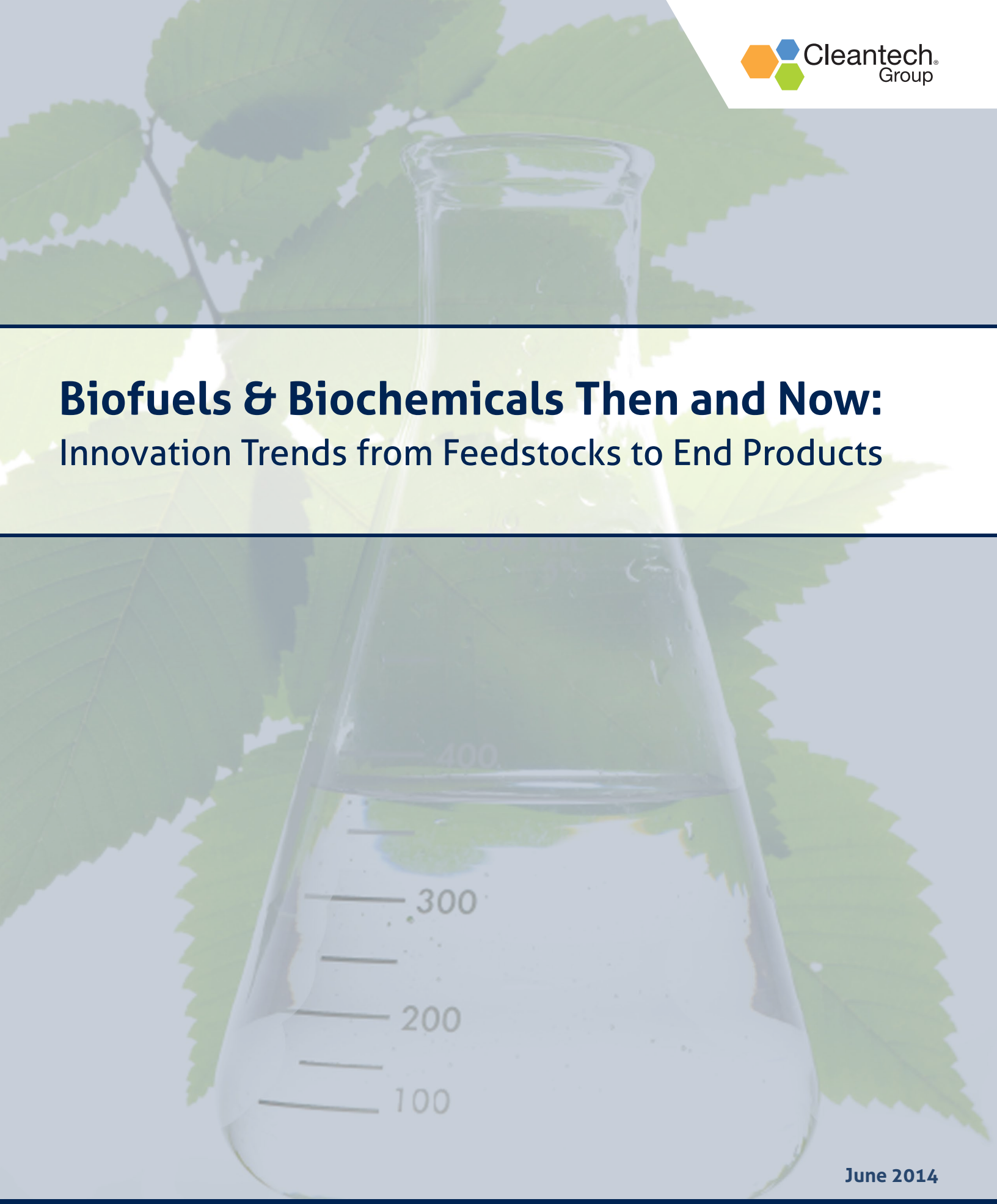


Biofuels & Biochemicals Then and Now:

Innovation Trends from Feedstocks to End Products

June 2014

Author:
Leo Zhang, Research Analyst, Cleantech Group

Introduction

The use of biofuels to power vehicle engines isn't a revolutionary concept. In fact, in 1908, Henry Ford designed the Model T to run on ethanol and expected biofuels to be the most common fuel source for the future. Fast forward 100 years: innovating entrepreneurs and venture capitalists began to crystalize the idea that biofuels can ultimately disrupt the liquid fuel market, which had historically been dominated by the oil majors. Combining biotechnology with an abundant supply of bio-based feedstocks—such as agriculture residues, energy crops and even algae—the industry is projected to produce billions of gallons of renewable liquid fuels, reduce overall greenhouse gas emissions, and finally achieve energy independence.

Starting in 2006, there was a wave of early-stage investments into new biofuels start-ups. The goal: to develop each company's unique technology to produce biofuels at commercial scale. Between 2006 and the financial crisis in 2008, venture capital firms and multinational corporations invested over $2.9 billion into **biofuels & biochemicals** companies[1]. In addition, the public sector also invested (and continues to invest) heavily in this space through government grants and loan guarantees. Nevertheless, the sector has severely underperformed and has yet to reach the scale that was once expected of it.

Despite initial underperformance, there are still an increasing number of innovations during the past five years—at both industry and company levels—in an effort to push through some of the scale-up challenges since the sector's initial rise. The biggest challenge—to be cost-competitive with petroleum-based equivalents—would require both inter-sector and cross-sector collaboration within the broader cleantech umbrella. Specifically, new technologies are being developed to better integrate the entire **biofuels & biochemicals** value chain, including new feedstock technologies that can address some of the key constraints of traditional bioenergy crops. In addition, growing cross-sector collaborations have also proven successful toward a better use of existing resources, while increasing efficiency within the value chain.

The following sections will highlight Cleantech Group's (CTG) insights around the challenges and innovation opportunities at each stage of the **biofuels & biochemicals** value chain. In addition, this paper will highlight investment and partnership trends that CTG believes would be instrumental to further advance this sector. Finally, we will share case studies on some of the most innovative companies working on solutions across multiple parts of the value chain.

BIOFUELS & BIOCHEMICALS VALUE CHAIN

Feedstock: Agriculture crops & residues, algae, waste

Logistics & Processing: Supply chain, storage, pre-treatment

Conversion & Refining: Biotechnology & refinery

Distribution: Pipes, trucks, barges, storage tanks

End User: Vehicles, airplanes, industrials, etc.

[1] www.i3connect.com

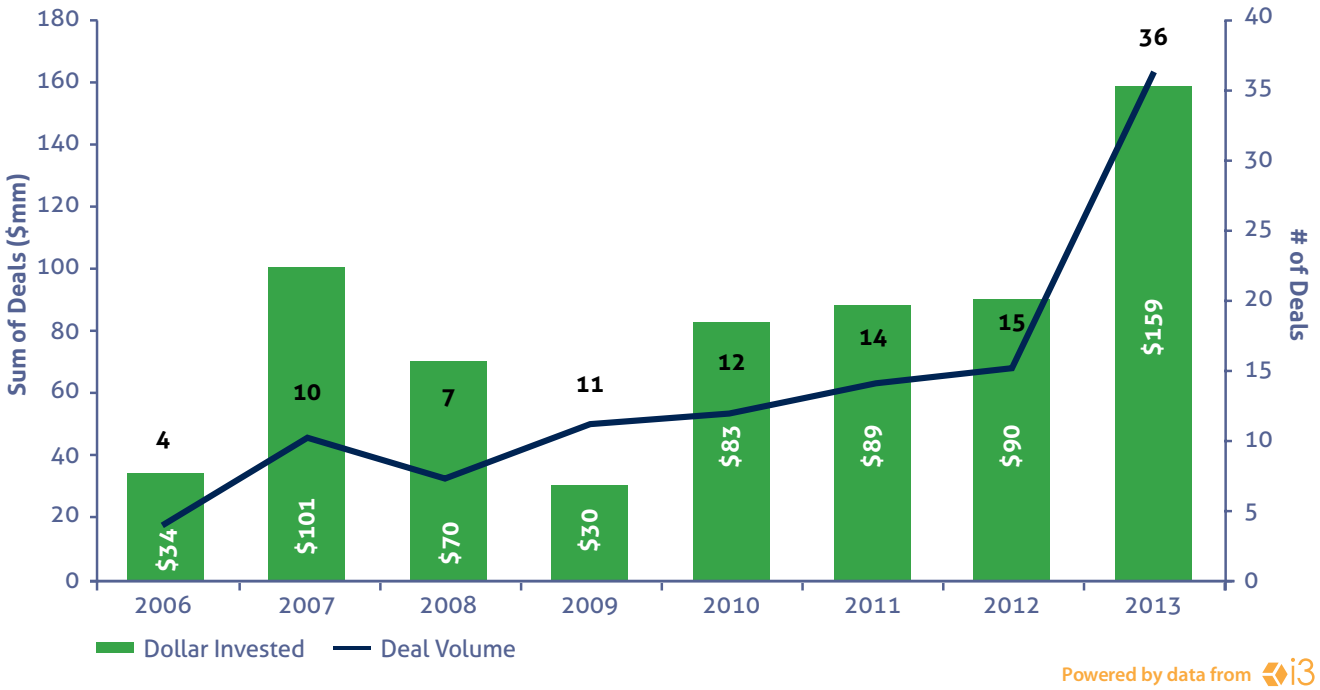
Feedstock: No single silver bullet – innovations in crops, oils and sugars

Conventional corn ethanol inherits fundamental sustainability issues in regard to the food and feed industries, as well as growing concerns of excessive water usage. First generation biofuels are nearing their capacity, the so-called blend wall, which defines the amount of corn ethanol that can be absorbed into existing transportation fuel infrastructure. As a much more mature sub-sector, we will likely see steady production of corn ethanol due to current blending requirements.

While conventional corn ethanol has reached its peak growth, ongoing innovations related to advanced feedstock options—including dedicated energy crops, waste sources and algae—continue to emerge in the market. Although much attention has been focused on conversion technology—a combination of biochemical and thermochemical processes to produce valuable end products—feedstock is equally critical as quality and access to feedstock supply is the first bottleneck to overcome towards commercial production.

Developing a streamlined supply chain for year-round, commercial-scale production is one of the critical challenges to the **biofuels & biochemicals** sector. Leading companies in the feedstock space are addressing this issue via multiple approaches, including the development of cellulosic crops, non-food oil plants and microalgae. More specifically, we have observed innovative technologies and business models ranging from yield improvements of bioenergy crops to direct production of fermentable sugars, all aimed at delivering sustainable feedstock for downstream conversions.

GLOBAL CORPORATE & VENTURE DEALS IN FEEDSTOCK DEVELOPMENT



From a technology point of view, there are three major feedstock innovation areas. The first and most notable area is focused on the development of dedicated energy crops, such as sorghum, miscanthus, and switchgrass, among many others. Based on the U.S. Department of Energy's Billion Ton Update, cellulosic biomass feedstock is estimated to reach 1.1

billion dry tons potentially available for biofuels production by 2030[2]. Global Cleantech 100 awardee, **NexSteppe,** is developing sweet and high-biomass sorghums using advanced breeding and analytical techniques. Similarly, **Ceres** is utilizing plant DNA sequencing technology to select the most optimized strains for cellulosic feedstock production.

Case Study

NexSteppe is a global renewable feedstock company based in California and dedicated to the next generation of scalable, reliable, cost-effective feedstock solutions for the biofuels, biopower, and bio-based products industries. Combining advanced breeding techniques and cutting-edge analytical technologies, **NexSteppe** is developing dedicated energy crops tailored for these industries. The company's Malibu sweet sorghum hybrids provide readily-accessible fermentable sugars for the production of bio-based fuels and chemicals. Its Palo Alto high biomass sorghum hybrids, standing at up to 20 feet tall after only 120 days of growth, provide high-yield, low-moisture biomass for biopower and cellulosic biofuels applications. Meanwhile, **NexSteppe** is also refining crop management practices to provide fully-integrated feedstock solutions. The company has received an equity investment and formed a strategic partnership with **DuPont** to help develop and commercialize **NexSteppe's** advanced feedstocks.

"Biofuels, biopower and bio-based products are rapidly emerging and maturing industries providing significant contributions to growing energy needs around the globe. However, these industries will not reach the desired level of scale or sustainability without a set of feedstocks optimized for these end-uses. In mature energy and chemical industries, feedstock generally accounts for greater than 50% of final product costs, so advanced feedstocks are critical to making these industries cost-competitive. **NexSteppe** optimizes and commercializes high-yielding, field-tested, compositionally optimized feedstocks for these markets. We have had our first sales in the U.S. and in Brazil. In Brazil, the most advanced market for bio-energy sorghums, we are the market share leader with 65% market share. We also have trials ongoing with commercial partners in more than a dozen additional countries spanning five continents. Ours are the first dedicated energy crops being used successfully at scale and without subsidy in commercial operations. We look forward to continuing to do our part to enable the growth of these industries and the advancement of sustainable and secure energy solutions around the world."

— Anna Rath, CEO, NexSteppe

In addition to biomass-based feedstock development, the market has also seen innovating technologies focused on oil-based feedstock, such as oil seed crops and microalgae. **SGB**, for example, is leveraging biotechnology to develop non-food based plant oil, protein and biomass for downstream industrial applications. One key emphasis in this example—non-food based plant oil—is a crucial differentiator for success in this space, especially with the ongoing food versus fuel debate initiated from the corn ethanol industry. While new feedstock development lays the initial groundwork for a sustainable bio-based feedstock supply chain, innovation in yield improvement is also critical in a resource-constrained world. Industrial biotech and plant science company, **Algenetix**, is developing biotechnologies to increase oil productivity of plants. Combining non-food oil crops and yield-increasing biotechnologies, renewable oils can

[2] U.S. Department of Energy, U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry, http://www1.eere.energy.gov/bioenergy/pdfs/billion_ton_update.pdf, 2011

potentially displace a significant amount of petroleum; this combination will also increase land availability for food production. In addition to oil-based crops, feedstock companies are also working on algae-based technologies, utilizing microalgae's natural ability to produce oil from a variety of nutrient inputs. For instance, **Heliae** and **Sapphire Energy** are researching advanced algae strains and production technologies, so that they can produce algae oils more efficiently to downstream customers.

Case Study

Algenetix

Algenetix is a California-based plant science company focused on the development of specialty crop traits for plant oils production. The company's flagship product, PhotoSeed™, has successfully expanded the production of synthetic seed-like oil bodies into new plant tissues and across kingdoms, while enabling considerable productivity gains in biomass crops, renewable oilseeds and industrial microbes. The company has received $1.7 million in investments from **Two Oceans** and other existing investors.

> "Plant oils, one of the world's most important agricultural outputs, intersect several diverse industries, including food, oleochemicals, fuels and everyday consumer products. While oilseed crops will continue to be an important part of the supply equation, squeezing further productivity from the seed alone simply cannot meet the scale of demand. PhotoSeed™ addresses this problem by biologically converting every single cell of a plant into a synthetic oil producing factory. Our crops can yield six to twelve times the oil per acre of first generation oilseeds such as soybeans without competing with food crops for arable land and resources. In turn, **Algenetix** is improving economic returns for farmers, while providing environmentally sustainable industrial oils at a guaranteed stable price for our customers."
>
> **— Han Chen, Chief Executive Officer, Algenetix**

Growing biomass feedstock inherits an essential challenge of land availability, especially for developing countries, where land scarcity for food production alone is a much greater concern. **Proterro** is leading the charge in addressing feedstock and land availability challenges by making sugars. The company's proprietary technology, a unique photosynthetic sugar-making platform, allows the company to make sugar rather than extracting it from crops by deconstructing cellulosic materials. In essence, this technology will bypass conventional agricultural lifecycles associated with biomass plantation, growing and harvesting, thus reducing land, fertilizer, and chemical usages.

Case Study

Proterro

Proterro is a New Jersey-based biofeedstock company that is making sugar instead of extracting it from crops or deconstructing cellulosic materials. By integrating a highly productive, patented cyanobacteria with a robust, modular photobioreactor—and using CO_2, sunlight and water—**Proterro's** process yields a continuous fermentation-ready sucrose stream, rather than a mixture of sugars, allowing simple, low-cost downstream processing.

In addition, the company's patent-pending photobioreactor system cuts down water use and total sugar production costs, housing the microorganisms on sheets of fabric—hanging in the photobioreactor—through which water slowly percolates, rather than being immersed in volumes of water. **Proterro** has recently announced the company's pilot production has reached four months of continuous operation, and learnings from this operation will lead to improvements in the next generation photobioreactor being developed with NASA spacesuit maker ILC Dover.

"Access to reliable, economical clean sucrose feedstock is a critical barrier to scale for production of biofuels and bio-based chemicals. Our patented biosynthetic process removes the price volatility that comes with crop-based feedstocks and eliminates the complex and costly steps required to produce cellulosic sugars derived from biomass. We're able to substantially lower the cost of sugar production, unleashing the economic value of biofuels and bio-based chemicals.

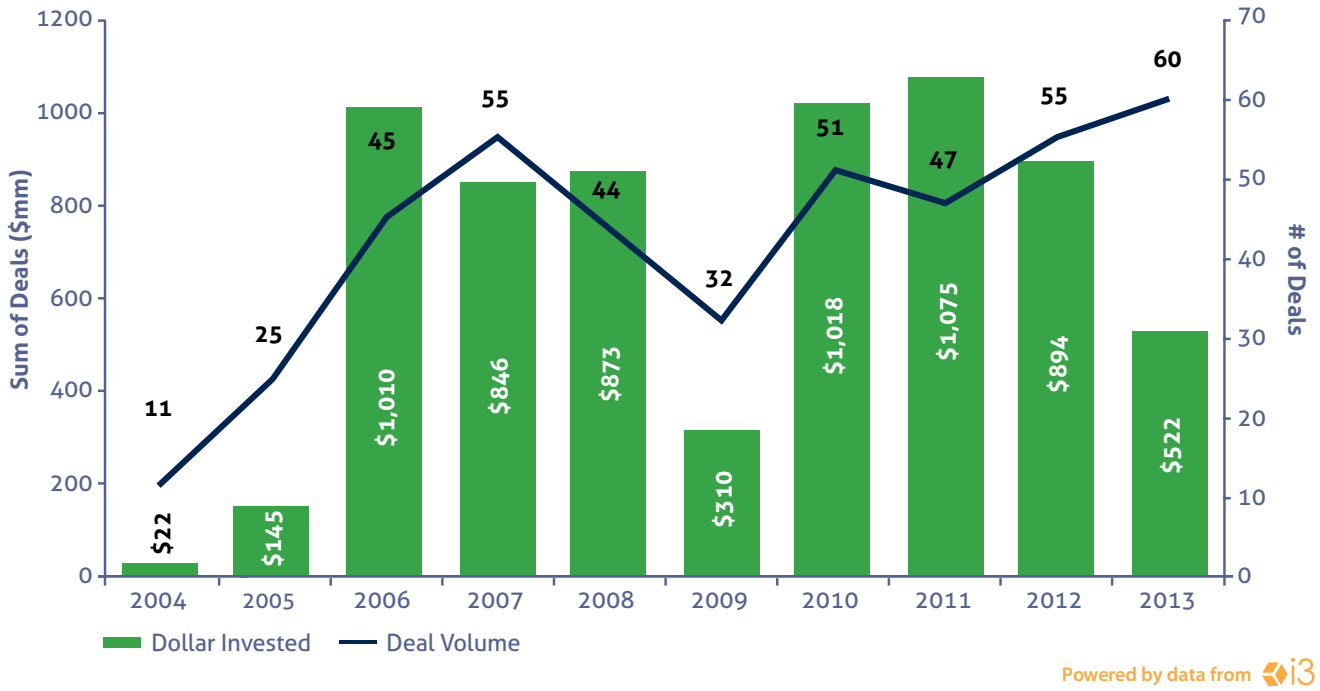
"Having successfully produced sugar at our Florida pilot plant, **Proterro** will scale up a demonstration plant with about 100 photobioreactors. For both the demonstration facility and subsequent commercial-scale facilities, we would need to be located close to an emitter of CO_2, which is the feedstock for our sugar-making process. The source of CO_2 could be an ethanol plant or other fermentation source that gives off CO_2 and would use **Proterro's** sucrose; or it could be an industrial process that emits CO_2."

— Kef Kasdin, CEO, Proterro

Path to Commercialization: Corporate investments and partnerships

Feedstock solutions alone will not achieve wide, commercial-scale production of **biofuels & biochemicals**. In addition to a sustainable and year-round feedstock supply chain, another barrier centers on the scale-up of current conversion technologies. In particular, young companies need to cross the so-called commercialization valley of death—the capital-intensive and high-risk stage—in order to validate the technology's capability at commercial scale. Because such demonstrations require a combination of technological, engineering, as well as capital challenges, we have observed an increasing number of investments and corporate partnerships aimed at pushing through the valley of death.

GLOBAL CORPORATE & VENTURE DEALS IN BIOFUELS & BIOCHEMICALS, EXCLUDING FEEDSTOCK



Given the global economic downturn since 2008, coupled with higher risks associated with capital-intensive and long-payback-period types of investments that are unconventional in the traditional venture capital industry, the fundraising market has undoubtedly become quite difficult in this sector. In particular, we have seen strong reluctance to invest in companies with capital-intensive business models. On the contrary, the **biofuels & biochemicals** sector still accounts for a relatively large sector share of total investment dollars, mainly as a result of growth-stage investments in existing portfolio companies to demonstrate their technologies at scale.

Despite a struggling period of investment activity in this sector, we have observed an increasing number of corporate partnerships between technology companies and larger multi-national corporations. Companies from three industries in particular—the **oil & gas**, **recycling & waste** and **transportation** sectors—have historically been active in investing and seeking collaborations with innovative start-ups. For **oil & gas** majors, strategic investments in biofuels companies that produce drop-in and crude-like oil products can decrease their overall carbon footprint, while also positioning them well for future strategic shifts into the renewables world. **Recycling & waste** companies are also actively involved in the **biofuels & biochemicals** space, often with specific interests toward waste-to-value technologies, where they can effectively derive additional value from existing waste sources. The airline industry has been active in conducting performance assessments and securing offtake agreements, mainly because fuel costs make up around 30% of airlines' operating costs, in conjunction with rising jet fuel prices and carbon emission taxes[3]. To highlight larger corporations' involvement in this sector, technology developer **Renmatix** is a textbook example due to its capital-light business model, as well as its key corporate partners

[3] International Air Transport Association (IATA), Industry on Track for Second Year of Improving Profits – Rising Fuel Costs Largely Offset by Increased Demand, 2014

Case Study

Renmatix is a technology licensor that enables the production of petrochemical equivalents from plants. The company's water-based Plantrose™ process is a low-cost method for converting a wide range of non-food biomass into (cellulosic) sugars, for applications in the global chemical and fuel markets. Plantrose technology employs supercritical hydrolysis to deconstruct biomass—such as agricultural residue, grasses, or woody biomass—in seconds, using only water at high temperatures and elevated pressure, without any significant consumables. Sector leaders like BASF, Waste Management and Finnish forester UPM, are engaged in JDAs with Renmatix in pursuit of real economic advantage for bioindustrial markets via Plantrose enabled biorefineries. Renmatix is privately held, with facilities operating at a scale of three dry tons of biomass to sugar per day in Georgia (USA), and a world-class technical center in Pennsylvania (USA).

"Renmatix recognized the advantages of supercritical hydrolysis early on and adopted an IP intensive, capital-light licensing model to commercialize it. Our affordable conversion technology is the critical link between upstream natural resources, and downstream products in bio-based value chains. Because our Plantrose technology is biomass agnostic and offers the lowest cost route to sugar, we can serve as the primary bridge for large strategic partners looking to grow their renewable material portfolios in pursuit of profitable new revenue streams. To reach critical mass and move beyond high-margin applications, the biochemical sector requires large volumes of economical cellulosic intermediates. Renmatix, alongside its strong investors and JDA partners, is already delivering these essential building blocks for cost-competitive plantrochemicals."

— Duncan Cross, Managing Director of International Development, Renmatix

Company	Partner	Partner's Industry	Year	Notes
VELOCYS	WM Waste Management, nrg	Recycling, Energy	2014	Joint venture to develop gas-to-liquid plants
gevo	Lufthansa	Transportation	2014	Partnership to test trial bio-based kerosene jet fuel
Global Bioenergies	Audi	Transportation	2014	Partnership to develop drop-in biofuels
AMYRIS	TOTAL	Oil & Gas	2013	Joint venture to commercialize renewable jet fuels
Sapphire Energy	Phillips 66	Oil & Gas	2013	Joint development agreement to commercialize algae crude oil

Company	Partner	Partner's Industry	Year	Notes
SYNTHETIC GENOMICS	ExxonMobil	Oil & Gas	2013	Co-funded research agreement to develop algae biofuels
UOP A Honeywell Company	LAN	Transportation	2013	LAN airlines conducted a trial flight using UOP's renewable jet fuel
avantium	Shell	Oil & Gas	2012	Collaboration relating to ethylene oxide catalyst development
Renmatix	WM Waste Management	Recycling	2012	Joint development agreement to research on converting post-consumer waste into sugars
SOLENA FUELS	British Airways	Transportation	2012	Joint venture to manufacture jet fuel using Solena's technology

Perhaps the biggest challenge in moving through the commercialization valley of death is to drive down production cost to a price that is competitive with petroleum-based fuels and chemicals. Although there is a wide range of developments from next generation feedstocks to highly efficient conversion pathways, it is also critical to link the various subsectors within the broader biofuels and chemicals value chain. By connecting a more streamlined value chain—from feedstock supply to end product distribution—each individual segment can yield cost savings once they are fully structured and integrated. There are several leading companies working specifically on connecting individual parts of the industry into an integrated value chain. For example, **Genera Energy** is on the forefront of feedstock integration through the company's integrated biomass supply solution for biofuels, biopower, and bio-based products industries. Leveraging the company's agricultural expertise, Genera Energy works with its customers on critical issues such as crop production, processing, and storage to achieve a more optimized feedstock supply chain. Shifting to the other side of the value chain, several leading companies are working on the distribution of refined bio-based fuels, including ethanol, biodiesel, and renewable jet fuels. For instance, **Propel Fuels** is developing ethanol and biodiesel fueling infrastructures in the Western United States to help drivers offset their emissions at the pump. For commercial aviation, companies such as **SkyNRG** and **BioJet** are working with key stakeholders from fuel producers, airlines, and commercial airports to develop an integrated renewable jet fuel supply chain.

Shifting to High-Margin Products

While **biofuels & biochemicals** companies continue to scale-up their technology, there is also a prominent shift from a primary biofuels focus to higher margin products, such as biochemicals, bioplastics, and bio-based products. As leading companies navigate through the commercialization valley of death, we recognize this natural transition as a necessary business strategy realignment based on progress we have observed in the marketplace. To be specific, building a commercial-scale biofuel refinery based on a lab-scale technology is an ambitious engineering challenge, especially given complex feedstock logistics described above. Furthermore, pricing for commodity-based products are determined simply as a function of their market value. As a result, biofuels cannot benefit from any pricing premium that biochemicals and other bio-based products may incur.

Veredezyne is a prime example of success achieved by using a biochemicals-based commercialization strategy to shift from fuels to chemicals. Having built a biotechnology platform, **Verdezyne** was initially set to target the advanced biofuels market, but has realigned its focus towards chemicals by selling its fuel-based intellectual property to **DuPont**. **Verdezyne** has since decided to focus on renewable petrochemical replacements instead. The company has also adopted an innovative business strategy, where it has partnered with the Michigan Biotechnology Institute (MBI) to run and prove the technology at demonstration-scale. By doing so, **Verdezyne** was able to obtain technology validation, while reducing capital costs for the construction of an internal demonstration plant.

Case Study

Verdezyne is a California-based industrial biotechnology company that produces biochemicals from renewable feedstocks. The company's proprietary yeast fermentation platform is designed to produce bio-based chemicals that are used in everyday products. By optimizing metabolic pathways, fermentation and downstream separation processes, **Verdezyne** is positioned to produce a number of chemical products, including dodecanedioic acid (DDDA), sebacic acid and adipic acid, more economically than current processes used today. **Verdezyne's** commercialization strategy includes partnerships with leading feedstock suppliers and downstream chemical producers, and has recently received $48 million from Malaysian multinational conglomerate, Sime Darby Berhad, and other existing investors to accelerate technology development in the U.S.

"**Verdezyne** shifted a while ago from developing enabling technologies for the biofuels industry to developing our proprietary routes to chemical intermediates in order to realize financial benefits sooner and with less commercialization risk. Chemicals in total are only about 3% of the barrel of oil, compared to 70% used to make fuels, but create the same total value in the supply chains they serve. Therefore, there is a lot more profit margin to tap in chemicals, and the path to success is less risky than with fuels. **Verdezyne's** commercialization strategy is to partner with key players in the entire value chain in order to secure low cost renewably sourced feedstocks and secure routes to existing markets for our high value bio-based products. Having Sime Darby, a major supplier in the palm products industry, as a major new strategic investor certainly helps to complete a future successful supply chain."

— Ray Miller, Chief Business Officer, Verdezyne

As more companies in this sector begin to shift their primary focus to biochemicals and bio-based products, we have since observed increasing corporate interests in this specific subsector. In fact, some of the pure-play biochemicals and biomaterials companies have received most of their attention and success from their partnerships with larger corporates. Unlike biofuels that would require a combination of public and private sectors "push" to the market, biochemicals have actually experienced a market "pull" by major corporations. For example, consumer product companies are demanding more renewable and bio-based chemicals and plastics from their supply chains for a broader increase in overall sustainability. In addition, chemical manufacturers are also increasing their renewable product portfolios by incorporating renewable and bio-based feedstocks into their manufacturing process.

Company	Partner	Year	Notes
AMYRIS	IFF International Flavors & Fragrances Inc.	2014	Multi-year agreement to co-commercialize renewable fragrance ingredients
Elevance RENEWABLE SCIENCES	eni versalis	2014	Jointly develop a new biochemical production technology
Rennovia	ADM	2014	$25mm equity investment to co-develop bio-based chemical products
genomatica sustainable chemicals	Braskem	2013	Joint development agreement to develop commercial production of bio-butadiene
opxbio good chemistry.	EVONIK INDUSTRIES	2013	Joint research agreement to develop bio-based chemicals
solazyme	AkzoNobel	2013	Development agreement to develop advanced tailored oils
avantium	DANONE	2012	Partnership to develop PEF bottles for use by Danone

Diverse Product Portfolio - From C2 to C12 Biochemical Building Blocks

Similar to petroleum-based chemicals, biochemicals produced from renewable feedstocks consist of a wide range of compositions, each with a multitude of downstream applications. From commodity to specialty chemicals, many pure-play biochemical companies are currently in the forefront of researching pathways to produce valuable molecules from renewable sources. **Genomatica**, one of the leading biochemical companies, is developing a proprietary fermentation technology platform to produce intermediate chemicals. **Genomatica** is also notably successful in its commercialization path as the company has adopted a licensing-based business model. As a result, the company reduces capital risks on plant construction by partnering with strategic corporate partners to co-commercialize its technology. To date, **Genomatica** has successfully licensed its technology to **BASF** to commercially produce 1, 4-butanediol. In addition, **Genomatica** has formed a joint venture with **Versalis** to develop a production plant in Europe using **Genomatica's** core intellectual property. Finally, the company has received numerous awards from leading industry associations, including two consecutive awards from Cleantech Group's Global Cleantech 100 list (2012 and 2013).

Case Study

Genomatica is a California-based industrial biotech company focused on the trillion-dollar mainstream chemical industry. It develops manufacturing processes that enable its licensee partners to produce the world's most widely-used chemicals from alternative feedstocks, with better economics and greater sustainability than current petroleum-based processes. **Genomatica** has the distinction of driving the first genuine commercialization of a bio-based production process for BDO, a high-volume intermediate chemical with a $4billion-plus annual market. Results include licenses with **BASF** and **Novamont**; millions of pounds produced; and public confirmation of application usability by leading firms. Its second process, for butadiene which has a $20 billion-plus annual market, has gained $100 million in industry support, with **Braskem** and **ENI**/**Versalis** as anchor partners. The company's biotechnology platform and intellectual property address more than 20 major chemicals, supporting long-term growth opportunities. **Genomatica's** licensing and sponsored R&D business model, validated through several large agreements, supports a capital-efficient and highly-scalable growth strategy that leverages the capital resources, application knowledge and distribution channels of the industry's leading firms.

"At **Genomatica** we use our expertise in biotechnology – both in science and in real-world process engineering – to offer compelling alternatives to major problems faced by the mainstream chemical industry. Our processes aim to deliver better overall economics and feedstock flexibility at the same time that they enable more sustainable chemicals and materials. Our value proposition, delivered through our leading technology, has led to multiple major partnerships and widespread recognition."

— Christophe Schilling, CEO, Genomatica

Another successful biochemical company, **Virent**, has formed a long-term strategic partnership with **Coca-Cola** to produce bio-based aromatic molecules to be used in plastic bottles. This partnership perfectly demonstrates the market "pull" for biochemicals and biomaterials, as consumers continue to demand more sustainable packaging solutions, as well as corporations' stronger commitments to resource conservation.

Case Study

Virent is a Wisconsin-based renewable fuels and chemicals company aimed at replacing crude oil with a wide range of renewable resources. The company has developed a patented catalytic chemistry technology platform to convert plant-based feedstocks into products such as gasoline, diesel, jet fuel, and chemicals for packaging and fibers. **Virent's** products have the same molecular composition and performance as their petroleum-derived counterparts and are considered to be "drop-in" replacements that enable full utilization of existing logistics infrastructure without blending limitations. The development of **Virent's** BioForming® technology platform is supported through strategic investors and collaborators including **Shell**, **Cargill**, **Coca-Cola** and **Honda**. In 2011, **Virent** and **Coca-Cola** signed a joint development and supply agreement to scale-up **Virent's** Paraxylene production technology to enable the production of 100% plant-based PET bottles.

"There is significant market demand for bio-chemicals across a broad set of opportunities, including apparel and product packaging applications, substantiated in large part by the demonstrated success of recently introduced green based packaging solutions. **Virent** is well positioned to deliver needed volumes to the marketplace through the strength of its exiting partners and the unique capabilities of the BioForming process. **Virent** sees bio-chemicals, particularly bio-based PET, as a very promising route to achieving commercial scale, all while providing additional progress towards delivering sustainable energy security, increasing economic growth and reducing carbon intensity."

— Lee Edwards, President & Chief Executive Officer, Virent

Conclusion

During the past several years, the **biofuels & biochemicals** sector has experienced a considerable amount of setbacks. Nevertheless, there has been an evolution of technology and business model innovation that has resulted in proven success for some pioneering companies. While first generation biofuels continue to morph into a mature subsector, advanced biofuels and biochemicals will evolve and make significant commercialization progress. Across the entire value chain, innovative technologies in feedstock and conversion are constantly being tested and validated at larger scale. The sector has reached a peak where commercial production of advanced biofuels and biochemicals are currently pursued by leading companies, including multinational corporations across the globe. The challenges and related opportunities are still ahead of us in terms of strengthening the entire value chain and transforming the industry to a truly sustainable business.

ABOUT CLEANTECH GROUP

Our clients – corporations, utilities, government agencies, and investors – recognize that innovating is crucial to business growth, yet can be challenging to pursue. We partner with our clients to accelerate innovation. With more than a decade of experience covering 18 sectors of resource technologies, we are uniquely positioned to guide clients along the innovation journey through our three lines of business.

Our i3 platform allows subscribers to discover and vet companies, as well as explore technology sector trends strategically using proprietary real-time data. Our Cleantech Forums, held around the globe, convene investors, entrepreneurs, and international policy makers to examine trends, develop innovation strategies, and make deals happen. Our Advisory Services help clients design and implement corporate strategies for sustainable growth and innovation sourcing, and then market the results. Details at www.cleantech.com.

Want to connect to more innovation in biochemicals and biofuels?
Use an i3 Campaign!

Developing your pipeline is hard
- Corporates have to manage technologies needs for global operations
- Company discovery and vetting takes time, and has low conversion rates
- It's often difficult to differentiate between the top innovators

We have access to great entrepreneurs
- Leverage i3 to broadcast your current needs to targeted groups of entrepreneurs
- Tap our network of 60,000+ entrepreneurs and innovation stakeholders worldwide
- Use our team to do your initial vetting

Simple process, great results
- We reach out to select groups of entrepreneurs
- Entrepreneurs answer a personalized questionnaire to speed up the initial validation process
- We tier the results and deliver direct introductions to a subset of 'best-fit' companies

Free trial: i3connect.com

"i3 is a fantastic tool. We use i3 to connect with and understand startups in the evolving M2M market. Startups recently vied for a spot on our latest i3 List: many look promising and the top 10 were all new prospects for me. I'm excited to have access to this tool going forward"

Gil Demeter
Senior Associate
Qualcomm Ventures