Extract from Forthcoming Report "Who Will Control the Green Economy" by ETC Group. October 2011.

Synthetic Biology

The term *biomass* narrowly refers to the weight of living matter (plants, animals, bacteria, fungi, etc.) found in a specified area, but is more often used to mean non-fossilized biological material that can serve as a feedstock for the manufacture of bio-based products. The term implies a particular way of thinking about nature: as a commodity even before it enters the commercial market. In other words, everything living is a potential article of commerce. Around the world, industry and governments are turning to biomass – touting it as a solution to climate change as well as a means to increase production, especially energy production.

Meanwhile, the field of synthetic biology has rapidly overshadowed transgenics – where single genes are transferred from one organism to another (as in genetically-modified crops, for example). Synthetic biology companies are engineering synthetic DNA to custom-build algae and microbes that behave as tiny "biological factories." The aim is to convert almost any biomass into almost any product. With billions of dollars of public and private investment over the past few years (including the world's largest energy and chemical companies), synthetic biology sees nature's biodiversity as a feedstock for its proprietary bugs – designer organisms that will be used to transform plant cellulose into fuels, chemicals, plastics, fibres, pharmaceuticals or even food – depending on market demand at harvest time. The new "BioMassters" see synthetic biology as the route to an additional revenue stream – a "green" complement to petroleum-based production – or possibly its replacement in the distant future.

Follow the Money: In the past five years, synthetic biology has moved from being a "fringe" science – a hybrid of engineering and computer programming, rather separate from biology – to an area of intense industrial interest and investment. Consolidation is visible in the form of established energy, chemical and pharmaceutical companies buying, making strategic investments in or partnering with pure play synthetic biology (syn bio) companies, which are, generally, start-ups operating in 'stealth mode' (few are publicly traded).

Synthetic biology is not a discreet technology sector, but a set of tools that is being integrated into many industry sectors. It's not easy to get a handle on the syn bo market. BCC Research valued the synthetic biology market at a mere $233.8 million in 2008 and predicts an almost 60 percent annual growth rate to $2.4 billion in 2013.[i] Global Industry Analysts, Inc. expects the market to swell to $4.5 billion by 2015, noting that what began as a North American and European industry is gaining traction in Japan, China and other Asian countries.[ii]

The synthetic biology industry currently breaks down into two types of companies: companies that provide synthetic DNA and lab-level tools (reagents, microarrays, DNA "chips") and those that use synthetic DNA and tools to design, create, test and commercialize engineered organisms for applications and products aimed at the consumer market.

Synthetic Biology's Key Players

Gene Synthesis and Tools	Applications
Agilent Technologies (USA)	Amyris Biotechnologies (USA)
Epoch Life Science, Inc. (USA)	Genencor/Danisco (now DuPont)
454 Life Sciences/Roche Diagnostics (USA)	Sapphire Energy (USA)
Geneart/Life Technologies (Germany)	Synthetic Genomics, Inc. (USA)
febit (Germany)	Solazyme, Inc. (USA)
DNA 2.0 (USA, Switzerland)	Metabolix (USA)
Blue Heron Biotechnology (USA)	Chiron Corporation (now part of Novartis Diagnostics Global)
Sangamo BioSciences (USA)	Draths Corporation (USA)
Gingko Bioworks (USA)	Evolva SA (Switzerland)
Intrexon Corporation (USA)	Chromatin, Inc. (USA)
GEN9, Inc. (USA)	LS9 (USA)

The Parts of Life: While companies such as **Blue Heron**, **febit** and **DNA 2.0** continue to crank out ever-longer lengths of synthetic DNA as an ever-cheaper commodity, the new heavyweight on the block is **Life Technologies Corporation**, formed by the late 2008 merger of two already powerful lab-tool companies, **Applied Biosystems** and **Invitrogen**. With more than $3.6 billion in revenues in 2010 and 11,000 employees worldwide, Life Tech has been expanding both vertically and horizontally. The company has acquired a controlling (75%) stake in the world's largest gene synthesis company, **Geneart**, an equity stake in **Synthetic Genomics, Inc.**, acquired **BioTrove** and **AcroMetrix** (genotyping analysis and molecular diagnostics companies, respectively) and inked an exclusive deal with **Novici Biotech**, a synthetic biology tool-smith that sells an error-correction kit to synthetic DNA manufacturers.

The wildcard in the "tools" kit is **Intrexon**, a privately held company that claims to have an extensive library of modular DNA parts that can be assembled as part of its industrial scale, "Better DNA" platform. Like Life Tech, Intrexon has been shopping – acquiring companies with expertise in disease diagnostics (**Avalon Pharmaceuticals, Inc.**), agricultural biotechnology (**Agarigen**) and forming a strategic partnership with cancer drug developer **Ziopharm, Inc**. New start-up **GEN9,** founded by high-profile Harvard, Stanford and MIT researchers, rose from the ashes of pioneer syn bio company Codon Devices, which folded in 2009.

The syn bio applications area is exploding. Early adopters **DuPont** and **ADM** are already selling their bioplastics derived from corn sugars. **Genencor**, which DuPont bought for $3.6

billion in January 2011, and **Metabolix** were the syn bio brains behind the Sorona (DuPont) and Mirel (ADM) plastics. Genencor also has an ongoing agreement with **Goodyear** to develop synthetic rubber for tyres. In pharmaceuticals applications, **Novartis** looms large. Not only does its 2006 acquisition – **Chiron Corporation** – hold key patents in synthetic biology, but it also has a high-profile collaboration with Synthetic Genomics, Inc. to develop flu vaccines.

Fueling Interest in Syn Bio: Most syn bio companies, however, are focusing on energy or chemicals, or both. Syn bio-based fuels and chemicals brought in $80.6 million in 2008; that figure is expected to grow to $1.6 billion in 2013, according to BCC Research.[iii] **Amyris Biotechnologies** and **Synthetic Genomics, Inc.** have amassed the larger war chests of investors, partnerships and market hype. Amyris in particular boasts a list of partners ranging from **Procter & Gamble** to **Shell**, **Total** (oil and gas), **Bunge Ltd**., **Cosan S. A.** (Brazil), **Mercedes** and a host of leading but lesser known chemical, cosmetics, plastics and fragrances companies. Synthetic Genomics, Inc. may not have sold any products yet, but its high profile announcement of "Synthia" – a self-replicating bacterial cell with an entirely synthetic genome – and the ongoing media attention paid to founder Craig Venter has helped it close deals (both equity investments and R&D partnerships) with **Exxon**, **BP** and Malaysian palm oil conglomerate, **Genting Group** for undisclosed sums. In March 2011, **Dow Chemical** announced it would buy 20 million gallons of synthetic oil for electrical applications from California, USA-based Solazyme. Solazyme produces the fluid from sugar-eating algae.

Industry tracker *Biofuels Digest* ranks the top companies in Bio-based Chemicals, Materials and Biofuels, which includes not just high-tech start-ups like Amyris, Solazyme, etc., but also the world's biggest corporate players, such as ExxonMobil, Monsanto, Cargill, DuPont and Dow.

***Biofuels Digest's* "Hottest Companies in Renewable Chemicals and Biomaterials" for 2011-12:[iv]**

1. Genomatica
2. Solazyme
3. Amyris
4. Gevo
5. LS9
6. DuPont
7. Codexis
8. Genencor
9. Novozymes
10. ZeaChem
11. Cargill
16. Dow Chemical
20. DSM
25. DuPont Danisco

***Biofuels Digest's* "Hottest Companies in Bioenergy" for 2010-11:[v]**

1. Amyris
2. Solazyme
3. POET
4. LS9
5. Gevo
6. DuPont Danisco
7. Novozymes
8. Coskata
9. Codexis
10. Sapphire Energy
18. Genencor
30. Synthetic Genomics
35. ExxonMobil
48. Chevron
49. Monsanto

Commercial Ag Makeover? While agriculture already looms large in syn bio's world – as a consumer of agricultural feedstocks – agriculture itself is also a growing target for syn bio applications. Both **Solazyme** and Synthetic Genomics are engineering algae to produce a palm oil substitute. Solazyme's research is in collaboration with **Unilever**, which also invests in the company, along with agribusiness giant **Bunge Ltd.** and Japan's **San-Ei Gen** (a leading food ingredient manufacturer). In early 2011, Swiss company **Evolva** announced a new partnership with **BASF** to produce agrochemicals. Weeks later, **Evolva** announced it would acquire **Abunda Nutrition,** its R&D collaborator in synthetically producing ingredients such as vanilla. It's not the first time that researchers have tried to employ new biotechnologies to displace natural, high-value tropical commodities.[vi] In March 2011, **Monsanto** announced it would both invest in and collaborate with US-based **Sapphire Energy**, another algal oil producer. Monsanto is interested in algae because of what it might reap for agricultural applications, in the form of traits.[vii] Sapphire's CEO Jason Pyle explains the appeal of the partnership for his company: "The biggest thing Monsanto brings is that it solidifies our hypothesis, that [in order to solve the problem of fossil fuels] you have to expand the resource base. It can't be about simply changing one thing into another. You have to create a new commercial agriculture."[viii]

Global Energy Giants Inching towards Bioeconomy: Industry statistics on world energy consumption put the "Green Economy" in much-needed perspective: In 2010 the world's energy consumption grew by 5.6% - faster than any year since 1973.[ix] Fossil fuels accounted for 88% of the world's primary energy (oil 34%; coal 30%; gas 24%). Nuclear, hydroelectric and "renewables" account for the remaining 12%. Non-hydro "renewables" (wind, geothermal, solar, biomass and waste) – including biofuels – account for 1.8% global energy consumption. *World biofuels production grew by 14% in 2010 – but accounted for just one-half of one percent of global primary energy consumption.*[x] The world's top 10 energy companies account for 25% of the estimated $7 trillion energy market. Many of the world's largest energy enterprises are high-profile investors in synthetic biology. Not only do they

seek a cleaner, greener image; they believe that future profits will depend on diversifying and controlling bio-based feedstocks for energy production.

Biofeedstocks for Industrial Chemical Production: The world's 50 largest chemical corporations control a global market valued at $697 billion in 2009. The top 10 chemical firms account for about 40% of the market. "Petrochemicals," by definition, are derived from petroleum and other fossil fuels. With soaring costs, unpredictable supplies and more challenging extractions, the industry is already making a transition from petrochemicals to biomass feedstocks. (In 2010, the world's top 50 chemical corporations rebounded with combined sales of approximately $850 billion, an increase of 25.3% over 2009.[xi])

Jurassic Green

The Return of the Dinosaurs: *Once More with Fueling?*

Wall Street describes the energy industry as the "Mother of all Markets." Until about 200 years ago, however, the energy industry and the biomass industry were essentially one. We heated our homes with firewood; fueled our horses and oxen with hay; and lit our pathways with whale blubber. The steam engine and, later, the internal combustion engine turned the energy market from living carbon to fossilized carbon as coal and then petroleum and natural gas took center stage in our anything-but Green Economy. Whatever our fields and forests could do, we discovered, could be done by dinosaurs and the food they once ate (i.e., ancient carbon).

But the energy industry (including petrochemicals) never lost interest in living carbon and "alternative" energy sources. ExxonMobil (then Standard Oil of New Jersey) positioned itself to control agricultural inputs turning petrol stations into farm supply centres including fertilizers and chemicals. With the oil crisis of the early 1970s, Shell Oil, Occidental Petroleum, Atlantic Richfield and Union Carbide all moved into seeds. In the late '70s and early '80s, Shell bought more than 100 seed companies and briefly became the world's biggest multinational seed enterprise.[xii] In the early days of biotechnology, petrochemical and pharmaceutical companies sought new ways to monopolize living carbon – less through the control of crops – more through biofermentation processes that, they theorized, would move agricultural production from fields to factories. Galvanized by the oil crises and the Club of Rome's *Limits to Growth* predictions, the energy market also moved to wind and nuclear power.

By the mid-1980s, the bloom was off energy's first Green Economy. Oil prices fell; biofermentation proved itself either premature or impossible; wind power failed to scale up and nuclear power ran aground at Three Mile Island and Chernobyl. (See box, *The Great Green Technological Transformation*, below.) The oil majors dumped seeds and went into deep-sea drilling. Only chemical companies like Monsanto and DuPont (and, later, Syngenta) stayed to reap the monopoly profits from using biotech to merge their pesticide and seed sales.

But now they're back. The combination of Peak Oil, BP oil spills and, especially, alarm over greenhouse gases and climate change have made the future profitability of fossil carbon more challenging and so the dinosaurs are returning to their historic habitat. Whatever fossil carbon can do, they assure us, living carbon can do as well. Instead of biotech and biofermentation, there is now synthetic biology promising to convert any kind of biomass into any kind of plastic, chemical, fuel or (even) food. Enter the Green Economy 2.0. …or, the *Greed Economy x 2*. The potential profits from merging fossil carbon and living carbon are huge. The energy market weighs in at about $7 trillion

per year but the agricultural/biomass economy rings up at least $7.5 trillion in annual sales. Wall Street got it wrong: if energy is the Mother of all Markets, agriculture (or biomass) is the Fodder.

---

[i] BCC Research, summary of "Synthetic Biology: Emerging Global Markets," June 2009: http://www.bccresearch.com/report/BIO066A.html

[ii] Global Industry Analysts, summary of "Synthetic Biology: A Global Market Report," 13 July 2010: http://www.prweb.com/releases/synthetic_biology/genetic_engineering/prweb4247114.htm

[iii] BCC Research, summary of "Synthetic Biology: Emerging Global Markets," June 2009: http://www.bccresearch.com/report/BIO066A.html

[iv] Jim Lane, "30 Hottest Companies in Renewable Chemicals and Materials," *Biofuels Digest*, 27 July 2011: http://www.renewableenergyworld.com/rea/news/article/2011/07/30-hottest-companies-in-renewable-chemicals-and-materials.

[v] Jim Lane, "50 Hottest Companies Hottest Companies in Bioenergy for 2010-11," *Biofuels Digest*, 7 December 2010: http://biofuelsdigest.com/bdigest/2010/12/07/the-50-hottest-companies-in-bioenergy-for-2010-11/.

[vi] ETC Group (RAFI), *Vanilla and Biotechnology*, 1987: http://www.etcgroup.org/en/node/541.

[vii] Monsanto news release, "Monsanto Company and Sapphire Energy Enter Collaboration to Advance Yield and Stress Research," 8 March 2011: http://monsanto.mediaroom.com/index.php?s=43&item=934.

[viii] Jim Lane, "Monsanto invests in Sapphire: goes hunting for yield traits in the wild, wild wet," *Biofuels Digest*, 9 March 2011: http://biofuelsdigest.com/bdigest/2011/03/09/monsanto-invests-in-sapphire-goes-hunting-for-yield-traits-in-the-wild-wild-wet/.

[ix] BP, *BP Statistical Review of World Energy June 2011*, p. 2.

[x] *Ibid*., p. 39.

[xi] Alexander H. Tullo, "Global Top 50," *Chemical & Engineering News*, 26 July 2010: http://pubs.acs.org/cen/coverstory/89/8930cover.html.

[xii] Pat Mooney," The Law of the Seed," *Development Dialogue*, 1983:1-2, Table 23, p. 96.