BIOTECH BIOFUELS: HOW PATENTS MAY SAVE BIOFUELS AND CREATE EMPIRES

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INTRODUCTION

The United States' primary transportation energy sources are fossil fuels, namely, gasoline and diesel. These products have high environmental, security, and financial costs. A strong emphasis has been placed on biofuels, especially ethanol and biodiesel, to lessen the United States' reliance on fossil fuels. Historically, high production costs, lack of infrastructure, return on investment anxieties, and concerns about scaling-up production have slowed the development of these alternative technologies. Today, biotechnological solutions are lowering productions costs and making large-scale production more economically feasible. Patents can lessen anxieties about investment, as they provide long-term protection[1] and market exclusivity for the patented technologies. As biofuels production is a relatively new field, there are many opportunities for companies to patent technologies that become industry standards, thereby increasing their chances of emerging as dominant players in the field. Various patent approaches can maximize a company's chances. Moreover, replacing a significant portion of the fuel supply with biofuels would require high-volume production, and this will require technologies that can reliably produce a uniform product on a large scale. The uniformity necessitated by large-scale production facilities will likely be a product of a few patented biotech platforms. Thus, the first to patent platform technologies will likely emerge as one of the leading companies in the field, and may even create a dominating market presence.

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1. A standard patent term is twenty years from the filing date, plus time added on for administrative or regulatory delays.

I. BACKGROUND

Biotechnology is already making a big impact on biofuel[2] production, and several companies are attempting to increase and protect their market share with patents. Driving this push is the hope that any given technology becomes the standard for the biofuel industry, particularly because it is a new industry with few entrenched companies and standards. Whoever patents the standard procedures or technologies, or platform technologies,[3] will have the right to exclude competitors from using the technology for up to twenty years,[4] with possibly longer periods of time if patents are sought on improvements.[5] This exclusionary right should ameliorate some of the anxieties about investing in biofuels, as the company that owns rights to a platform technology should be able to recoup investment by either using its technology, licensing it to others, or both.

Patents have allowed companies not only to become the dominant players in certain areas, but also to gain substantial portions of the market. For instance, the most powerful tool of modern genetic engineering is a method used in cloning genes and DNA fragments, the polymerase chain reaction (PCR) and the enzymes involved in the process.[6] This technique revolutionized science and became an indispensible procedure that was used in all genetic engineering, molecular biology, and genetic research, spawning the creation countless procedures and technologies.[7] One company, Cetus Corporation, was able to consolidate all of the patent rights to

2. The term "biofuel," as used herein, generically refers to any fuel that is produced from renewable biomass and that is used to replace or reduce fossil fuel use. "Biofuels" are also known as "renewable fuels" or "additional renewable fuels," but for consistency sake, the term "biofuels" will be used throughout the article. *See* Energy Independence and Security Act of 2007 § 201, 42 U.S.C. § 7545(o)(1)(A) (2006 & Supp. 2007) (defining "additional renewable fuel" as "fuel that is produced from renewable biomass and that is used to replace or reduce the quantity of fossil fuel present in home heating oil or jet fuel").

3. The term "platform technologies," as used herein, generically refers to technologies that become industry standards or that enable other technology to be developed from it.

4. As noted previously, a standard patent term is twenty years from the filing date, plus time added on for administrative or regulatory delays.

5. Patent policy and its implications on societal effects and entrepreneurial development, although potentially significant, are beyond the scope of this article.

6. One such enzyme is the Taq DNA polymerase from the thermaphilic bacterium *Thermus aquaticus*. *Advice on How to Survive the Taq Wars: Insights on Purchasing Preferences & Analysis of Price Sensitivity and Elasticity of Demand*, GENETIC ENGINEERING & BIOTECHNOLOGY NEWS, May 1 2006, *available at* http://www.genengnews.com/gen-articles/advice-on-how-to-survive-the-taq-wars/1656/.

7. *History and Development of the Polymerase Chain Reaction (PCR)*, MOLECULAR STATION, http://www.molecularstation.com/pcr/history-of-pcr/#pcrintro (last visited Nov. 8, 2010). Despite being discovered in 1983, it is still a platform technology today.

this platform technology.[8] It sold the rights to the technology to Hoffman-La Roche, which in turn made billions of dollars from its licensing revenues and also developed and patented numerous technologies derived from it.[9]

Roundup Ready plants, like Roundup Ready Soybeans, are another example of a platform technology and patent strategy that created a dominant market presence.[10] Monsanto developed genetically modified plants that were resistant to its glyphosate herbicide, commercially known as Roundup. This technology enabled farmers to spray only one herbicide, and less frequently, to kill all types of weeds while still leaving the crops unharmed. This development revolutionized the agricultural field and led to Monsanto's Roundup Ready Soybeans having a ninety-three percent market share for U.S. soybean plantings.[11] By patenting the rights to a technology that became an industry standard, Monsanto became a dominant market force.

Patenting biofuels technology in its early stages of research and development is critical. As a general rule, early entrants and adopters are more likely to improve and develop the core technologies that become industry standards; this, in turn, enables broader patent rights. Broader patents more fully encompass a particular technology—thereby making it more difficult and expensive for others to develop designs around—and correspondingly, they are considered more valuable.

Patents also help companies to generate more investment and provide leverage in negotiations and cross-licensing agreements.

The obtainment of patents also helps to ease a company's anxieties about whether it can pursue a particular technology or area of development. For example, if a competitor patents a technology that is critical to a company's goals, the company may be prohibited from using that technology or forced to pay expensive licensing fees in order to proceed with the devel-

8. *See* U.S. Patent No. 4,965,188 (filed June 17, 1987); U.S. Patent No. 4,683,195 (filed Feb. 7 1986); U.S. Patent No. 4,683,202 (filed Oct. 25, 1985). All three patents have since expired. *Advice on How to Survive the Taq Wars*, *supra* note 6.

9. Joe Fore Jr., Ilse R Wiechers & Robert Cook-Deegan, *The Effects of Business Practices, Licensing, and Intellectual Property on Development and Dissemination of the Polymerase Chain Reaction: Case Study*, J. BIOMEDICAL DISCOVERY & COLLABORATION, July 3, 2006, *available at* http://www.j-biomed-discovery.com/content/1/1/7/.

10. Glyphosate-tolerant 5-enolpyruvylshikimate-3-phosphate Synthases, U.S. Patent No. 6,248,876 (filed Aug. 20, 1998).

11. Jack Kaskey, *Monsanto's Roundup Ready Soybeans Probed by Justice (Update4)*, BLOOMBERG BUSINESSWEEK, Jan. 14, 2010, http://www.businessweek.com/news/2010-01-14/monsanto-says-investigators-request-more-information-update1-.html. The increased use of the glyphosate-resistant trait in genetically modified plants also led to greater sales of Monsanto's glyphosate herbicide.

opment of its own technology. However, if the company had filed a patent application, it would potentially own rights to that technology, or because the application was published, prevent others from patenting it, thus eliminating potential landmines.

Patents are particularly crucial for the biofuels industry because large-scale production facilities require standardized procedures and technologies to produce large amounts of uniform fuel. Because of this need for uniformity, a few patented biotech platforms will likely become the new industry standards. Thus, the first companies to patent such platform technologies will likely emerge as leaders in the field.

A. Biofuels

Unlike fossil fuels,[12] biofuels can be replenished in a relatively short amount of time. They are broadly defined as any fuel that is produced from renewable biomass that replaces or reduces fossil fuel use.[13] In essence, energy produced from biomass is solar energy which plants have converted to sugar or sugar complexes. Currently, the biofuels that are most notably being pursued include ethanol derived from various sources, biodiesel,[14] and higher alcohols like propanol and butanol.[15]

Facilitating the drive to increase biofuels production—and presumably innovation—the U.S. government mandated stepwise increases in conventional and advanced biofuels development with the Energy Independence and Security Act of 2007.[16] Title II of the Act categorizes biofuels into two main groups—conventional and advanced biofuels—which are differentiated by their originating material and chemical properties.[17] Conventional biofuel is ethanol derived from corn starch (corn ethanol).[18] Advanced biofuels are broadly construed as cellulosic ethanol, ethanol from non-corn based sugar and starch, ethanol from other plant or animal waste material, biodiesel, biogas (gas from landfills or waste treatment centers), other alcohols derived from biomass, and any other biomass derived fuel.[19] While

12. The term "fuels," as used herein, refers to transportation fuels.

13. *See supra* note 2 and accompanying text.

14. *See Technology*, SOLAZYME, http://www.solazyme.com/content/technology (last visited Nov. 8, 2010).

15. *See* Shota Atsumi, Taizo Hanai & James C. Liao, *Non-fermentative Pathways for Synthesis of Branched-Chain Higher Alcohols as Biofuels*, NATURE, Jan. 3, 2008, at 86.

16. Energy Independence and Security Act of 2007 § 202, 42 U.S.C. § 7545(o)(2) (2006 & Supp. 2007).

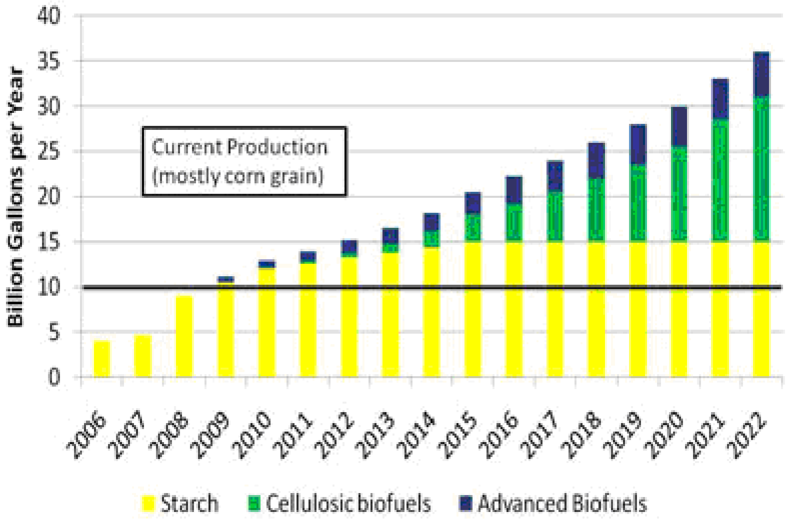
17. 42 U.S.C. § 7545(o)(1)(B), (F).

18. 42 U.S.C. § 7545(o)(1)(F).

19. 42 U.S.C. § 7545(o)(1)(B).

the mandated conventional biofuel production levels stabilize after about 2015—with only slight increases from 2010 levels—the mandated advanced biofuels production levels increase dramatically, with the greatest increases designated for cellulosic ethanol.[20]

EISA 2007 RSA MANDATE[21]



Approaches to increase efficiency in biofuels production will likely focus on a few key steps: (1) creating plants with higher yield of fuel or substrate (engineering/breeding plants that produce more fuel or substrate), (2) extracting more fuel or substrate from plants, (3) extracting that fuel or substrate more efficiently, (4) fermenting/metabolizing ethanol quicker and more efficiently, (5) using less energy to grow and harvest plants, and (6) breeding or modifying plants to grow faster. Accordingly and as discussed below, these steps also appear to be the focus of many patents and patent application filings from several biotech companies, and potentially represent areas where a few companies will develop some of the industry's platform technologies.

20. 42 U.S.C. § 7545(o)(2)(B)(i). Cellulosic ethanol is defined as renewable ethanol fuel derived from any cellulose, hemicellulose, or lignin that originates from renewable biomass. 42 U.S.C. § 7545(o)(1)(E).

21. *Policy*, MICH. ST. U. EXTENSION BIOENERGY, http://bioenergy.msu.edu/other/policy.shtml (last visited Nov. 8, 2010) ("Figure 1. Renewable Fuel Standard production goals set in the 2007 Energy Independence and Security Act").

B. *Costs of fossil fuels are greater than what is paid at the pump.*

Replacing fossil fuels with renewable fuels is desirable for several reasons. Fossil fuels are undesirable commodities for long-term use due to their volatile pricing, geopolitical instability in production/extraction areas, diminishing supply, environmental impacts, and increasing costs, among other reasons.

The low cost of fossil fuels for consumers (i.e., a low price per gallon) is a likely reason that a transition away from fossil fuels has not been pursued with greater zeal. However, there are external costs not factored into the price per gallon model that are paid indirectly by consumers. These include oilfield defense expenditures,[22] loss of domestic employment, development and investment losses, loss of government revenues, and environmental cleanup and remediation costs.[23]

Nevertheless, the undesirable aspects of fossil fuels and the government-mandated support for biofuels put them in a commanding position to displace fossil fuels' market share.

C. *Ethanol*

Ethanol production is the oldest form of biotechnology.[24] The same alcohol that exists in beer, wine, and spirits is used as a transportation fuel, albeit in higher concentrations.[25] Ethanol is produced by the conversion of sugars (carbohydrates) into alcohol by a process known as fermentation.[26] Whether it is the sugar from grapes, grains, or otherwise, the basic process involves microbes, primarily yeast,[27] that break down sugars and transform them into alcohol through a biochemical process.[28]

22. Some authors estimate that it costs the United States $49.1 billion annually to protect foreign oil fields and $137.8 billion annually if Operation Iraqi Freedom is factored in. Milton R. Copulos, *The Hidden Cost of Oil: An Update*, NAT'L DEF. COUNCIL FOUND. 2 (Jan. 8 2007), http://ndcf.dyndns.org/ndcf/energy/NDCF_Hidden_Cost_2006_summary_paper.pdf.

23. *Id.* at 2–4.

24. Simon Ostergaard, Lisbeth Olsson & Jens Nielsen, *Metabolic Engineering of* Saccharomyces cerevisiae, 64 MICROBIOLOGY & MOLECULAR BIOLOGY REV. 34, 34 (2000), *available at* http://mmbr.asm.org/cgi/content/full/64/1/34.

25. Nancy W. Y. Ho, Zhengdao Chen & Adam P. Brainard, *Genetically Engineered* Saccharomyces *Yeast Capable of Effective Cofermentation of Glucose and Xylose*, 64 APPLIED & ENVTL. MICROBIOLOGY 1852 (1998), *available at* http://aem.asm.org/cgi/reprint/64/5/1852; *see also* Ostergaard, Olsson & Nielsen, *supra* note 24.

26. Ostergaard, Olsson & Nielsen, *supra* note 24, at 34–50.

27. Yeast, or *Saccharomyces cerevisiae*, is a microorganism in the Kingdom Fungi. *Id.* It has been used in baking and fermenting alcohol for thousands of years. *Id.* It is also one of the most studied organisms in microbiology and is commonly used for molecular biology experiments. *Id.*

28. *Id.*

Ethanol biofuels fall into two categories: corn-starch ethanol and cellulosic ethanol. Corn ethanol is derived from starch extracted from corn kernels (also known as conventional ethanol or conventional biofuels).[29] Cellulosic ethanol originates from plant matter which is broken down through various processes into simple sugars subsequently fermented.[30] Due to advances in biotechnology and governmental mandates, the focus is shifting away from corn-starch ethanol, and toward cellulosic ethanol, algae-produced ethanol, and higher alcohols.[31]

D. Corn Starch & Other Starch-based Ethanol

Conventional ethanol is ethanol made from corn starch, which is present in many grains, corn kernels being the most common source used for ethanol production.[32] Starch is made of chains of sugars[33] that get broken down and fermented into ethanol.[34]

There are many inefficiencies in making conventional ethanol from corn. To begin with, starch makes up only fifty percent of kernels, which in turn are small parts of an ear of corn.[35] The corn plant itself contains a lot of other unused mass, like the stalks, cobs, roots, leaves, etc. On the whole,

29. Energy Independence and Security Act of 2007 § 201, 42 U.S.C. 42 U.S.C. § 7545(o)(1)(B), (F) (2006 & Supp. 2007).

30. E. BOULLANGER, DISTILLERIE AGRICOLE ET INDUSTRIELLE (1924), *translated in* F. Marc de Piolenc, *Wood Alcohol*, JOURNEYTOFOREVER.ORG, http://journeytoforever.org/biofuel_library/wood_alcohol.html (last visited Dec. 30, 2010).

31. *See* MINN. PROJECT, TRANSPORTATION BIOFUELS IN THE UNITED STATES: AN UPDATE (2009), *available at* http://www.mnproject.org/pdf/TMP_Transportation-Biofuels-Update_Aug09.pdf; *see also* 42 U.S.C. § 7545(o)(2).

32. Jon Evans, *Wet Better than Dry for Ethanol*, 4 BIOFUELS, BIOPRODUCTS & BIOREFINING 1 (2010), *available at* http://onlinelibrary.wiley.com/doi/10.1002/bbb.200/pdf.

33. Starch is a carbohydrate molecule, also known as a polysaccharide, that is made of glucose molecules joined together to form chains of the sugars by chemicals bonds known as alpha-glycosidic bonds. Ostergaard, Olsson & Nielsen, *supra* note 24, at 34–50. These chains are interconnected with other chains and form complex structures. *Id.* A process known as hydrolysis breaks apart the starch and frees the simple sugars. *Id.*

34. Starch needs to be broken down into simple sugars because microbes like yeast cannot metabolize (eat) such large molecules. Evans, *supra* note 32, at 7. An analogy is humans eating hamburgers. *Id.* They cannot walk up to a cow and take a bite; the meat has to be broken down into manageable pieces that can fit into 'mouths' and can be digested. *Id.* The process generally involves grinding up whole corn kernels into flour and then combining the flour with water to produce a starchy mash. *Id.* Enzymes are added to the starchy mash to break down the starch into basic sugars. *Id.* Yeast is then added to the mash and it ferments the sugars into ethanol. *Id.*

35. *Id.*; *see also Corn Kernel Components*, NEW ENERGY & FUEL (Dec. 9, 2009), http://newenergyandfuel.com/http:/newenergyandfuel/com/2009/12/31/a-20-more-ethanol-production-process/corn-kernel-components/.

a lot of energy goes into producing a corn plant, while only a small fraction of the plant is starch that is ultimately used to produce ethanol.[36]

Corn is an energy intensive crop that requires a lot of inputs and resources to grow into a mature crop.[37] For instance, corn plants need to be planted every year, and are susceptible to insects, diseases, and competition from other plants, necessitating significant pesticide use.[38] They also require added nutrients to fully mature.[39] Accordingly, substantial use of insecticides, fungicides, herbicides, and fertilizers is required.[40] All of these inputs require energy and time to manufacture and distribute, and increase the resource expenditure to grow the plants.[41]

Despite the high resource expenditures to produce corn, corn ethanol is still energy efficient to produce, and biotechnology and improved methods are making it even more efficient.[42] Furthermore, use of corn ethanol as a substitute for traditional fossil fuels decreases greenhouse gases like CO_2 emissions anywhere from eighteen to twenty-eight percent,[43] with some sources saying as high as fifty-nine percent.[44]

36. *Net Energy Balance of Ethanol Studies Corn Production Inputs Per Acre Comparison Chart*, NRBP.ORG, http://www.nrbp.org/pdfs/ethanol_balance.pdf (last visited Dec. 30, 2010)*; see also* Bruce Erickson, Alan Miller & Craig Dobbins, *Producing the 2010 Crop: Input Cost Projections & Analysis*, TOP FARMER CROP WORKSHOP NEWSL. (Top Farmer Crop Workshop, Purdue, Ind.), Sept. 2009, at 1, http://www.agecon.purdue.edu/topfarmer/newsletter/TFCW9_2009.pdf; *Corn Kernel Components*, *supra* note 35.

37. *Net Energy Balance of Ethanol Studies Corn Production Inputs Per Acre Comparison Chart*, *supra* note 36; Erickson, Miller & Dobbins, *supra* note 36; *Corn Kernel Components*, *supra* note 35.

38. *Net Energy Balance of Ethanol Studies Corn Production Inputs Per Acre Comparison Chart*, *supra* note 36; *see also* David Pimentel & Tad W. Patzek, *Ethanol Production Using Corn, Switchgrass, and Wood; Biodiesel Production Using Soybean and Sunflower*, 14 NAT. RESOURCES RES. 66 (2005).

39. *Net Energy Balance of Ethanol Studies Corn Production Inputs Per Acre Comparison Chart*, *supra* note 36; Pimentel & Patzek, *supra* note 38.

40. *Net Energy Balance of Ethanol Studies Corn Production Inputs Per Acre Comparison Chart*, *supra* note 36; Pimentel & Patzek, *supra* note 38.

41. *Net Energy Balance of Ethanol Studies Corn Production Inputs Per Acre Comparison Chart*, *supra* note 36; Pimentel & Patzek, *supra* note 38.

42. Katie Bolcar, Expanding the Life Cycle Analysis Boundaries for Corn-based Ethanol to Include Land-Use Change: Implications for Greenhouse Gas Emissions (Aug. 27, 2007) (Master's project, Duke University), *available at* http://dukespace.lib.duke.edu/dspace/bitstream/10161/393/1/MP_kcb10_a_082007.pdf. 0.78 million British thermal units (Btu) of fossil energy consumed for each 1 million Btu of ethanol delivered, compared to 1.23 million Btu of fossil energy consumed for each 1 million Btu of gasoline delivered. *Ethanol: The Complete Energy Lifecycle Picture*, U.S. DEP'T ENERGY, OFF. ENERGY EFFICIENCY & RENEWABLE ENERGY (Mar. 2007), http://www1.eere.energy.gov/vehiclesandfuels/pdfs/program/ethanol_brochure_color.pdf.

43. *Ethanol: The Complete Energy Lifecycle Picture*, *supra* note 42.

44. *Cellulosic Ethanol Overview*, POET, http://www.poet.com/innovation/cellulosic_ethanol.asp (last visited Dec. 30, 2010).

E. Biotech Improvements to Corn Efficiency

As noted, ethanol derived from corn is already energy efficient to produce using conventional farming techniques.[45] Basic plant breeding and fertilization advancements have increased corn yields steadily for the past 100 years,[46] resulting in an increase of bushels per acre and, hence, more corn starch. But since the late 1990s, biotechnology has increasingly played a role in allowing corn growing to become even more efficient and with less input requirements.[47]

Biotechnology first made corn growing more efficient with the advent of corn plants that were genetically modified to produce their own insecticides (e.g., BT Corn), and that were genetically modified to be resistant to herbicides (e.g., Roundup Ready Corn).[48] BT Corn decreased insecticide use, while Roundup Ready Corn decreased overall herbicide use amounts and application frequency.[49] Since then, various companies have made variations on technologies that are decreasing resource expenditures and making the production of kernels more efficient.[50]

However, technological improvements did not stop at the plant stage. Improvements to starch processing, starch extraction, the enzymes that break down starch, and uses of the "excess" parts of the corn plant have

45. Bolcar, *supra* note 42.

46. In the last 50 years alone, average corn yields from 1960 to 2009 have increased from under 55 bushels per acre, to over 150–160 bushels per acre. *Table 10. Corn and Soybeans: Harvested Acreage and Yield Per Acre*, IOWA ST. U. DEP'T ECON., http://econ2.econ.iastate.edu/outreach/agriculture/periodicals/chartbook/Chartbook2/Tables/Table10.pdf (last visited Nov. 8, 2010); *2007 Corn Crop a Record Breaker, USDA Reports*, U.S. DEP'T AGRIC. NAT'L AGRIC. STAT. SERV. (Jan. 11, 2008), http://www.nass.usda.gov/Newsroom/2008/01_11_2008.asp. Since 1930, yield has risen from about 25 bushels per acre to about 150–160 bushels per acre. R.L. (Bob) Nielsen, *Corn Yield Trends for Indiana 1930 – 2003*, PURDUE U. DEP'T AGRIC., http://www.agry.purdue.edu/ext/corn/news/articles.03/cornyldtrend2003.html (last updated Jan. 2004).

47. *Benefits of Biotechnology*, MONSATO, http://www.monsanto.com/products/Pages/benefits-of-plant-biotechnology.aspx (last visited Dec. 30, 2010); *see also Ethanol Facts: Agriculture*, RENEWABLE FUELS ASS'N, http://www.ethanolrfa.org/pages/ethanol-facts-agriculture (last visited Dec. 30, 2010).

48. *Core Technology*, MENDEL, http://www.mendelbio.com/technology/index.php (last visited Dec. 30, 2010).

49. Roundup Ready Corn decreased herbicide use amounts and application frequency by permitting spraying a powerful herbicide that killed all plants but the target corn plants, thereby lessening competition for resources from weeds. *Roundup Ready Corn 2*, MONSANTO, http://www.monsanto.ca/seeds_traits/roundup_ready/corn/default.asp (last visited Dec. 30, 2010); *see also* Mark Moore, *Preemergence Herbicides Are Back In Demand*, FARM INDUSTRY NEWS (Nov. 18, 2010), http://farmindustrynews.com/herbicides/preemergence-herbicides-are-back-demand.

50. For example, DuPont, Syngenta, and Monsanto. *See* Ian Berry, *Pioneer Hi-Bred Says Syngenta Deal To Expand Seed Offerings To Farmers*, NASDAQ, Dec. 15, 2010, *available at* http://www.nasdaq.com/aspx/stock-market-news-story.aspx?storyid=201012141752dowjonesdjonline000421&title=pioneer-hi-bred-says-syngenta-deal-to-expand-seed-offerings-to-farmers.

been, and continue to be, made. For instance, several companies produce and have patented more robust enzymes that break down starch more quickly than their predecessors, which, in turn, cuts down on processing and development costs.[51] Enzyme cost has historically been a large fraction of the expense in conventional ethanol production.[52] With biotechnological developments, these costs have decreased from $5.50 per gallon of ethanol produced to $0.50 per gallon,[53] with some estimates as low as $0.10 per gallon,[54] justifying optimism about the ability of this fuel source to become economically feasible.

Novozymes and Danisco AS (and its subsidiary Genencor) are two companies that develop enzymes that break down starch for fermentation. They have used aggressive patenting and litigation strategies to attain seventy percent of the market share between them, while simultaneously decreasing fuel development costs.[55] For instance, Danisco, along with its subsidiary Genencor, is one of the largest enzyme producers and has over 290 issued U.S. patents[56] that relate to various steps in ethanol production, including enzymes that break down starch and cellulose into simple sugars, and processes to pretreat the starting material.[57]

Novozymes, another large producer, has over 240 issued U.S. patents that relate in some way to ethanol production, with many specifically relating to enzyme and fermentation technologies.[58] However, despite having such a large share of the marketplace, the two companies still try to expand

51. *Biomass Refining: Technology is Driving Down the Cost of Producing Biofuels*, CERES, http://www.ceres.net/AboutUs/AboutUs-Biofuels-Refining.html (last visited Nov. 8, 2010).

52. *Danisco Backs Novozymes' 2nd-gen Biofuel Cost View*, REUTERS, Mar 18, 2010, *available at* http://www.reuters.com/article/idUSLDE62H1WN20100318.

53. *Id.*

54. *Biomass Refining: Technology is Driving Down the Cost of Producing Biofuels*, *supra* note 51.

55. Christian Wienberg, *Danisco Sues Novozymes in London as Pair 'Sits on 70% of Enzyme Market,'* BLOOMBERG, July 20, 2010, http://www.bloomberg.com/news/2010-07-20/danisco-sues-novozymes-in-london-as-pair-sits-on-70-of-enzyme-market-.html; *Danisco Backs Novozymes' 2nd-gen Biofuel Cost View*, *supra* note 52.

56. All estimates of the number of patents and applications a company has are based off of information publicly available on the U.S. Patent and Trademark Office patent and application database. The actual number of patents and applications these companies have could be larger due to applications that have not yet been published, assignment documents that have not yet been recorded or processed, and licensing agreements or collaborations that have not yet been made public, among other reasons.

57. *E.g.*, Purified Cellulase and Method of Producing, U.S. Patent No. 6,017,870 (filed Oct. 9, 1996); Mutant α-Amylase, U.S. Patent No. 5,958,739 (filed June 6, 1996); Expression of Granular Starch Hydrolyzing Enzyme in Trichoderma, U.S. Patent No. 7,335,503 (filed Dec. 4, 2006).

58. For example, Polypeptides Having Alpha-Amylase Activity and Polynucleotides Encoding Same, U.S. Patent No. 7,833,771 (filed Dec. 5, 2007); Alkaline Bacillus Amylase, U.S. Patent No. 7,659,101 (filed Dec. 15, 2005); Methods for Enhancing the Degradation or Conversion of Cellulosic Material, U.S. Patent No. 7,608,689 (filed Sept. 29, 2006).

their reach into the ethanol production market by suing each other for using their respective technologies.

For instance, in 2007 Danisco settled a suit with Novozymes for over fifteen million dollars for infringing on one of Novozymes' bioethanol enzyme patents.[59] A few years later and on the same day that Novozymes' U.S. Patent No. 7,713,723 (the '723 patent) issued,[60] it again sued Danisco for patent infringement to prevent them from using or selling certain enzymes that break down starch.[61]

Less than two months after Novozymes filed its '723 patent infringement suit, Danisco sued Novozymes in Europe for infringing one of its bioethanol patents.[62] The fact that these two companies, which already have a substantial share of the enzyme market and over 500 patents related to ethanol production between them, are attempting to prevent each other from using their technologies demonstrates the importance of patenting and making one's own enzymes or production technologies the industry standard. It also shows how important it is for some companies to exclude competitors from using their technologies in order to increase market share.

Other advances that led to greater efficiency from corn-derived starch include better starch extraction.[63] For instance, researchers have shown that different ways of extracting starch from kernels can generate up to eleven percent more ethanol than conventional processes.[64] In summary, this process cuts down the cost of production while increasing the amount of product attained from the same amount of starting raw material.[65]

A different source of starch that shows promise and that lacks many of the disadvantages of corn starch is duckweed.[66] Duckweed is a small, grain-sized plant that can survive on the surface of virtually all types of open freshwater environments.[67] It produces from five to six times more

59. *Novozymes Again Sues Danisco*, COPENHAGEN POST, May 14, 2010, http://www.cphpost.dk/business/119-business/48973-novozymes-again-sues-danisco.html.

60. Alpha-Amylase Mutants with Altered Properties, U.S. Patent No. 7,713,723 (filed Dec. 22, 2009).

61. *Id*. The amylase enzymes of the '723 patent were genetically modified to have increased stability and be less sensitive to various environmental factors, like high temperature and low pH conditions, which make ethanol production more consistent and efficient. *Id.*; *see also Novozymes Again Sues Danisco*, *supra* note 59.

62. Wienberg, *supra* note 55.

63. Evans, *supra* note 32, at 7.

64. *Id*. Rather than grinding up the whole kernels into flour, of which only 50% is starch, and fermenting the resulting mash, the researchers found that a processes of removing a kernel's shell (outer pericarp) first, concentrated the starch and helped break it down more efficiently. *Id.*

65. *Id.*

66. *Tiny Super-Plant Can Clean Up Animal Waste, Be Used for Ethanol Production*, PHYSORG.COM (Apr. 7, 2009), http://www.physorg.com/news158321497.html.

67. *Id.*

starch per acre than corn and requires less energy and processing to free it.[68] It also does not compete with the human food chain, and it functions as a water purifier in waste treatment.[69] This property allows it to be manufactured at waste treatment facilities and used to clean up waste at industrial farms; whereas, as a byproduct, it can be harvested for the corresponding starch it produces which gets turned into ethanol.[70] However, this technology may have analogous pitfalls to algae, as discussed below.

F. Cellulosic Ethanol

Cellulose is the primary component of all plants. It makes up their cell walls, stalks, leaves, branches, bark, etc. Cellulose for a plant is like the frame for a house—it gives plants their structure and form. Paper, cloth, and lumber are all comprised of cellulose. It is the most common organic compound on Earth.

Cellulose is made of sugar molecules, specifically glucose, that are linked together chemically.[71] However, unlike the sugar in starch, which is relatively accessible, the sugar in cellulose is less accessible because it is tightly bound and compacted by chemical bonds.[72] Due to this tight bonding, accessing the sugar in order to free it for fermentation requires more effort and energy, resulting in higher procedural and input costs.[73] Yet despite the sugar in cellulose being less accessible than that of starch, cellulosic ethanol technology is being vigorously pursued by biotechnology companies because of the copious quantities of sugar that cellulose contains, and the ease of producing its source, biomass.[74]

While corn-starch ethanol can only be made from starch in a corn kernel, which itself is a small part of the corn plant, cellulosic ethanol can be made from any part of a plant.[75] Furthermore, virtually every plant and

68. *Id.*

69. *Id.*

70. *Id.*

71. Yoshiharu Nishiyama, Paul Langan & Henri Chanzy, *Crystal Structure and Hydrogen-Bonding System in Cellulose Iβ from Synchrotron X-ray and Neutron Fiber Diffraction*, 124 J. AM. CHEMICAL SOC'Y 9074 (2002). Cellulose is a polysaccharide that comprises strands of glucose molecules that chemically bond together (by beta-glycosidic bonds) to form a rigid matrix with other strands. *Id.* These beta-glycosidic bonds require more energy to break than alpha-glycosidic bonds that comprise starch. *Id.* Cellulose is further intertwined with and comprises hemicellulose, lignin, pectin and proteins that increase its rigidity and robustness. *Id.*

72. *Carbohydrates: The More Carbs the Better*, CERES, http://ceres.net/AboutUs/AboutUs-Biofuels-Carbo.html (last visited Dec. 30, 2010).

73. *Ethanol: The Complete Energy Lifecycle Picture*, *supra* note 42.

74. *Core Technology*, *supra* note 48.

75. *Cellulosic Ethanol Overview*, CERES, http://poet.com/innovation/cellulosic/index.asp (last visited Dec. 30, 2010).

plant material contains cellulose that can be converted to ethanol.[76] For instance, leaves, branches, bark, grass clippings, plant compost, etc. can all be used.[77] The ubiquitous nature of cellulose means that the biomass can be grown anywhere, including on land not traditionally used to farm and unsuitable for corn.[78] It also means that waste products of farming, like stalks, leaves, hulls, etc., can be used.[79]

There are several techniques used to break down cellulose to sugars.[80] In their most basic form, all of these processes attempt to break the chemical bonds that bind the sugars[81] together in order to free them. One procedure involves using acids to break down the plant material.[82] However, this process is expensive and the acids leave byproducts that interfere with fermentation and can modify the very sugars they are meant to free.[83] Another way to free sugars is using specific enzymes to do the work that do not interfere with downstream fermentation efforts.[84] Accordingly, this latter approach is the objective of many biotech companies.

Using enzymes to break down cellulose is common in nature.[85] Termites break down the cellulose in wood into sugars as energy sources.[86] Ruminants, like cows, contain microbes in their stomachs that convert cellulose from grasses into easily accessible energy.[87] Cellulose also breaks down naturally in some plants, like when fruits ripen and become softer (e.g., tomatoes and bananas).[88]

Enzyme producing companies like Novozymes and Danisco have been developing and producing enzymes in this area for years, with many patent application filings between them. In this regard, their patent approach is multifaceted. Their approach includes applications directed to not

76. *Cellulose*, ENCYCLOPÆDIA BRITANNICA, http://www.britannica.com/EBchecked/topic/101633/cellulose (last visited Dec. 30, 2010).

77. *Id.*

78. *Id.* Land use policy debates are acknowledged, but are outside the scope of this article.

79. *Id.*

80. A process known as cellulolysis.

81. The chemical process is known as hydrolysis.

82. *Biomass Refining: Technology is Driving Down the Cost of Producing Biofuels,* CERES, http://ceres.net/AboutUs/AboutUs-Biofuels-Refining.html (last visited Dec. 30, 2010).

83. *Carbohydrate Processing*, GENECOR, 2010, http://www.genencor.com/wps/wcm/connect/genencor/genencor/products_and_services/agri_processing/carbohydrate_processing/carbohydrate_processing_en.htm (last visited Dec. 30, 2010).

84. *Biomass Refining: Technology is Driving Down the Cost of Producing Biofuels, supra* note 82.

85. *Cellulose, supra* note 76.

86. *Id.*

87. *Id.*

88. *Id.*

only pretreating cellulose for ease in subsequent processing,[89] but also directed to enzymes that break it down into simple sugars.[90] With such a high volume of patents and pending patent applications directed at various steps in cellulosic ethanol production, coupled with years of experience, the head-start that these companies have may position them to overcome later emerging companies.

Nonetheless, a company that has not only entered the market, but already began selling cellulosic ethanol en mass is POET. POET transitioned from making ethanol from just kernel derived corn starch and developed technologies that integrated the remainder of the plant once considered waste product, like corn cobs, stalks, and leaves.[91] This technique, although not abandoning using corn plants themselves, maximizes the amount of energy that can be harvested from a corn plant.[92] In essence, the process makes cellulosic ethanol from the leftover products, while still being able to use the corn kernels for either food consumption or ethanol production.[93] Additionally, the company uses the biogas that is normally a byproduct of cellulosic ethanol production, and cycles it back into its operations, eliminating some of its need for outside energy inputs.[94] Currently, the company has at least seven pending patent applications relating to various ethanol-producing steps.[95] Many of these applications relate to increasing efficiencies in various places in the ethanol production process. In addition to using more parts of the plant, POET also generates high-protein feed for livestock from the leftover residue from its processes, which it in turn sells as its own product.[96] Basically, POET focuses on developing and patenting technology with immediate uses in the market place, its raw material is waste-product so it is inexpensive, its technology can be converted to whatever

89. As covered in Methods for Increasing Hydrolysis of Cellulosic Material, U.S. Patent Application No. 12/638,881 (filed Dec. 15, 2009).

90. Like Polypeptides Having Cellulolytic Enhancing Activity and Polynucleotides Encoding Same, U.S. Patent Application No. 12/631,101 (filed Dec. 4, 2009).

91. *Innovation*, POET, http://www.poet.com/innovation/index.asp (last visited Dec. 30, 2010).

92. *Id.*; *see also* MINN. PROJECT, *supra* note 31.

93. Essentially using the same amount of land as conventional farming but maximizing its energy output.

94. *POET Project LIBERTY Lifecycle Analysis: Ethanol Production, Feedstock & Fuel Transportation*, POET, http://www.poet.com/media/PL_lifecycle.jpg (last visited Nov. 8, 2010).

95. *See* System for Production of Ethanol and Co-Products with Raw Starch Hydrolysis and Solvent Washing of Fermentation Product, U.S. Patent Application Nos. 12/646,766, 12/646,746, 12/646,695, 12/646,647, 12/646,720 (filed Dec. 23, 2009); System for Production of Ethanol and Co-Products Including Corn Meal, U.S. Patent Application No. 12/646,796 (filed Dec. 23, 2009); Oil Composition and Method of Recovering the Same, U.S. Patent Application No. 12/208,127 (filed Sep. 10, 2008).

96. *Producing Ethanol*, POET, http://www.poet.com/innovation/producing_ethanol.asp (last visited Nov. 8, 2010).

biomass source becomes a standard, and it adds value to its process and technology by converting byproducts into other revenue sources. In effect, POET's patenting strategy focuses on technology with immediate uses, maximizing those uses, but that also has versatility to adapt if the market shifts.

Rather than just engineering fermentation to be more efficient, or breaking down cellulose more efficiently, Mascoma Corp. filed patent applications on combining the two steps into one.[97] While yeast can normally only ferment simple sugars into ethanol but not break down cellulose, and bacteria and various enzymes could only break down cellulose but not ferment, Mascoma has developed processes and genetically modified yeast to do both. The company is seemingly attempting to patent two approaches of this technology: (1) using modified yeast to break down cellulose into simple sugars and simultaneously fermenting those sugars into ethanol, and (2) mixing one or more modified yeast strains that are efficient at breaking down cellulose with other yeast that maximize fermentation efficiency.[98]

One of the ways that it developed this technology was by isolating genes from termites and inserting them into yeast.[99] It is currently attempting to patent this technology through several approaches to maximize the technology's potential market impact. For instance, its international application, WO 2010/005551, is directed to several approaches, namely: (1) the isolated genes from termites; (2) the enzymes that those genes produce; and (3) the genetically modified yeast that produces those termite enzymes that break down cellulose.[100] Thus, in this instance, the company seemingly turned one invention into three avenues of protection, which can perhaps each have its own enforcement capabilities if different aspects of the technology become more commercially valuable in the future.

97. *See* Yeast Expressing Cellulases for Simultaneous Saccharification and Fermentation Using Cellulose, World Intellectual Property Organization (WIPO) Publication No. WO/2010/060056 (filed Nov. 23, 2009); Gene Knockout Mesophilic and Thermophilic Organisms, and Methods of Use Thereof, WIPO Publication No. WO/2010/056805 (filed Nov. 12, 2009); Production of Pure Lignin from Lignocellulosic Biomass, WIPO Publication No. WO/2010/045576 (filed Oct. 16, 2009); Flow-Through Biological Conversion of Lignocellulosic Biomass, WIPO Publication No. WO/2010/008578 (filed July 17, 2009); Isolation and Characterization of Schizochytrium Aggregatum Cellobiohydrolase I (CBH 1), WIPO Publication No. WO/2010/005553 (filed July 7, 2009); Construction of Protrophic/Celluloytic Yeast Strains Expressing Tethered and Secreted Cellulases, WIPO Publication No. WO/2009/139839 (filed May 11, 2009); Progressive Fermentation of Lignocellulosis Biomass, WIPO Publication No. WO/2009/043012 (filed Sep. 29, 2008).

98. Mascoma Corp. named the approach "Consolidated Bioprocessing."

99. *See* Heterologous Expression of Termite Cellulases in Yeast, WIPO Publication No. WO/2010/005551 (filed July 7, 2009).

100. *Id.*

G. Biomass Efficiency

In addition to developing more efficient ways of breaking down and fermenting cellulose, many companies are developing plants that produce more cellulose, that grow more efficiently, and that reduce overall inputs into their growth and extraction costs.[101] Growing a higher concentration of biomass (plant mass) in one area produces more potential energy that can be harnessed, i.e., more cellulose/sugar production per square foot results in more energy per acre. Additionally, using fewer inputs to grow plants and less energy to harvest them results in greater lifecycle energy benefits. Other considerations in choosing suitable plants for use in cellulosic ethanol production are whether they have adequate balances of cellulose concentration, the ease of extracting cellulose and breaking it down,[102] rapidity of replenishing the biomass, and volatility of yields regionally and temporally.[103] If a company expends all its resources developing technology for a plant that becomes obsolete or unsuitable, it risks being marginalized. If, however, it develops platform technologies that can be used across multiple crops, develops crops that become elite varieties, or patents genes that encode favorable traits that can be used in multiple crops, it may emerge as a dominant industry leader like Monsanto with its Roundup Ready Soybeans.

One company that is using biotechnology to produce more efficient, higher-yielding biomass crops is Ceres. Moving away from using corn, Ceres focuses its efforts on breeding plants like sorghum, switchgrass, and miscanthus for ethanol production.[104] One advantage of crops like these, particularly switchgrass and miscanthus, is that they require very few inputs, thus cutting down on energy expenditure to develop the biomass. [105]

For instance, miscanthus grows densely and up to twelve to fifteen feet or more in height.[106] Due to its growth density and height, it out-

101. For example, companies like Ceres, see *Traits from Multiple Platforms*, CERES, http://www.ceres.net/Technology/Tech-Trait.html (last visited Dec. 30, 2010), and Mendel Biotechnology, see *Increased Yield*, MENDEL, http://www.mendelbio.com/technology/increasedyield.php (last visited Dec. 30, 2010), are both pursuing increasing biomass/cellulose production.

102. For example, tree bark has a high concentration of cellulose, but it is a lot more energy intensive to free it. As a general rule, the harder the bark, the greater the cellulose concentration. The more concentrated the cellulose in a given volume, the harder and more expensive it is to extract.

103. *See Core Technology*, *supra* note 48.

104. *Products Pipeline*, CERES, http://ceres.net/Products/Products-Ovw.html (last visited Nov. 8, 2010). These crops are non-invasive and presumably have similar or less effects on biodiversity than conventional crops.

105. *See Products: Miscanthus*, CERES, http://www.ceres.net/Products/Products-Miscanthus.html (last visited Nov. 8, 2010); *Products: Switchgrass*, CERES, http://www.ceres.net/Products/Products-Switchgrass.html (last visited Nov. 8, 2010).

106. *See Products: Miscanthus*, *supra* note 106.

competes weeds, eliminating herbicide use, and also requires virtually no fertilizer.[107] Miscanthus can be harvested every spring, with plantings every ten years.[108] Switchgrass is a grass that grows up to nine feet high, can also be harvested every spring, and also requires virtually no inputs.[109] An advantage of using switchgrass over many other types of biomass crops is that it is a perennial grass, meaning that once planted, it does not need to be replanted every few years.[110] Another potential biomass source is sorghum or sweet sorghum. These plants use water very efficiently, grow up to twenty feet high, have low input requirements, high sugar levels, and can be grown in most of the continental United States.[111] All of these plants can also be easily harvested with simple mowing, which reduces harvesting and technology development expenses.

In addition to breeding them, Ceres is attempting to engineer these various plants to extract more of their required nutrients from the environment, produce more mass, be more resistant to adverse weather, and enhance cellulose-processing characteristics.[112] It uses genetic markers to find and pick the most fruitful traits, and attempts to modify plants to express them.[113] Ceres claims to have exclusive rights to over sixty U.S. patents and 250 U.S. and foreign patent applications directed to these goals.[114] Basically, Ceres is diversifying its technology development by simultaneously producing products for various platforms, thereby maximizing its odds of having a market presence in whatever biomass crop becomes the industry standard. This strategy, however, risks diluting its research and development efforts and being beat to developing a leading commercial technology, but it may still lead to inventions that provide enough patent protection to cushion its place in the market no matter which biomass crop becomes the standard.

Mendel Biotechnology is taking a different approach. Rather than focusing on developing technology for a variety of biomass crops, it is mainly concentrating on producing traits that add value to biomass crops, with

107. MINN. PROJECT, *supra* note 31, at 3.

108. *Id.*

109. *Products: Switchgrass*, *supra* note 105.

110. MINN. PROJECT, *supra* note 31, at 3.

111. *Products: Sorghum*, CERES, http://www.ceres.net/Products/Products-Sorghum.html (last visited Nov. 8, 2010).

112. *Traits from Multiple Platforms*, CERES. http://ceres.net/Technology/Tech-Trait.html (last visited Nov. 8, 2010).

113. *Technology Overview*, CERES, http://ceres.net/technology/tech-ovw.html (last visited Dec. 30 2010).

114. *About Us*, CERES, http://www.ceres.net/AboutUs/AboutUs-CompOvw.html (last visited Nov. 8, 2010); *Technology: Intellectual Property*, CERES, http://ceres.net/Technology/Tech-IP.html (last visited Nov. 8, 2008).

miscanthus being its main target.[115] For instance, it currently has over twenty U.S. patents and over forty published U.S. patent applications on a range of plant genes and processes.[116] Many of the patents and applications are directed to increasing yield, increasing environmental stress tolerance of plants, and reducing water requirements.[117] Essentially, it tries to make the biggest, most densely growing plants that have little yield variability and that use little water and other inputs. Despite its ostensible concentration on miscanthus, many of the traits it is developing may have overlapping beneficial gains for other plants too.

Thus, similar to Monsanto's approach to Roundup Ready Soybeans, by focusing its patents on the traits and genes for the traits rather than particular plants, Mendel Biotech is seemingly trying to position itself based on the value that a trait provides, rather than the crop that it is ultimately placed in. In this manner, the potential applications for and value of the patents is broadened while providing more flexibility for future licensing and business arrangements. For example, an exclusive license could be granted to one company to use a gene responsible for a desired trait in plant X, while another exclusive license is granted to another company to use a similar gene responsible for a similar trait in another plant Y.

H. Algae Biofuel

Using algae for biofuel production has spawned a variety of interesting approaches. Using algae as a fuel producer is attractive because of the ease of extracting the fuel, the lack of competition with human water consumption (it uses seawater), the ability of algae to use our waste as nutrients, and the possibilities of locating production facilities in non-desirable areas.[118] These and other reasons have led to large investments by not only biotech companies, but also oil companies.[119] Additionally, algae byproducts have many varying uses in biotechnology and as lubricants, soaps, cosmetics, human and animal nutrients, and fertilizers.[120] However, due to limited locations where temperature and seasonal factors are accept-

115. *Core Technology*, *supra* note 48; *Breeding Tools*, MENDEL, http://www.mendelbio.com/technology/breedingtools.php (last visited Dec. 30, 2010).

116. *Issued Patents*, MENDEL BIOTECHNOLOGY, http://www.mendelbio.com/newsevents/issuedpatents.php (last visited Nov. 8, 2010).

117. *Core Technology*, *supra* note 48.

118. MINN. PROJECT, *supra* note 31, at 4–5.

119. Steve Gelsi, *Fuel from Algae Growing Beyond the Laboratory: Algenol, Sapphire, Solazyme, Synthetic Genomics Draw Backing*, MARKETWATCH (March 23, 2010), http://www.marketwatch.com/story/fuel-from-algae-growing-beyond-the-laboratory-2010-03-23.

120. *See, e.g.*, *Technology*, *supra* note 14.

able and where there is steady access to seawater, algae-based fuel may have geographic restrictions that limit its practical utility for replacing fossil fuels.[121]

Algenol Biofuels uses unique technology where it grows algae and collects the ethanol that is secreted,[122] whereas almost all other biofuel production depends on dead and processed biomatter. This technology typically relies upon engineering algae to secrete ethanol directly, rather than accumulating sugars and then fermenting it.[123] Algenol Biofuels has patented,[124] and has pending applications[125] for, growing genetically modified algae in outdoor clear plastic polyethylene containers as well.[126] The company claims that this process can produce up to 6,000 gallons of ethanol per acre per year,[127] compared to about 400 gallons of corn ethanol or 2,000 gallons for biomass crops.[128] Moreover, this process eliminates the expensive and energy intensive refining process that other technologies still require.[129] This technology has also been proposed for carbon sequestration, where the algae would in theory use the carbon emissions from coal plants as input nutrients, which would provide added value if future carbon-regulation creates more costs for energy producers.[130] By patenting the underlying process of producing ethanol in this matter, and decreasing production costs while pursuing other revenue streams, Algenol may be positioning itself to own a potential platform technology that may become the industry standard. This strategy has not only helped it gain millions of dollars in grants from the Department of Energy, but also significant investment from some of the biggest oil and chemical companies.[131] Algae-

121. MINN. PROJECT, *supra* note 31.

122. Closed Photobioreactor System for Continued Daily in Situ Production, Separation, Collection, and Removal of Ethanol from Genetically Enhanced Photosynthetic Organisms, U.S. Patent No. 7,682,821 (filed Oct. 30, 2007).

123. *Id.*

124. *Id.*

125. Closed Photobioreactor System for Continued Daily in Situ Production of Ethanol from Genetically Enhanced Photosynthetic Organisms with Means for Separation and Removal of Ethanol, U.S. Patent Application No. 12/387,911 (filed May 8, 2009).

126. Algenol Biofuels patented growing genetically modified algae in outdoor clear plastic polyethylene containers in which the ethanol is secreted by the algae and is subsequently separated out from the water by a sieve-like process, all without killing the algae.

127. Gelsi, *supra* note 119.

128. *The Biomass Advantage: Projections of Per-Acre Fuel Yields*, CERES, http://www.ceres.net/AboutUs/AboutUs-Biofuels-Advantage.html (last visited Nov. 8, 2010).

129. *Overview of Technology*, ALGENOL BIOFUELS, http://www.algenolbiofuels.com/overview.htm (last visited Nov. 8, 2010).

130. *Id.*

131. *See* Joshua Kagan, *Valero Invests in Algenol: What's Going on?*, GREENTECH MEDIA (May 10, 2010), http://www.greentechmedia.com/articles/read/valero-invests-in-algenol/ (partnering with Valero and receiving $25 million from the Department of Energy); Martin LaMonica, *Algae Farm in*

based biodiesel has several potential advantages over its ethanol counterpart, but it has some downsides as well. Biodiesel comes from oils isolated from vegetable or animal fats that are later chemically modified,[132] and it has similar chemical properties to petroleum diesel oil but with fewer emissions.[133] An advantage of biodiesel[134] over ethanol is that it can use the same storage and distribution systems that current diesel uses, and it also has a high-energy output.[135] If biodiesel's use increases, there is reason to believe that algae may be its primary source. For instance, some sources estimate as much as 10,000 gallons of biodiesel can be produced per acre with algae, whereas other sources like soybeans produce dramatically less fuel per unit area (48 gallons per acre).[136] Furthermore, due to diesel's low water solubility, less energy is required to separate it from water when compared to ethanol.[137] However, only about three percent of U.S. cars run on diesel, though most trucks and buses already have engines that run on it.[138] Consequently, it may have potential to at least become a niche technology.

For instance, Solazyme is a company that has directed its focus on algal biofuels, but rather than producing ethanol, it is developing biodiesel and hydrogen gas production.[139] The company has pursued a niche market of using algae to produce biodiesel and renewable jet fuel.[140] This has in turn attracted large, niche industries like the military, and as a result of this

Mexico to Produce Ethanol in '09, CNET NEWS (June 12, 2008), http://news.cnet.com/8301-11128_3-9966867-54.html (partnering with BioFields, who paid over $100 million to license Algenol Biofuels' technology); Mara Lemos Stein, *Algenol, Dow Chemical Partner for Algae-to-Fuel Pilot Plant*, NASDAQ (June 30, 2009), http://www.nasdaq.com/aspx/company-news-story.aspx?storyid=200906301433dowjonesdjonline000558 (partnering with The Dow Chemical Co.).

132. The process consists of isolating fatty oils and modifying them by a process referred to as transesterificaiton.

133. *Biodiesel Basics*, NAT'L BIODIESEL BOARD, http://www.biodiesel.org/resources/biodiesel_basics/ (last visited Nov. 8, 2010).

134. The term ''biodiesel'' is defined by § 102 of the Energy Independence and Security Act of 2007 as "monoalkyl esters of long chain fatty acids derived from plant or animal matter." 42 U.S.C. § 17021(c)(3) (2006 & Supp. 2007).

135. MINN. PROJECT, *supra* note 31.

136. *Id.* (noting other crop outputs, such as "safflower (83 gallons per acre), sunflower (102 gallons per acre), rapeseed (127 gallons per acre), castor bean (151 gallons per acre), coconut (287 gallons per acre), and oil palm (636 gallons per acre)").

137. G. SHELEF, A. SUKENIK & M. GREEN, MICROALGAE HARVESTING AND PROCESSING: A LITERATURE REVIEW (1984), *available at* http://www.nrel.gov/docs/legosti/old/2396.pdf.

138. As of 2007, over 80% of commercial trucks and major bus networks in municipal areas ran on diesel gas. Will Thurmond, *Biodiesel's Bright Future*, THE FUTURIST, July-Aug. 2007, at 27, 28.

139. *Technology*, SOLAZYME, http://www.solazyme.com/content/technology (last visited Nov. 8, 2010).

140. *Id*.

concentration, Solazyme already supplies much of the U.S. Navy's jet fuel requirements with its algae-based jet fuel.[141]

I. Improving Fermentation & Using Other Sugars

Other technologies involve increasing the types of sugars that can be fermented into alcohol and increasing the speed and efficiency of fermentation.[142] One approach has been to genetically engineer yeast to increasingly ferment other sugars, like xylose.[143] These improvements allow yeast to use parts of a plant and other sugars that were previously inaccessible to fermentation.[144]

Furthermore, research into the metabolic pathways of yeast metabolism and fermentation is also promising to maximize efficiency.[145] By gaining understanding of the ways that yeast makes compounds, researchers hope to understand which biological pathways to genetically engineer.[146]

J. Higher Alcohols

Some researchers and companies like Gevo are betting on developing organisms and processes that produce higher alcohols, rather than just ethanol.[147] The use of higher alcohols, like butanol or propanol, is desirable because they have higher energy density than ethanol, mix with conventional fuels well, and do not take up water that interferes with engines.[148] Furthermore, unlike ethanol, higher alcohols do not degrade existing pipelines and storage containers,[149] though they may only require minor retrofitting for use with ethanol.[150] However, higher alcohols may have some

141. Press Release, Solazyme, Inc., Solazyme Delivers 100% Algal-Derived Renewable Jet Fuel to U.S. Navy (July 19, 2010), http://www.solazyme.com/media/2010-07-19.

142. *See e.g.* Ostergaard, Olsson & Nielsen, *supra* note 24, at 34-50.

143. *See* David Brat, Eckhard Boles & Beate Wiedemann, *Functional Expression of a Bacterial Xylose Isomerase in* Saccharomyces Cerevisiae, 75 APPLIED & ENVTL. MICROBIOLOGY 2304 (2009), *available at* http://aem.asm.org/cgi/reprint/75/8/2304; Nancy W. Y. Ho, Zhengdao Chen & Adam P. Brainard, *Genetically Engineered* Saccharomyces *Yeast Capable of Effective Cofermentation of Glucose and Xylose*, 64 APPLIED & ENVTL. MICROBIOLOGY 1852 (1998), *available at* http://aem.asm.org/cgi/reprint/64/5/1852.

144. *See* Brat, Boles & Wiedemann, *supra* note 143; Ho, Chen & Brainard, *supra* note 143.

145. Ostergaard, Olsson & Nielsen, *supra* note 24, at 40 (providing a great review of various metabolic engineering approaches to utilize various sugars and modify different biological pathways).

146. *Id.*

147. *Our Technology: GEVO Integrated Fermentation Technology (GIFT™)*, GEVO, http://www.gevo.com/our_technology.php (last visited Nov. 8, 2010).

148. Atsumi, Hanai & Liao, *supra* note 15.

149. *Id.*

150. *Piping Ethanol*, KIPLINGER'S BIOFUELS MARKET ALERT, August 20, 2008, at 5, *available at* https://www.kiplinger.com/orders/kbf/Biofuels071607.pdf.

compatibility problems similar to ethanol, and may also have limited production capabilities.[151]

Researchers have already developed genetically modified organisms that can make higher alcohols without the need of fermentation.[152] At least one company, Gevo, has filed eight patent applications on processes to make higher alcohols[153] from genetically modified organisms using sugars as their food,[154] and it is currently developing technologies to make cellulosic butanol.[155] Some of its filed applications are also directed to separating the higher alcohols once they are made.[156] This dual approach of directing efforts to separation and creation of higher alcohols may maximize Gevo's odds of owning rights to a platform technology if higher alcohols end up becoming the industry standard.

CONCLUSION

The right to exclude competitors from using a patented technology for twenty years should draw substantial investment and ameliorate many investment concerns, as the potential gains of patenting a technology that becomes an industry standard may outweigh the risk. This can be particularly true for new areas of research and development like biofuels, where early entrance into a field increases the odds of obtaining patents that protect fundamental/platform technologies. Using a multifaceted patenting approach increases the chances of creating or impacting a platform technology, which can subsequently help companies raise more investment and increase leverage for negotiations and licensing agreements. A few companies are already filing patent applications and have issued patents in areas that may become platform technologies for the biofuel industry. As demand

151. Atsumi, Hanai & Liao, *supra* note 15; *Butanol Fuel*, OILGAE, http://www.oilgae.com/energy/sou/ae/re/be/alc/but/but.html (last visited Dec. 30, 2010).

152. Atsumi, Hanai & Liao, *supra* note 15.

153. For example, isobutonol and isopropanol.

154. Gevo's patent applications on processes to make higher alcohols include Engineered Microorganisms for Producing Propanol, U.S. Patent Application No. 12/371,557 (filed Feb. 13, 2009); Yeast Organism Producing Isobutanol at a High Yield, U.S. Patent Application No. 12/343,375 (filed Dec. 23, 2008); Recovery of Higher Alcohols from Dilute Aqueous Solutions, U.S. Patent Application No. 12/342,992 (filed Dec. 23, 2008); Methods for the Economical Production of Biofuel from Biomass, U.S. Patent Application No. 12/263,436 (filed Oct. 31, 2008); Methods for the Economical Production of Biofuel Precursor that is also a Biofuel from Biomass, U.S. Patent Application No. 12/263,442 (filed Oct. 31, 2008); Engineered Microorganisms for Producing Isopropanol, U.S. Patent Application No. 12/106,173 (filed Apr. 18, 2008); Butanol Production by Metabolically Engineered Yeast, U.S. Patent Application No. 11/963,542 (filed Dec. 21, 2007); Engineered Microorganisms for Producing N-butanol and Related Methods, U.S. Patent Application No. 11/949,724 (filed Dec. 3, 2007).

155. *Our Technology: GEVO Integrated Fermentation Technology (GIFT™), supra* note 147.

156. *Id.*

grows and governmental mandates force larger amounts of biofuels to be produced, some of these technologies will likely emerge as global standards, and with the protection of patents, may create empires.