forestry and paper companies totaled US $343,300 million in 2007.[30] The 10 largest companies account for 42% of total sales. The 20 largest account for nearly 60% of total sales.

Companies involved in Oilseed, Grain and Sugar Processing/Trading: Top 11



Company	FY2007 Revenues (US$ millions)
1. Cargill (USA)	88,300
2. Bunge Ltd. (Bermuda)	44,804
3. Archer Daniels Midland (USA)	44,018
4. Marubeni (Japan) (includes Columbia Grain International)	36,481
5. The Noble Group (UK)	23,497
6. Itochu Intl. (Japan)	22,424
7. China National Cereals, Oils & Foodstuffs (China)	21,202
8. Louis Dreyfus Commodities (France)	>20,000[28]
9. Wilmar International Ltd. (Singapore)	16,466
10. Associated British Foods (UK)	13,355 (3,610 sugar)[29]
11. ConAgra Foods (USA)	12,755

Sources: ETC Group, GRAIN, company information, CNN/Global Fortune 500 2008

Notes

1 Bio-era, "Genome Synthesis and Design Futures: Implications for the U.S. Economy," A Special Bio-era Report Sponsored by the U.S. Department of Energy, February 2007, p. 89.

2 For extensive examples of university-industry alliances, see: ETC Group, "Peak Soil + Peak Oil = Peak Spoils," *Communiqué*, November/December 2007. www.etcgroup.org/en/materials/publications.html?pub_id=668

3 Emily Waltz, "Do biomaterials really mean business?" *Nature Biotechnology*, Vol. 26, Number 8, August 2008.

4 Ibid.

5 www.economist.com/specialreports/displaystory.cfm?story_id=11565647

6 www.hkc22.com/bioplastics.html

7 Bio-era, "Genome Synthesis and Design Futures: Implications for the U.S. Economy," A Special Bio-era Report Sponsored by the U.S. Department of Energy, February 2007.

8 The title of one OECD working paper on biofuels said it all: "Is the cure worse than the disease?"

9 http://esa.un.org/un-energy/pdf/susdev.Biofuels.FAO.pdf

10 According to leaked World Bank document (April 2008). http://image.guardian.co.uk/sys-files/Environment/documents/2008/07/10/Biofuels.PDF

11 A June 2008 report from Oxfam claims that biofuel policies in OECD countries have already plunged more than 30 million additional people into poverty. Source: www.oxfam.org.uk/resources/policy/climate_change/bp114_inconvenient_truth.html

12 When total carbon costs of biofuel production are taken into account, all the major agrofuels increase greenhouse gas (GHG) emissions. (Corn-based ethanol nearly doubles GHG emissions over 30 years and increases GHG for 167 years).Timothy Searchinger, et al. "Use of U.S. Croplands for Biofuels Increases Greenhouse Gases Through Emissions from Land-Use Change," *Science* 319, 1238 (2008).

13 www.newsweek.com/id/34406

14 By 2022, U.S. energy policy dictates that 44% of U.S. production of biofuels must come from cellulosic feedstocks.

15 Amyris News Release, "Amyris Biotechnologies Announces $70 Million Series B Round," September 19, 2007. www.amyrisbiotech.com

16 Amyris News Release, "Amyris and Crystalsev Join to Launch Innovative Renewable Diesel from Sugarcane by 2010," April 23, 2008. www.amyrisbiotech.com

17 Solazyme, Inc., News Release, "Solazyme Produces World's First Algal-Based Jet Fuel - Fuel Passes All Tested Specifications including the Most Critical ASTM D1655 Specifications, September 9, 2008." www.solazyme.com

18 According to DuPont, Sorona contains "37% renewably sourced material (by weight) derived from corn." Sorona is neither compostable nor biodegradable. See: www2.dupont.com/Renewably_Sourced_Materials/en_US/sorona.html

19 Dave Nilles, "Tate & Lyle and DuPont ship propanediol from Tennessee plant," *Ethanol Producer Magazine*, November 2006. On the Internet: www.ethanolproducer.com/article.jsp?article_id=2488

20 Peg Zenk, "Biotech's Third Wave," *Farm Industry News,* 1 February 2007.

21 Biotechnology Industry Organization, "Achieving Sustainable Production of Agricultural Biomass for Biorefinery Feedstock," on the Internet: www.bio.org

22 "Not your father's biofuels," *Nature*, Vol. 451, 21 Feb. 2008.

23 Anonymous, "Grow Your Own," *Economist*, June 19, 2009.

24 ETC Group, "Peak Soil + Peak Oil = Peak Spoils," *Communiqué*, November/December 2007. www.etcgroup.org

25 U.S. Department of Energy, "Basic Research Needs for Solar Energy Utilization: Report on the Basic Energy Sciences Workshop on Solar Energy Utilization," 2005. www.sc.doe.gov/bes/reports/files/SEU_rpt.pdf

26 Helmut Haberl et al., "Quantifying and mapping the human appropriation of net primary production in earth's terrestrial ecosystems," *Proceedings of the National Academy of Sciences*, vol. 104, no. 31, July 31, 2007 www.pnas.org/cgi/doi/10.1073/pnas.0704243104

27 U.S. Department of Energy and U.S. Department of Agriculture, *Biomass as Feedstock for a Bioenergy and Bioproducts Industry: the Technical Feasibility of a Billion-Ton Annual Supply*, April 2005. www1.eere.energy.gov/biomass/pdfs/final_billionton_vision_report2.pdf

28 Louis Dreyfus Commodities is part of Louis Dreyfus Group, a privately-held company headquartered in France. According to its website: "Aggregate average annual gross sales in recent years have exceeded $20 billion." LDCommodities is "consistently ranked among the largest merchandisers of grains…[and] oilseeds…ranks as one of the top three sugar merchants and traders in the world, handling both raw and white sugar and handling more than 2.5 million tons of sugar annually. The company owns three Brazilian sugar mills that produce 450,000 tons of sugar and 150,000 cubic meters of alcohol annually." http://www.ldcommodities.com/index.php?id=1410

29 ABF's fiscal year ends 15 September. September 2007 ABF reported global sales of GBP 6,800 million (US$13,355.2) and GBP 1,838 million (US$3,610 million) from its sugar and agriculture business. Average exchange rate from 16 Sept. 2006-15 Sept. 2007: 1 GBP = US$1.96400. www.oanda.com

30 PricewaterhouseCoopers, *Global Forest, Paper & Packaging Industry Survey*, 2008 edition, p. 7.

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 developments 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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For additional background:

Extreme Genetic Engineering: An Introduction to Synthetic Biology
January 2007

Venter Institute Builds Longest Sequence of Synthetic DNA (that Doesn't Work)
January 2008

Peak Soil + Peak Oil = Peak Spoils
November/December 2007

Extreme Monopoly: Venter's Team Makes Vast Patent Grab on Synthetic Genomes
8 December 2007

Syns of Omission: Civil Society Organizations Respond to Report on Synthetic Biology Governance
17 October 2007

The G(e)nomes of Zurich: Civil Society Calls for Urgent Controls on Synthetic Life
25 June 2007

Patenting Pandora's Bug: J. Craig Venter Institute Seeks Monopoly Patents on the World's First-Ever Human-Made Life Form
7 June 2007

Global Coalition Sounds the Alarm on Synthetic Biology
19 May 2006

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