



# **Advancing the Biobased Economy:**

## **Renewable Chemical Biorefinery Commercialization, Progress, and Market Opportunities, 2016 and Beyond**

**Advancing the Biobased Economy: Renewable Chemical Biorefinery  
Commercialization, Progress, and Market Opportunities, 2016 and Beyond**

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## INTRODUCTION

A review of operating biorefineries displays a range of technology solutions undergoing commercial development – beyond just advanced biofuels – to produce commodity and specialty renewable chemicals. Industrial biotechnology companies are pursuing renewable chemicals and biobased materials because they can be commercialized at smaller scale, as well as promise environmental benefits, stable costs and novel properties in comparison to fossil fuel-derived chemicals. Competition to produce platform renewable chemicals provides manufacturers assurance of a steadily available, high-quality supply of renewable chemicals for consumer product applications.

Analysts predict a rapid expansion of renewable chemical production in the near future based on planned capacity expansion or new construction. McKinsey & Co. estimates that there were \$252 billion (€204 billion) in sales of biobased products in 2012, with biofuels and plant extracts comprising more than half. Sales of renewable chemicals represented 9 percent of the \$2,820 billion (€2,281 billion) in worldwide chemical sales in 2012. By 2020, McKinsey expects biobased products to make up 11 percent of the \$3,401 billion (€3,130 billion) global chemical market. Sales of biobased products would reach \$375 – \$441 billion (€345 – €406 billion) by 2020, with a compound annual growth rate of 8 percent over the preceding decade. Worldwide sales of chemicals are expected to grow at 4 percent annually, overall. While biofuels and plant extracts continue to comprise half of the projected sales of biobased products in 2020, McKinsey expects the highest growth rates in sales of new biopolymers and renewable chemicals, biocatalysts for industrial processes and biologic medicines, as well as biofuels.

Supportive policies will help grow the 21st century biobased economy. The

Renewable Fuel Standard (RFS), for instance, not only helped stimulate innovation in biofuels, but also opened discussions and policy development in renewable chemicals and biobased products. The 2014 Farm Bill (*The Agriculture Act of 2014*) extended loan guarantee eligibility to renewable chemicals and biobased products producers, through Section 9003, the *Biorefinery, Renewable Chemical, and Biobased Manufacturing Assistance Program*.

Other policy drivers include draft legislation, introduced in both federal chambers, creating tax incentives for production of or investment in qualifying renewable chemicals. Spurred by the federal legislation, Iowa and Minnesota announced enactment of state-level production tax credits for renewable chemicals that will speed capital investment availability and commercialization. Additionally, draft legislation introduced in the 114th Congress — the Master Limited Partnerships Parity Act (MLP) – proposes to extend tax benefits currently available only to the oil and gas industry to renewable chemicals and biofuels producers. If enacted, the legislation will provide renewable chemical producers access to low-cost capital and attract investors and lower corporate stock tax liabilities.

Enactment of the Frank R. Lautenberg Chemical Safety for the 21st Century Act, updating and revising the Toxic Substances Control Act (TSCA), has favorable provisions for Class 2 renewable chemical manufacturers who use renewable feedstocks. The new law could minimize costly pre-commercial reviews, if the renewable chemical has already been produced from fossil fuel feedstocks.

### Background

The *Economist* magazine's Technology Quarterly edition for December 2015 heralded a "golden age" of material

science, highlighting recent developments in inorganic chemistry. The magazine utilized the "materials genome" as a metaphor for the pace of pre-commercial innovation in the field. The industrial biotechnology sector should welcome the analogy, especially as its list of commercial successes grows. The industrial biotech sector has reached a stage where first-of-a-kind biorefineries are paving the way for rapid commercialization of new applications.

The National Science and Technology Council's Subcommittee on Advanced Manufacturing, in an April 2016 report, titled "*Advanced Manufacturing: A Snapshot of Priority Technology Areas Across the Federal Government*," identifies engineering biology and advanced bioproducts manufacturing as technology areas of emerging priority. The report estimates the size of the U.S. biobased economy at roughly \$350 billion annually, citing a National Research Council roadmap to accelerate advanced chemical manufacturing through industrial biotechnology.

To document the progress and illustrate the growing potential for biobased production of renewable chemicals, the Biotechnology Innovation Organization's (BIO) Industrial and Environmental Section has compiled a new body of data on established biorefineries. The data includes descriptions of the technologies along with common applications and measures of the market potential. And since the renewable chemical sector seeks a level playing field in government support and regulatory policies, the data includes the demographic and economic impact of each biorefinery.

Biobased production holds many potential benefits for consumers, including cleaner, more efficient manufacturing processes that incorporate renewable ingredients in everyday

products found in the home. Delivering these benefits requires continued growth of the sector to ensure that product manufacturers have a reliable, sustainable, and scalable supply of renewable chemicals.

### **Renewable Chemical Processes at Demonstration and Pilot Scale**

Coca-Cola, H.J. Heinz, Nike Inc., Ford Motors and Procter & Gamble are cooperatively working to accelerate the development of 100 percent renewable polyethylene terephthalate (PET), a common plastic used in packaging materials such as bottles, footwear, apparel and automobile fabrics. Coca-Cola currently markets PlantBottle™ with renewable ethylene glycol, which makes up as much as 30 percent of the plastic bottle. Coca-Cola Company has partnered with Virent, Gevo and Avantium and, similarly, Suntory Holdings has partnered with Anellotech to develop renewable para-xylene to replace petroleum terephthalic acid. These strategic partnerships have demonstrated the feasibility of a 100 percent renewable PET bottle.

A potential alternative to PET is polyethylene furanoate (PEF). Avantium has commercialized 100 percent biobased PEF resin, which is made from the company's patented biobased 2,5 furandicarboxylic acid (FDCA) combined with plant-based monoethylene glycol (MEG). Avantium is currently producing FDCA at a 40 metric ton per year pilot plant in Geleen, Netherlands. Avantium plans to start commercial production of FDCA and PEF at 50,000 ton per year plant in 2017 and announced its intention to establish a joint venture with BASF in the production and marketing of FDCA.

A few companies have focused efforts on producing C5 and C6 sugars as a feedstock for other companies to produce biofuels and renewable

chemicals. Renmatix is operating a demonstration-scale Feedstock Processing Facility in Rome, New York, to supply its Integrated Plantrose Complex, based in Atlanta, where it converts the processed woody biomass to cellulosic sugars. Sweetwater Energy is securing financing to build a biorefinery at Mountain Iron, Minnesota, which will convert 51,000 tons of timber to sugars and lignin. Sweetwater has also leased space at Eastman Business Park in Rochester, New York, to produce alcohols from cellulosic sugars. Similarly, American Process has developed GreenPower® process technology, which produces low-cost, mixed cellulosic sugars from biomass.

Several companies are currently piloting production of adipic acid, which is a precursor to nylon and can be used in coatings and detergents. Rennovia is currently operating a pilot project at the Johnson Matthey Process Technologies R&D Center in Stockton, England, converting biobased glucaric acid to adipic acid. Verdezyne is operating a pilot production facility in Carlsbad, California. And, BioAmber has formed a partnership with Cellexion to produce adipic acid from succinic acid. Genomatica of Carlsbad, California, began efforts in 2014 to commercialize biobased production of adipic acid and other nylon intermediates.

At least one company has commercialized production of polyhydroxyalkanoate (PHA), a polymer that can be blended into various plastic applications. Metabolix's current range of Mirel® PHA copolymers are produced by fermentation, using specially engineered microorganisms that bioaccumulate the inert polymer. The PHA is co-polymerized with PVC to make a stronger and more flexible plastic. Metabolix uses contract manufacturing to produce Mirel®; the company's partners are currently ramping up

pilot production to run at nameplate capacity for 2016.

Two companies, Cargill and Novozymes, have partnered since 2008 to demonstrate biobased production of 3-hydroxypropionic acid (3-HPA), which is a precursor to acrylic acid. Acrylic acid is polymerized and used as an absorbent in diapers and hygiene products as well as in coatings, adhesives, carpets, and fabrics. The traditional petrochemical process for 3-HPA synthesis is achieved through the oxidation of propylene, a product of crude oil refining. Under the partnership, Cargill is operating a pilot scale production plant fermenting 3-HPA and converting it to acrylic acid. Cargill acquired Colorado based OPX Biotechnologies and its proprietary fermentation-based process for 3-HPA.

### **Renewable Chemical Commercialization Successes**

One of the earliest renewable chemicals to be successfully commercialized is 1,3-propanediol (1,3-PDO™), a chemical building block for nylon and emollients used in cosmetics, coolant and fibers for the production of high-end carpets. DuPont Tate & Lyle has operated a 63,500 metric ton per year biorefinery in Loudon, Tennessee, since late 2006. The company markets the diol for industrial uses as Susterra® propanediol.

One biobased process has been commercialized and another process is being scaled up to produce propylene glycol (1,2-propanediol), which can be used as a building block for saturated and unsaturated polyesters, a humectant or a food preservative. ADM began production of propylene glycol in March 2011 at a 100,000 metric ton per year facility in Decatur, Illinois, that uses glycerin as a feedstock in a catalytic process. More recently, Metabolic Explorer and UPM have formed a joint

## INTRODUCTION

venture to demonstrate monopropylene glycol via fermentation of sugar at a facility in Clermont-Ferrand, France.

Another of the earliest renewable chemicals to be commercialized is polylactic acid (PLA), which was truly a tipping point for renewable chemicals. PLA is commonly used in food wrap and utensils and can be made into textile fibers. Since 2003 NatureWorks has produced PLA at a facility in Blair, Nebraska, with name plate capacity of 300 million pounds (140,000 metric tons). NatureWorks markets the product as Ingeo® biopolymer. Corbion more recently announced that it will build a biobased PLA plant with an annual capacity of 75 kilotons and expand by 25 kilotons per year its existing lactide plant in Rayong Province, Thailand.

Several companies have commercialized biobased routes to succinic acid, a building block chemical that replaces petroleum-based maleic anhydride in polyesters, alkyd resins, polyurethanes, plasticizers and solvents. Companies that are currently producing succinic acid include Myriant, which is operating a 13,600 metric ton per year facility in Lake Providence, Louisiana. BioAmber piloted its biobased process for succinic acid at a 3,000 metric ton facility in Pomacle, France, and is now producing 17,000 metric tons per year in Sarnia, Ontario, Canada. Reverdia, a joint venture between DSM and Roquette, has built a 10,000 metric ton per year facility in Cassano Spinola, Italy. And Succinity, a joint venture between BASF and Corbion, is due to start up a 25,000 metric ton per year facility in Barcelona, Spain.

One company has commercialized a biobased route to 1,4-butanediol (BDO), which is a building block in the production of tetrahydrofuran (THF), which is an intermediate for spandex

and other performance polymers, and polybutylene terephthalate (PBT) resins, which are used for engineering plastics. BASF has licensed direct fermentation technology developed by Genomatica and secured rights to commercially produce up to 75,000 metric tons per year of renewable 1,4-BDO. To date, BASF reports producing volumes for its downstream customers to test and at a purity comparable to petrochemical-based 1,4-BDO for use in commercial applications. BASF is also producing and offering polytetrahydrofuran (PolyTHF®) made from renewable 1,4-BDO.

Multiple competitors are also commercializing biobased routes to iso-butanol and n-butanol. Iso-butanol can be used as an oxygenate and octane-enhancing fuel additive while n-butanol is used as a solvent and intermediate in paints, coatings, printing inks, adhesives, sealants, textiles and plastics. In addition, iso-butanol can be cyclized to para-xylene, the precursor to terephthalic acid; Gevo is commercializing a process based on this chemistry. Green Biologics, which focuses on n-butanol for chemical markets, is currently refitting a 21 million gallon ethanol plant in Little Falls, Minnesota, with plans to begin commercial production of n-butanol and acetone during 2016. Butamax has completed phase 1 of its retrofit of a 50 million gallon ethanol plant in Lamberton, Minnesota, and projects completion of phase 2 for production of iso-butanol in 2016. The company in early 2016 petitioned the U.S. Environmental Protection Agency (EPA) to approve its production and feedstock technology for iso-butanol as an advanced renewable fuel. Gevo retrofitted an ethanol biorefinery in Luverne, Minnesota, and is targeting production of up to 1 million gallons of iso-butanol and 17 million gallons of ethanol in 2016. The facility is registered with EPA as Agri-Energy LLC to produce

renewable fuels. Intrexon, located in the San Francisco Bay Area, began operation of a pilot plant to produce iso-butanol in early 2016.

Multiple companies have researched and developed biobased production routes for isoprene, which when polymerized is used in synthetic rubber applications for footwear, mechanical instruments, medical appliances, sporting goods, and most extensively as polyisoprene in rubber tires. But only one company is currently producing commercial quantities. Using its bacterial fermentation platform, GlycosBio has built its first commercial facility in southern Malaysia to supply the Southeast Asian region with up to 40,000 tons of bioisoprene annually. DuPont Industrial Biosciences and Goodyear developed a fermentation process for gas-phase capture of isoprene, and have demonstrated a prototype tire using the bioisoprene monomer. Ajinomoto has already successfully manufactured bioisoprene at a laboratory scale using a fermentation process, and Bridgestone has successfully produced polyisoprene rubber using the material. Michelin is also working with Amyris Biotechnologies to develop liquid-phase bio-isoprene using farnesene – a 15-carbon isoprenoid – as a building block. Amyris has begun commercialization of this new, renewable isoprene. Zeon, Yokohama Rubber, and RIKEN, Japan's national R&D agency, expect to commercialize a process for synthesizing isoprene from biomass in 2020. Aemetis now owns Zymetis' proprietary aerobic marine organisms, (*Saccharophagus degradans* 2-40) that will enable the company to produce bio-isoprene and other renewable chemicals.

One company, Itaconix Corporation, has commercialized fermentation technology, using *Aspergillus*, to pro-

duce itaconic acid, a building block for adhesives and sealants, finishing agents, paint and coating additives, detergents and cleaners, absorbents and dispersants. Itaconic acid can replace banned chemical phosphates in detergents. Itaconix operates a large-scale production facility in Stratham, New Hampshire, marketing a growing line of itaconic acid applications and polyitaconic acid. Itaconix recently announced its acquisition through merger by U.K. based Revolymer plc, a specialty chemical company.

Another company has commercialized a biobased process for aliphatic diacids, a building block for polyurethanes and polyamides. Elevance Renewable Sciences is producing Inherent™ C18 diacid, also known as octadecanedioic diacid (ODDA) at a biorefinery in Gresik, Indonesia, using the company's proprietary olefin metathesis technology.

And at least one company is producing commercial quantities of levulinic acid, a renewable specialty chemical building block for coatings, flavors/fragrances, polymers, detergents. Traditional petrochemical process of producing levulinic acid is from maleic anhydride; this process is expensive, limiting its use to low-volume applications such as fragrances and food additives. At larger, lower-cost production volumes, levulinic acid can replace bisphenol A (BPA) as a plasticizer. GFBiochemicals is currently expanding levulinic acid production capacity, from 2,000 to 8,000 metric tons by 2017, at a facility in Caserta, Italy.

### Market Potential for Renewable Chemicals

A number of recent studies provide estimates of the current value of renewable chemical production, which overall represent a small percentage of the worldwide chemical market. Production is expected to grow most rapidly

in Asia in response to the region's demand for products, supply of biomass raw material and favorable policies. Future value is dependent on the price of competing fossil-based chemicals, the price of oil, and a somewhat unpredictable policy environment.

Robert Carlson, writing in *Nature Biotechnology* in 2016, estimates that the U.S. industrial biotechnology industry revenues reached \$105 billion at a growth annual rate of 12 percent, and renewable chemicals contributed \$66 billion.

A report by the U.S.-based Biomass Research and Development Board estimates that the U.S. share of the biobased economy is approximately \$50 billion (€46.9 billion). More than a quarter million U.S. workers are employed in the industry.

The nova-Institute of Germany more recently examined the biobased polymer segment of the industry, which represented about \$12.8 billion (€10 billion) or 5 percent of biobased product sales in 2013. Production capacity for biobased polymers is growing at a 20 percent compound annual growth rate, with 3.5 million metric tons produced in 2011 and 5.1 million metric tons in 2013. The nova-Institute projects production capacity to reach 17 million metric tons by 2020. Biobased polymers currently represent a 2 percent share of the overall 256 million metric ton market for polymers (up from 1.5 percent of the 235 million metric ton market in 2011). By 2020, the 17 million metric tons of biobased polymers are expected to represent 4 percent of a 400 million metric ton market. The strongest growth in market demand for biobased polymers will be in food packaging and utensils, according to the nova-Institute. Production capacity for biobased polyethylene terephthalate (PET) is projected

to grow from 600,000 metric tons in 2013 to 7 million metric tons in 2020, leading the group of polymers. Based on planned capacity, nova-Institute projects similar expansion in production of biobased polyhydroxyalkanoates (PHA), and strong growth in production of polylactic acid (PLA) and biobased polyurethanes (PUR).

Lux Research based in Boston has also projected growth in the renewable chemical market through 2018. Their estimate includes the biobased polymer sector as well as intermediates – such as biobased succinic acid or adipic acid – and renewable specialty chemicals – such as farnesene or terpenes. Based on announced capacity construction, Lux expects biobased production capacity for intermediate chemicals to reach 2.9 million metric tons in 2018, reflecting an 11 percent compound annual growth rate; specialty chemical capacity is perhaps a quarter the size of the intermediate market. Lux Research projects leveling off of production capacity for polymers, due to the low prices of oil and natural gas. But renewable specialty chemicals continue to represent a profitable market opportunity.

### Potential Advantages for Consumer Product Applications

Renewable chemicals have been recognized for more than a decade as having environmental, economic, and performance advantages when compared to fossil fuel-based chemicals. Biotech routes to chemical production are inherently consistent with the principles of green chemistry.

In 2004, the U.S. Department of Energy (DOE) published a report, *Top Value Added Chemicals from Biomass*, acknowledging that biobased processes are often faster and more energy efficient production routes than pet-

## INTRODUCTION

rochemical processes. Reduction of time and energy inputs potentially can be translated into cost reductions, providing manufacturers an economic benefit. Further, renewable chemical production processes use raw material resources more efficiently and have less environmental impact overall than petrochemical production. The improvement potentially can save manufacturers material handling and regulatory compliance costs. Additionally, biomass is less volatile in price than fossil resources, which have characteristic boom and bust production cycles. Long-term stability in prices for renewable chemicals provide product manufacturers the ability to plan production well in advance and provides hedging.

A few years later, in 2007, the U.S. Environmental Protection Agency (EPA) published a report, *Bioengineering for Pollution Prevention*, recognizing that industrial biotechnology used in biobased processes and in renewable chemical production can reduce carbon emissions via many of the same attributes recognized by DOE – namely, improved process efficiency, the displacement of fossil fuels and petroleum-based materials, and the creation of closed loop industrial systems that eliminate waste. EPA recognized that these innate characteristics of biotech and biobased processes prevent waste and reduce derivatives, which closely match the principles of green chemistry. Since the introduction of EPA's Presidential Green Chemistry Challenge in 1996, one-third of all awards have gone to industrial biotechnology or biobased processes. Consumer demand for environmentally conscious products continues to rise.

More recently, in April 2016, the White House Office of Science and Technology Policy released a report on *Advanced Manufacturing: A Snapshot*

of Priority Technology Areas Across the Federal Government. This roadmap emphasizes that growth of the biobased economy is dependent on advanced biobased manufacturing and engineering biology. According to the roadmap, synthetic biology foundries hosted by federal government efforts will promote the commercial development of new renewable chemicals via faster and cheaper methodologies that use appropriate design of microorganisms.

Most producers of renewable chemicals can demonstrate comparable performance as drop-in replacements for petroleum-based chemicals. A few applications demonstrate improved performance. To cite one example, Avantium's PEF has superior properties to PET in drink bottle applications, including a higher barrier to oxygen, carbon dioxide and water. These properties can extend product shelf life and reduce production costs for beverage producers. PEF's carbon footprint is 50-70 percent lower compared to PET.

## Conclusion

Consumer product manufacturers have indicated that they are eager to use renewable chemicals in formulations in order to meet consumer demand for environmentally preferable products. The main challenge producers have cited for adoption of renewable chemicals is their ability to secure reliable, competitive supplies for large-scale product applications. Providing sufficiently large-scale supplies of drop-in renewable chemicals for some applications may require multiple manufacturers who adhere to common standards for chemical purity and quality.

Some renewable chemicals – such as succinic acid and PLA – are already being produced commercially by multiple, competing companies and could potentially have commodity

applications. A few additional renewable chemicals – such as butanol and isoprene – are approaching the same status. Several other renewable chemicals are being produced at commercial levels by a single company – such as 1,3-propanediol, propylene glycol and some diacids – with production tailored to niche product markets.

Many additional companies are scaling up and demonstrating new renewable chemical technologies. And in some cases, there are multiple companies competing to reach commercial scale. Forming partnerships with consumer product manufacturers or larger mid-market chemical producers – who can provide offtake agreements or capital investment in some form – is a common strategy for emerging companies commercializing new renewable chemicals. Ensuring that consumers receive the environmental, economic and performance benefits of renewable chemicals requires an integrated effort across this entire production value chain.



# AGRIVIDA

Medford, MA

Number of employees: 40

AGRIVIDA, INC. IS DELIVERING THE NEXT GENERATION OF ENZYME SOLUTIONS.

Above: Agrivida founder Michael Raab and U.S. Secretary of Energy Steven Chu, Medford, MA

## KEY FACTS

- + Feedstock: Grain, lignocellulosic biomass and sugar
- + Agrivida's GralNzyme® technology is an expression platform for making recombinant or synthetic proteins in grain and other plant tissues. Using GralNzyme® technology, Agrivida is commercializing a series of enzyme and protein products that are produced and delivered in grain. These initial products target the animal nutrition industry and improve feed conversion, yields, and the efficiency of food production.

## PARTNERSHIPS AND FINANCING

In 2014, Agrivida entered a trait development collaboration with Precision BioSciences to use Directed Nuclease Editor™ (DNE) technology. In 2015, Agrivida completed a \$23 million Series D financing led by Cultivian Sandbox Ventures, joined by an affiliate of Maschhoff Family Foods, ARCH Venture Partners, Middleland Capital and existing investors Kleiner Perkins Caufield & Byers, DAG Ventures, Bright Capital Partners, Gentry Venture Partners, Northgate Capital, Prairie Gold and private investors.

**About:** Agrivida is developing and commercializing solutions that are the next evolutionary step in animal nutrition, using the plant as a factory to produce and deliver highly differentiated agricultural and nutritional products.

**Product applications:** Animal health and nutrition; grain, food and feed processing; first and second generation biofuels and bio-based chemicals; industrial enzymes for a variety of industries.

**Potential market size:** Animal nutrition enzymes represent an \$850 million market. With increased food demand, sales of animal feed enzymes are expected to exceed \$1.8 billion by 2020.

**Technology:** Agrivida's INzyme® technology is a biological "off-on" switch engineered into enzymes to control their activity. Enzymes can be engineered with self-splicing peptides, called inteins, and produced in grain, green plants, fermentation microbes, or other hosts in a "dormant" form, where they accumulate in high concentrations. The enzymes are reactivated "on command" using a selected, controlled change in temperature or pH at a precise time, maximizing their value in the process or application.



# AMERICAN PROCESS

Atlanta, GA

Number of employees: 100

AMERICAN PROCESS IS COMMERCIALIZING GREENPOWER+ FOR ETHANOL.



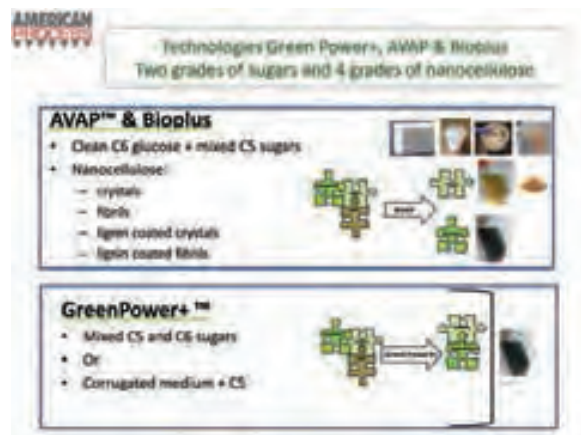
Above: AVAP Demonstration Plant, Thomaston, GA

**About:** American Process Inc. (API) specializes in the development, demonstration and commercialization of GreenPower+, AVAP and Bioplus technologies for the commercial production of cellulosic ethanol, cellulosic sugars and nanocellulose from biomass.

**Product applications:** Cellulosic ethanol, cellulosic sugars, nanocellulose.

**Potential market size:** Transparency Market Research reports that the global biofuels market was valued at \$168.18 billion in 2016 and is projected to reach \$246.52 billion by 2024.

**Technology:** GreenPower+® is a patented technology suite for producing low-cost mixed cellulosic sugars from biomass hemicelluloses and cellulose in co-production mode. These sugars are fermented to ethanol. AVAP® technology produces low-cost clean cellulosic sugars from biomass cellulose – and ethanol from the hemicelluloses – in a stand-alone facility. Bioplus® technology produces highly functional, hydrophilic and hydrophobic nanocellulose fibrils or crystals, in gel or dried form.

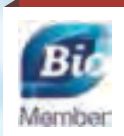


## KEY FACTS

- + Thomaston, GA  
Integrated demonstration plant for GreenPower+, AVAP and Bioplus
- + Alpena, MI  
Demonstration pre-commercial GreenPower+ plant – successfully completed demonstration – currently furloughed
- + Feedstock: Any woody or agricultural residue biomass

## PARTNERSHIPS AND FINANCING

American Process is privately owned by a joint venture of GranBio and TRILC. API has formed partnerships with Green Tech America and Valmet. American Process sponsors biorefinery research consortiums at the Empire State Paper Research Institute, North Carolina State University, and TEKES, Finnish Funding Agency for Technology and Innovation. It directly commissions biorefinery research projects at Georgia Institute of Technology, University of Maine, and Michigan Technological University.



# AMYRIS

Emeryville, CA

Number of employees: 400

AMYRIS, INC. IS PRODUCING FARNESENE.



Above: Brotas, São Paulo, Brazil Plant

## KEY FACTS

- + Brotas, São Paulo, Brazil
- + 1.2 million liters
- + Feedstock: Sugarcane juice

## PARTNERSHIPS AND FINANCING

With Total - Amyris launched in 2010 an ongoing research and development collaboration to accelerate the deployment of farnesene for the production of renewable jet fuel. In 2014, following regulatory approvals, Amyris began to commercialize its renewable jet fuel.

With Firmenich - Amyris developed a technology to produce sustainable, cost-effective ingredients for the flavors and fragrances (F&F) industry and have successfully produced its first fragrance oil.

**About:** Amyris delivers high-performance renewable products across a wide range of consumer and industry segments. Our products offer customers a way to reduce environmental impact with No Compromise® in performance or availability.

**Product applications:** Flavors, fragrances, cosmetics, detergents, fuels, lubricants, performance materials and biopharmaceuticals.

**Potential market size:** The personal care business represented \$25 million of 2015 revenue and is expected to contribute \$40 million of 2016 revenue. Amyris expects existing collaboration and supply agreements to generate over \$200 million in revenue through 2020 from the company's flavors and fragrances partners.



**Technology:** Through synthetic biology, Amyris is able to engineer the metabolic pathways of sugar, so that it can design microbes, primarily yeast, and use them as living factories in fermentation processes to convert plant-sourced sugars into target molecules. Amyris uses proprietary high-throughput processes to create and test thousands of yeast strains a day in order to choose those yeast strains that are most efficient and scalable for industrial production.



# ANELLOTECH

Pearl River, NY

Number of employees: 23

ANELLOTECH, INC. IS PRODUCING  
BENZENE, TOLUENE AND XYLENES.

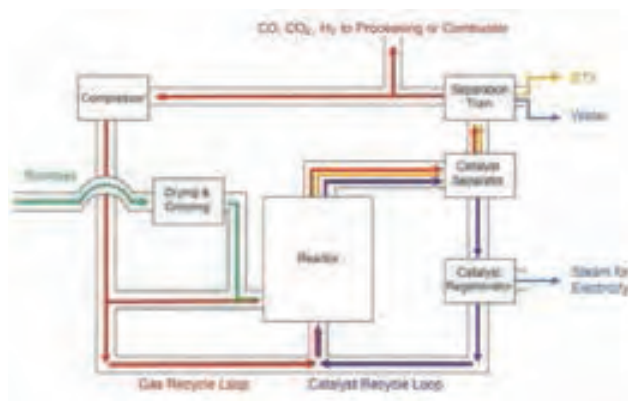
## Anellotech

**About:** Anellotech is a green innovation and technology company developing an efficient process for producing bio-based aromatic chemicals (BTX) from non-food biomass. We use proprietary thermal catalytic biomass conversion (Bio-TCat™) technology to provide sustainable chemical building blocks as an alternative to identical fossil-derived counterparts.

**Product applications:** Polyester, (polyethylene terephthalate or PET), polystyrene, polyurethane, nylon, styrene butyl rubber (SBR), acrylonitrile butadiene styrene (ABS) and other polymers, which are used to produce beverage bottles, clothing, carpeting, automotive components, and a broad range of other household and industrial products.

**Potential market size:** The global market for benzene, toluene and xylenes was approximately \$130 billion in 2014.

**Technology:** Through Bio-TCat™ technology, non-food biomass is rapidly heated in a fluid-bed reactor and the resulting gases are immediately converted into hydrocarbons by a proprietary, recirculating zeolite catalyst. Bio-based BTX, which is identical to petroleum-derived counterparts, can be further purified, separated and converted into a broad range of plastics using existing commercial technologies and industry infrastructure.



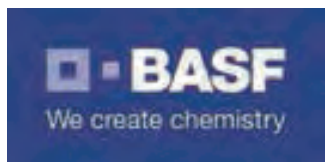
Above: Anellotech's T-Cat-8™ development and testing unit for converting biomass to BTX.

### KEY FACTS

- + Pearl River, NY
- + Feedstock: Biomass (wood, corn stover, sugarcane bagasse) and other non-food agricultural products
- + Anellotech's new, fully-integrated development and testing facility (TCat-8™) is currently under construction and will be operational in 2016. This continuous unit will confirm the viability and suitability of the process for scale-up and generate data needed to design commercial Bio-TCat plants. The TCat-8 unit was jointly designed by Anellotech and its R&D partner IFP Energies nouvelles (IFPEN) and will use a novel catalyst under joint development by Anellotech and Johnson Matthey.

### PARTNERSHIPS AND FINANCING

IFP Energies nouvelles (IFPEN) is our process development and scale-up partner. Johnson Matthey is our catalyst development and commercial catalyst supply partner. Axens is our partner for industrialization, commercialization, global licensing and technical support. In November 2015, Anellotech Inc. announced an equity investment of \$7 million from a new, strategic investor.



# BASF CORPORATION

Florham Park, NJ

Number of employees: 17,471 in North America

Above: Grain processing facility

## KEY FACTS

+ In addition to its own manufacturing facilities, BASF secures contract manufacturing relationships with qualified third parties possessing sufficient fermentation capacity to meet commercial production requirements.

For example, BASF has an important partnership with Fermic, which operates a U.S. FDA cGMP approved fermentation and synthesis facility and has a large fermentation plant in a suburb of Mexico City.



**About:** BASF Enzymes LLC is a wholly owned subsidiary of BASF Corporation located in San Diego, CA. It is a recognized pioneer in the development and commercialization of high-performance enzymes for use in industrial processes.

Our interdisciplinary, international research and development teams work at several BASF sites: Ludwigshafen (Germany), Tarrytown (New York, United States) and San Diego (California, United States).

**Product applications:** BASF sells enzymes developed using its unique patented R&D capabilities, harnessing the power of nature to satisfy the needs of the global market. Key markets are: human and animal health and nutrition, home care, grain processing, oilfield solutions, and pulp and paper.

**Technology:** Genetic expression libraries are constructed and quickly screened using automated and high-throughput robotic technologies. BASF uses patented, state-of-the-art gene evolution capabilities – suite of DirectEvolution® technologies – that make possible rapid optimization of proteins at the DNA level.

White Biotechnology develops and refines methods to use microorganisms, enzymes and cells to produce chemical and biochemical products. For thousands of years, people have been harnessing natural chemical processes to produce food, medicines and other products. Today, rapid technological progress in the life sciences is leading to innovative ways to use nature's variety for completely new applications.

BASF White Biotechnology uses natural synthesis techniques to develop products such as vitamins, food and feed supplements, chiral compounds, and pharmaceutical and agricultural intermediates. These techniques can increase efficiency and reduce raw materials, energy requirements and carbon emissions as compared to conventional chemical processes.



# BIOBASED TECHNOLOGIES® LLC

Rogers, AR

Number of employees: 15

BBT STRIVES TO REDUCE THE USE OF NONRENEWABLE INGREDIENTS BY INTEGRATING RENEWABLE INGREDIENTS.



**About:** BioBased Technologies® is an innovative leader in renewable chemistry and the maker of Agrol®, a line of USDA Certified Biobased polyols. Agrol® polyols are made from farm-grown plants and are suitable for all polyurethane applications as a substitute for petrochemicals in the making of products.

**Product applications:** Agrol®, commercialized in 2005, is used in lubricants, building products, furniture, bedding, automotive foams and parts, adhesives, agricultural products, carpet backings, industrial coatings and printing inks.

**Technology:** Agrol® polyols have a high bio-content and are made from plant-based ingredients, including soy and cashew nuts. Using a patented oxidation process, Agrol® can be used in various polyurethane applications with properties ranging from semi-flexible to semi-rigid. Qualities such as low acid number, mild odor and light color make Agrol® polyols ideal replacements for petroleum-based polyols. Custom blends are also available.



## KEY FACTS

- + Fountain Inn, SC
- + Dalton, GA Laboratory
- + Feedstock: Soybean oil
- + 100percent Woman-owned small business.
- + Collaborates with customers to create sustainable products that reduce costs while adding value.
- + Multiple U.S. and international patents.
- + Ample manufacturing capacity with room for growth.
- + Agrol® is cost competitive compared to other traditional polyols.
- + We enable sustainability ... through partnerships.

## PARTNERSHIPS AND FINANCING

Agrol® and Agrol Diamond® have been approved to use the U.S. Department of Agriculture certified biobased product label. The label indicates that the products have been independently certified to meet USDA BioPreferred™ program standards for biobased content.



Amy Sorrell, CEO



# BIO-CAT/BIO-CAT MICROBIALS

Troy, VA; Shakopee, MN

Number of employees: 15

BIO-CAT/BIO-CAT MICROBIALS IS PRODUCING ENZYMES.

Above: Shakopee, MN Plant

## KEY FACTS

+ Shakopee, MN

## PARTNERSHIPS AND FINANCING

BIO-CAT launched in 1988. BIO-CAT purchased AMS in 2004 and renamed it BIO-CAT Microbials. Facilities were updated, new fermentation equipment was purchased and larger blenders were added.

**About:** BIO-CAT offers a wide range of products, from single enzymes to multi-enzyme blends. BIO-CAT Microbials is an innovator in the field of biological solutions for a broad range of emerging and existing markets and industries.

**Product applications:** Detergent and other cleaning products, animal nutrition and aquaculture, food and beverage ingredients, dietary supplements, septic and drain care, waste treatment.

**Potential market size:** The potential market for industrial enzymes is 6.2 billion by 2020 according to Markets and Markets.

**Technology:** Enzymes can be produced from animal, bacterial, fungal, yeast and plant sources. They can be Kosher, Halal, and GRAS or industrial grade. They come in dry and liquid form.

Bacillus is a specific type (genus) of bacteria which grow aerobically (with oxygen) and to some extent anaerobically (without oxygen) and forms spores.

# BIORESOURCE INTERNATIONAL

Research Triangle Park, NC

Number of employees: 17

BIORESOURCE INTERNATIONAL, INC IS PRODUCING ENZYMES.



**About:** A global biotechnology company specializing in the research, development and manufacture of enzyme feed additives that help poultry and swine producers optimize animal nutrition.

**Product applications:** Versazyme® has become the leading protease in the global animal nutrition market. Valkerase® is an enzyme that improves the processing of feathers and the quality of feather meal. BRI's newest product, Xylamax™, is an intrinsically thermo-stable xylanase that delivers consistent all-around performance in nutrient release and absorption, total energy availability, and feed conversion rate. To quickly test animal feed on site to confirm the presence of Xylamax, the company has developed XylaQuick™, a qualitative in-feed calorimetric kit.

**Potential market size:** Animal nutrition enzymes represent an \$850 million market. With increased food demand, sales of animal feed enzymes are expected to exceed \$1.8 billion by 2020.

**Technology:** Dr. Shih's 1980s research and development of a thermophilic digester to generate power from poultry waste led to his discovery of keratinase, an enzyme that digests the keratin protein found in feathers. Further research proved that keratinase could also improve digestibility of animal feed.

## KEY FACTS

- + Research Triangle Park, NC
- + Feedstock: Poultry waste

## PARTNERSHIPS AND FINANCING

BRI has signed a marketing agreement with Jubilant Life Sciences, an integrated pharmaceutical and life sciences company, for marketing and distribution of selected feed enzyme products in South Asia. BRI has signed an agreement with ilender Corp. for the distribution and marketing of selected feed enzyme products in Latin American countries.



# BIOSYNTHETIC TECHNOLOGIES

Irvine, CA

Number of employees: 10

BIOSYNTHETIC TECHNOLOGIES IS PRODUCING BIOSYNTHETIC BASE OIL.



Above: Baton Rouge, LA Plant

## KEY FACTS

- + Baton Rouge, LA
- + Feedstock: Organic fatty acids found in plant oils

## PARTNERSHIPS AND FINANCING

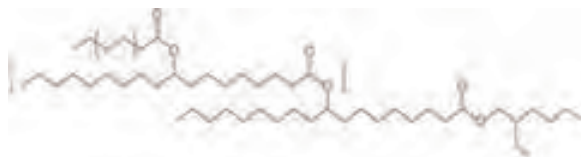
Biosynthetic Technologies holds exclusive rights to patented USDA technology that converts fatty acids found in plant and animal oils into high-performance synthetic oils. Biosynthetic Technologies is funded in part by multiple Financial Times Global 500 companies. For more information, visit [Biosynthetic.com](http://Biosynthetic.com).

**About:** Biosynthetic Technologies (BT) manufactures a renewable high-performance lubricant base oil that exceeds the toughest performance standards, even in challenging applications like motor oil. BT has received ILSAC GF-5 certification on both SAE 5W-20 and 5W-30 grade passenger car motor oil formulations using its Biosynthetic Base Oil. These formulations have also been certified by the American Petroleum Institute (API) to exceed the requirements of the most recent service category issued by API's Lubricants Group, the API SN "Resourcing Conserving" designation.

**Product applications:** Passenger car motor oil (PCMO); Marine lubricants; Small engine oil (2T/4T); Hydraulic fluid; Wind turbine; Refrigeration/compressor oil; Food-grade lubricant grease; Dielectric (transformer) fluid; Metalworking fluid; Gear oil; Bar and chain oil; General purpose lubricant; Plastics.

**Potential market size:** 1 billion gallons per year.

**Technology:** Biosynthetic Technologies (BT) manufactures a revolutionary new class of biobased synthetic molecules that are made from organic fatty acids found in plant oils.



# BLUE MARBLE BIOMATERIALS

Missoula, MT

Number of employees: 80

BLUE MARBLE BIOMATERIALS IS PRODUCING SPECIALTY CHEMICALS - SULFUR COMPOUNDS, THIOESTERS, ESTERS, SPECIALTY OFFERINGS, EXTRACT & OILS.



Above: Bitterroot Valley of Montana Plant

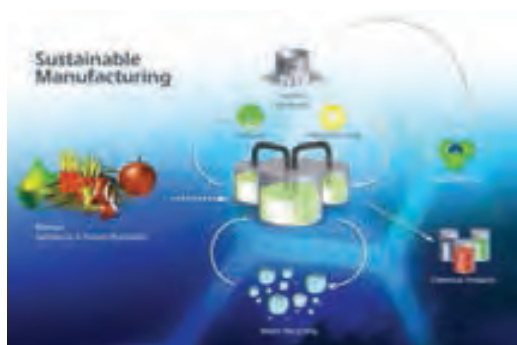
**About:** Our mission is to replace petroleum-based chemicals with fully sustainable, zero carbon specialty chemicals.

**Product applications:** Natural flavours and fragrances

**Potential market size:** In 2014, the world's ten largest specialty chemicals segments accounted for 61 percent of the market, reported IHS. Markets and Markets projects that specialty chemicals will reach \$470 billion by 2020.

**Technology:** Patented processes utilize plant material and managed ecosystems of bacteria to produce complex chemical compounds. We refine our compounds using green chemistry processes. Its proprietary AGATE system uses cellulosic, lignin, and protein based biomass to produce target products. Uses non-GMO polyculture fermentation and extraction.

Blue Marble is working with researchers at the University of Montana to develop natural algal products using patent-pending algae strains, growth systems, and extraction technologies.



## KEY FACT

- + Bitterroot Valley of Montana
- + Feedstock: Organic material (biomass): food co-products, spent brewery grain, spent coffee and tea, algae, milfoil, agricultural silage, wood chip

## PARTNERSHIPS AND FINANCING

In the fall of 2010, Blue Marble was awarded the Regional Woody Biomass Utilization Grant by Montana's Department of Natural Resources and Conservation. Innovate Montana is a public/private partnership, led by the Governor's Office of Economic Development working in collaboration with Montana's business community. Their goal is to highlight innovative businesses like Blue Marble Biomaterials that are advancing the state's economy by creating quality jobs.

# CALYSTA



## CALYSTA

Menlo Park, CA

Number of employees: 50

CALYSTA IS DEVELOPING FEEDKIND® PROTEIN, ALCOHOLS, ESTERS, OXIDES AND OLEFINS.

Above: FeedKind®

### KEY FACTS

- + Menlo Park, CA
- + Feedstock: Methane
- + In January 2016, Calysta received a conditional award of up to £2.8 million Exceptional Regional Growth Fund (eGRF) grant subject to due diligence from the UK Government to develop a Market Introduction Facility in northern England to develop a production process for FeedKind® protein. FeedKind® is approved for sale in the European Union. In June 2014, Calysta announced it has successfully fermented methane into lactic acid, under a research collaboration with NatureWorks. Lactic acid is the building block for NatureWorks Ingeo lactide intermediates and polymers.

### PARTNERSHIPS AND FINANCING

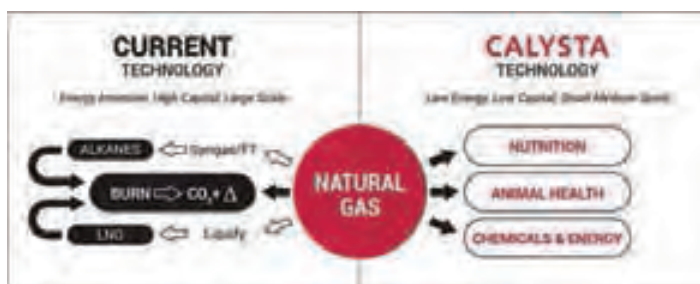
In February 2016, Calysta announced \$30 million in Series C funding with Cargill, the Municipal Employee Retirement System (MERS) of Michigan and Old Westbury Global Real Assets Fund LLC. In January 2015, Calysta completed a Series B financing round totaling \$10 million, led by Walden Riverwood Ventures, a venture firm focused on investing in core technology companies globally, and Aqua-Spark, a Netherlands-based firm focused on sustainable aquaculture investments.

**About:** Calysta creates high-value nutrition products and industrial materials by converting energy-rich methane into sustainable building blocks for life.

**Product applications:** Fish and livestock nutrition products, industrial materials and consumer products. FeedKind® protein is a natural, safe, non-GMO, sustainable fish feed ingredient to reduce the global aquaculture industry's use of fishmeal.

**Potential market size:** Specialty.

**Technology:** Calysta is converting novel feedstocks to high value sustainable products using synthetic biology. Calysta is developing Biological Gas-to-Chemicals® and Biological Gas-to-Liquids® platforms and Biological Gas to Feed™ and Biological Gas to Fuel™ fermentation platforms. These platforms create valuable cost and performance advantages over current gas conversion processes without competing for food, land or water. FeedKind® is produced using methanotrophs, natural organisms that consume methane from multiple sources, including anaerobic digestion and municipal solid waste, as their energy source.



BIOBASED PRODUCTS ARE MADE FROM RENEWABLE BIOMASS, OILS OR OTHER CARBON WASTE STREAMS, INCLUDING WASTE STACK GASES. RENEWABLE CHEMICALS ARE THE BUILDING BLOCKS FOR BIOBASED PRODUCTS.



# CELLANA, LLC

Kailua-Kona, HI

Number of employees: 20+

CELLANA LLC IS PRODUCING ALGAE OILS, PROTEINS/CARBOHYDRATES AND BIOMASS.

Above: Kailua-Kona, HI Plant

## KEY FACTS

- + Kailua-Kona, HI
- + 12+ tons per year, current capacity
- + Feedstock: Algae

## PARTNERSHIPS AND FINANCING

Cellana has received multiple large grants from the U.S. Departments of Energy (DOE) and Agriculture (USDA). Cellana has entered into a commercial-scale off-take agreement with Neste, the world's leading supplier of renewable diesel and jet fuel, for Cellana's ReNew™ Fuel biocrude oil for fuel applications.

**About:** Cellana is a leading developer of algae-based bioproducts for sustainable nutrition and energy applications.

**Product applications:** Algae-based bioproducts such as Omega-3 nutritional oils, Aquaculture/animal feeds, human foods and fuels.

**Potential market size:** \$4 billion Omega-3 oils, \$9 billion aquaculture feeds, \$1 trillion fuels/chemicals, \$100 million whole algae products for aquaculture hatcheries, cosmetics, & functional foods.

**Technology:** Cellana's patented production system, called ALDUO™, is unique in that it couples large-scale photobioreactors (PBRs) with open ponds in a two-stage process. Open ponds, which are very cost-effective, have historically been limited by contamination from undesirable algae strains (weeds) or grazer organisms (pests). PBRs are generally unable to produce algae at an acceptable cost for commodity applications. ALDUO™ minimizes the footprint of PBRs & maximizes the footprint of the open ponds, in order to minimize overall cost & minimize risk of contamination. By operating the PBRs in semi-continuous mode to provide inoculum for the open ponds, which are operated in batch mode, Cellana has successfully grown more than 10 strains of algae at commercial yields without pesticides or herbicides.





# THE COCA-COLA COMPANY

Atlanta, GA

Number of system employees: >700,000

THE COCA-COLA COMPANY PRODUCES PLANTBOTTLE™ PACKAGING, THE FIRST-EVER FULLY RECYCLABLE PET PLASTIC BEVERAGE BOTTLE MADE PARTIALLY FROM PLANTS.

*The Coca-Cola Company*



**About:** The Coca-Cola Company is the world's largest beverage company, refreshing consumers with more than 500 sparkling and still brands and more than 3,800 beverage choices.

**Product applications:** PET packaging and materials.

**Potential market size:** PlantBottle™ packaging accounts for 30 percent of the company's packaging volume in North America and 8 percent

globally, some 7 billion bottles annually, making The Coca-Cola Company a large bioplastics end user.

**Technology:** Coca-Cola introduced PlantBottle™ Technology in 2009 as the first recyclable PET plastic bottle made partially from plants. Since then, more than 40 billion PlantBottle™ packages have reached the market in over 40 countries, saving more than 845,000 barrels of oil. The company's goal is to adopt the PlantBottle™ packaging (which consists of 30 percent plant-based material) for all of its new PET plastic bottles in the future. To achieve this objective, Coca-Cola is partnering with other companies to expand technology and build manufacturing facilities around the world.

## KEY FACTS

+ Feedstock: Sugarcane

## PARTNERSHIPS AND FINANCING

In June 2012, Coca-Cola, Ford, Heinz, Nike and Procter & Gamble formed the Plant PET Technology Collaborative to accelerate development of products made entirely from plants. The PlantBottle™ technology has also been applied beyond beverage bottles. Coca-Cola now has developed partnerships with the Ford Motor Company to use the PlantBottle™ technology for polyester car interiors, and SeaWorld® Parks & Entertainment (as well as other theme parks and zoos), to introduce a refillable souvenir cup made with PlantBottle technology.



# CORBION

Amsterdam, Netherlands

Number of employees: 1,673

CORBION IS PRODUCING LACTIDE MONOMERS AND POLYMERS, 2,5-FURANDICARBOXYLIC ACID, AND SUCCINIC ACID.

Above: Blair Manufacturing Facility, Blair, NE

## US PRODUCTION FACILITIES

- + Blair Manufacturing Facility, Blair, NE
- + Dolton Manufacturing Facility, Dolton, IL
- + East Rutherford Manufacturing Facility, East Rutherford, NJ
- + Grandview Manufacturing Facility, Grandview, MO
- + Totowa Manufacturing Facility, Totowa, NJ
- + Tucker Manufacturing Facility, Tucker, GA

## PARTNERSHIPS AND FINANCING

In 2011, Corbion signed a partnership agreement with Perstorp; and in 2015 jointly announced development of a new lactide (PURALACT® B3) caprolactone co-polymer (Capa™) for use in hot melt adhesive applications.

In 2013, Corbion and BASF established the 50/50 joint venture, Succinity GmbH, to produce high-quality succinic acid based on renewable resources.

In 2015, Corbion and MedinCell established a 50/50 joint venture, CM Biomaterials, to supply biobased copolymers for controlled-release drug delivery. The joint venture will sell the co-polymers to MedinCell partners who license the MedinCell technology (BEPO™).

**About:** Corbion is the global market leader in lactic acid, lactic acid derivatives, and lactides, and a leading company in emulsifiers, functional enzyme blends, minerals, and vitamins.

**Product applications:** The company delivers high performance biobased products made from renewable resources and applied in global markets such as bakery, meat, home and personal care, packaging, pharmaceuticals and medical devices, automotive, coatings and adhesives. Its products have a differentiating functionality in all kinds of consumer products worldwide.

**Potential market size for bioplastics:** Global bioplastics production capacity is set to increase from around 1.7 million tonnes in 2014 to approximately 7.8 million tonnes in 2019, according to Institute for Bioplastics and Biocomposites.

**Technology:** Corbion has an established technology platform based on over 80 years of fermentation experience. Corbion leads the way in lactic acid as well as in cutting-edge emulsification technology and functional blending capability. Drawing on the deep rooted application and market knowledge that has been built up over decades, Corbion works hand in hand with our customers to make our technology work for them.

With the construction of a 75 kiloton per year PLA plant in Rayong Province, Thailand, Corbion is moving one step in the value chain.





# THE DOW CHEMICAL CO.

Midland, MI

Number of employees: 49,495

THE DOW CHEMICAL COMPANY IS PRODUCING  
ETHANOL, PLASTICIZERS, POLYOLS.



**About:** The Dow Chemical Company is a diversified, worldwide, manufacturer and supplier of products, used primarily as raw materials in the manufacture of customer products and services.

**Product applications:** Flexible packaging, hygiene and medical markets, adhesives and sealants.

**Potential market size:** The global market for adhesives and sealants is expected to reach \$43,195.5 million by 2020, according to a 2014 study by Grand View Research, Inc.

**Technology:** RENUVA™ Renewable Resource Technology breaks down natural oil and functionalizes it, then uses a distinct process to polymerize the molecules into designed polyols with control of functionality and molecular weight for greater quality and consistency.

## KEY FACTS

- + U.S. Gulf Coast
- + Feedstock: Soy
- + DOW's Santa Vitória, Minas Gerais, Brazil integrated alcohol-chemical complex uses sugarcane as a renewable feedstock for the production of ethanol. The mill has the capacity to convert 2.7 million tons of sugarcane into 240,000 cubic meters of hydrous fuel ethanol per harvest year.

## PARTNERSHIPS AND FINANCING

BioVinyl™ flexible vinyl compounds incorporate phthalate-free DOW ECOLIBRIUM™ Bio-Based Plasticizers, which are manufactured using plant byproducts by Dow Electrical and Telecommunications, a business unit of The Dow Chemical Company. Under a Joint Collaboration Agreement, Teknor Apex has the exclusive right to market in North America flexible vinyl compounds containing DOW ECOLIBRIUM™ Bio-Based Plasticizers in consumer and industrial products, automotive components, certain medical devices, and certain wire and cable uses.



# DUPONT

Wilmington, DE

DUPONT IS DEVELOPING PLATFORMS FOR BIOFUELS, FOOD INGREDIENTS, MATERIALS AND CHEMICALS.

Above: DuPont Cellulosic Ethanol, Nevada, IA

## KEY FACTS

- + DuPont Cellulosic Ethanol Nevada, IA
- + 30 million gallons per year
- + Feedstock: Corn stover



## PARTNERSHIPS:

In 2016, DuPont and Archer Daniels Midland announced a method for producing furan dicarboxylic methyl ester (FDME) from fructose. One of the first polymers under development utilizing FDME is polytrimethylene furandicarboxylate (PTF).

**About:** DuPont has been bringing world-class science and engineering to the global marketplace in the form of innovative products, materials, and services since 1802.

**Product applications:** Animal nutrition, food, detergents, textiles, carpets, personal care, biobased materials and biofuels.

**Technology:** DuPont integrates proven strengths in chemistry, materials science and engineering with cutting-edge biology, augmenting or replacing chemical transformations with biological ones. DuPont's biobased materials reduce the use of petroleum while improving performance. DuPont is leading the world in meeting growing biofuel needs.

By adding modern science and knowledge to nature's own material, DuPont™ Danisco® food enzymes bring added value and previously unattainable functionalities to many food products. They help extend shelf life, optimize production, add texture, ensure quality consistency and reduce costs – gains that in turn enable customers to reduce water use, energy consumption and waste. POWERFlex®, an enzyme solution developed for tortilla baking, reduces the stickiness of dough and gives tortillas long-lasting freshness and improved flexibility. Enzymes also support health and wellness by promoting the digestion of milk lactose, starch, proteins, fats and oils.

DuPont offers a wide range of liquefaction, saccharification and isomerization products to customers in the wet milling industry, backed by our applications laboratories in the US, China and Europe. Experienced DuPont professionals provide technical support to optimize the production of HFCS, high dextrose and high maltose syrups. This enzyme technology also contributes to energy, water and chemical reduction by increasing dry solids, reducing process temperatures and pH adjustments and improving filtration efficiencies.

# DUPONT TATE & LYLE BIO PRODUCTS

Loudon, TN

DUPONT TATE & LYLE BIO PRODUCTS IS  
PRODUCING 1,3 PROPANEDIOL.



Above: Loudon, TN plant

**About:** DuPont Tate & Lyle Bio Products provides natural and renewably sourced ingredients that enhance product performance.

**Product applications:** 100 percent biobased 1,3 propanediol is used to produce fiber grade polyester polymer for residential and commercial carpets, apparel and automotive mats and carpets. In addition the Zemea® brand of 1,3 propanediol is found in cosmetics, personal care, food, flavors, laundry, cleaning and pharmaceutical products. The Susterra® brand is targeted for industrial applications such as heat transfer fluids, deicing, polyurethanes, paints, coatings and inks.

**Technology:** Under exact temperatures and conditions, a patented microorganism functions as a bio-catalyst, converting sugar into 1,3 propanediol. The deactivated microorganism is separated from the broth, along with unfermented sugars, salts and water. The material is then refined to remove any trace quantities of water and other by-products. The resulting product is highly purified 1,3 propanediol ready for commercial use.



Copyright © 2016 DuPont Tate & Lyle Bio Products. All rights reserved. Zemea®, Susterra® and the Circle Logo are registered trademarks of DuPont Tate & Lyle Bio Products Company, LLC.

## KEY FACTS

- + The global headquarters and production facility for DuPont Tate & Lyle Bio Products is located in Loudon, TN.
- + The plant started production in 2006 and has a current capacity of 140 million pounds per year.
- + Feedstock: Glucose from corn wet milling operation.

## PARTNERSHIPS AND FINANCING

DuPont Tate & Lyle Bio Products is a joint venture between DuPont, a global science company, and Tate & Lyle, a world-leading renewable food and industrial ingredients company. DuPont and Tate & Lyle jointly funded the plant with total investment of \$100 million.

## AWARDS

2003 EPA Presidential Green Chemistry

2007 ACS Heroes of Chemistry

2009 ACS-BIOT Industrial Biotechnology

2010 State of Tennessee Governor's Award for Trade Excellence



# ECOSYNTHETIX

Burlington, ON, Canada

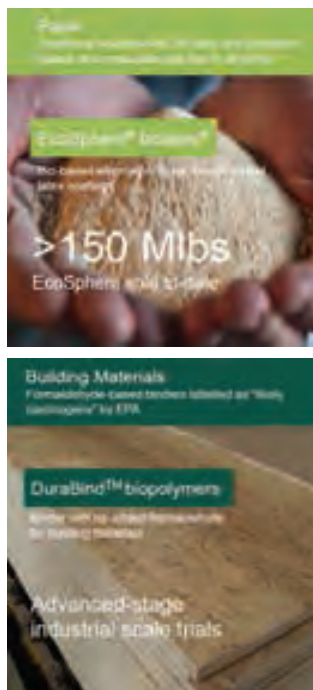
Number of employees: 50

ECOSYNTHETIX IS PRODUCING ECOSPHERE® BIOPOLYMERS AND ECOMER® BIOMONOMERS.

Above: EcoSynthetix, Burlington, Ontario

## KEY FACTS

- + Centre of Innovation, Burlington, Ontario, Canada. Production sites in Tennessee and The Netherlands.



## PARTNERSHIPS AND FINANCING

The company has established a number of academic and government funding partnerships to support its research and development activities. EcoSynthetix is a public company trading on the Toronto Stock Exchange (TSX: ECO). For further details, visit us at [ecosynthetix.com](http://ecosynthetix.com).

**About:** EcoSynthetix is a renewable chemicals company specializing in bio-based materials used as inputs in a wide range of end products. Our commercial bio-based products exhibit similar performance characteristics compared to non-renewable products that they replace, often at reduced total systems cost.

**Product applications:** Binders and modifiers for key global markets, including: paper & paperboard, building and construction, personal care, and others.

**Potential market size:** \$60 billion of synthetic polymers.

**Technology:** EcoMer® is the flagship product family of functional engineered biopolymers that are patented and exclusively available from EcoSynthetix. These products represent a class of highly efficient binders derived from renewable materials which can cost-effectively displace traditional synthetic binders in a number of significant market applications, including coated paper and paperboard, building products such as wood composites and insulation, and others.



# EDENIQ

Visalia, CA

Number of employees: 30

EDENIQ IS PRODUCING CELLULOSIC SUGARS.

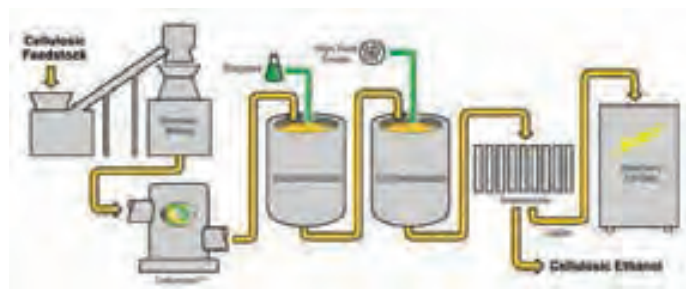


Above: Visalia, CA Plant

**About:** EdeniQ is a biorefining and cellulosic technology company. EdeniQ delivers integrated process innovations that unlock sugars.

**Product applications:** Technology to produce cellulosic ethanol from corn kernel fiber at existing ethanol plants using EdeniQ's Cellunator™ pretreatment and cellulases.

**Technology:** EdeniQ combines a mechanical pretreatment (Cellunator) process with enzymatic hydrolysis to efficiently and cost-effectively break down structural plant materials into cellulosic sugars. EdeniQ's PATHWAY Platform integrates enzymes with the Cellunator and SmartFlow™ Technology for water and lignin recovery to allow for conversion of corn kernel fiber into cellulosic sugars and ethanol. PATHWAY produces up to 2.5 percent cellulosic ethanol; a 15,000 gallon per year plant could produce 375 gallons per year of cellulosic ethanol.



## KEY FACTS

- + Visalia, CA
- + Feedstock: Corn stover, sugarcane bagasse
- + The PATHWAY Platform has been licensed for commercial production of cellulosic biofuel from corn kernel fiber. EdeniQ has announced commercial licenses for its PATHWAY Platform with Pacific Ethanol, Flint Hills Resources, Siouxland Energy, and Aemetis.
- + EdeniQ is partnering with Usina Vale to build a demonstration plant at Usina Vale's sugar mill in Brazil to convert sugarcane bagasse to cellulosic ethanol

## PARTNERSHIPS AND FINANCING

Department of Energy program funded \$20 million of EdeniQ's \$25 million cellulosic ethanol pilot plant; with nearly \$4 million from the California Energy Commission (CEC).

EdeniQ is a privately held company. EdeniQ and Aemetis have announced a planned merger to close in the third quarter 2016.



# ELEVANCE RENEWABLE SCIENCES

Woodridge, IL

Number of employees: 100

ELEVANCE RENEWABLE SCIENCES, INC IS PRODUCING ETHYLENE.

Above: Woodridge, IL Plant

## KEY FACTS

- + Woodridge, IL
- + Feedstock: Plant-based oils like soybean, canola, palm, mustard and jatropha or algae

## PARTNERSHIPS AND FINANCING

Elevance has a collaboration with Genting Plantations Berhad through Genting Integrated Biorefinery Sdn Bhd (GIB). The collaboration will build a 240,000 megaton (MT) biorefinery in the Palm Oil Industrial Cluster (POIC) in Lahad Datu, Sabah, Malaysia. Versalis, the chemical subsidiary of Eni, has licensed Elevance technology to build a biorefinery at Porto Maghera, Italy.

Elevance and Wilmar International Limited formed a joint venture that operates a world-scale biorefinery in Gresik, Indonesia, based on Elevance's technology. The commercial-scale manufacturing facility capacity is 180,000 MT per year.

**About:** Elevance is a high-growth company that creates novel specialty chemicals from renewable feedstocks by using a proprietary, Nobel Prize-winning technology called olefin metathesis. With olefin metathesis, Elevance helps enable its customers to deliver everyday products that exceed the performance of existing products while leaving a smaller environmental footprint.

**Product applications:** Personal care, detergents, cleaners, polymers, lubricants and oilfield chemicals.

**Potential market size:** The outputs from Elevance's production process are relevant to markets valued well in excess of \$200 billion. The specialty chemicals market is estimated at \$176 billion. The oleochemical market was \$38 billion in 2010. The intermediate olefin market was \$7 billion in 2008.

**Technology:** Olefin metathesis chemistry, a groundbreaking catalyst technology, allows carbon atoms in natural oils to "swap" places, enabling new chemical compounds and manufacturing processes.

## Elevance Biorefinery Process





# EVOLVA

Reinach, Switzerland

Number of employees: 116

EVOLVA IS PRODUCING HIGH-VALUE SPECIALTY INGREDIENTS.

**About:** Evolve is a pioneer and global leader in sustainable, fermentation-based approaches to ingredients for health, wellness and nutrition.

**Product applications:** Evolve's products include stevia, resveratrol, vanillin, nootkatone and saffron

**Potential market size:** \$91.2 billion by 2020, according to Markets and Markets.

**Technology:** We have an array of technologies that allow us to rapidly insert and express tens to hundreds of genes in billions of individual yeast cells in a highly combinatorial fashion. This allows us to explore large numbers of gene combinations and hence find those gene combinations that are necessary to biosynthesise a given ingredient. Funded by the Innovative Medicines Initiative, The CHEM 21 project (Chemical Manufacturing Methods for the 21st Century Pharmaceutical Industries) brings together six pharmaceutical companies, five SMEs and research groups eight other universities from the UK and Europe.

Above: Evolve fermenter

## KEY FACT

+ Feedstock: Baker's yeast

## PARTNERSHIPS AND FINANCING

The partners in the BioPreDyn project are developing software tools to facilitate metabolic engineering by the use of computer-based cell models. The PROMYS project has a duration of four years and a total EU funding of € 7.2 million (CHF 8.9 million), of which Evolve's share is 9.8 percent. The PROMYS project is part of the European Commission's 7th Framework Programme for Research ("FP7"). Evolve's role in the project will be to construct a yeast that is able to produce high yields of a taste modulating ingredient.





# FORELIGHT

Chicago, IL

Number of employees: 6

FORELIGHT IS PRODUCING ALGAE BIOMASS.

Above: Algae bioreactor with Illumesis™ lighting

## KEY FACTS

- + Chicago, IL
- + Feedstock: Algae
- + ForeLight's production facility is located in the University Technology Park on the Chicago campus of the Illinois Institute of Technology (IIT).

## PARTNERSHIPS AND FINANCING

Privately held.

**About:** ForeLight's advanced artificial light bioreactor enables unparalleled control over the growth of algae, cyanobacteria and other photosynthetic organisms, offering a stable, cost-effective solution to the biomass production needs of the life sciences, material sciences and biological research & diagnostics fields.

**Product applications:** Forelight, Inc. provides fluorescent biomarkers. ForeLight's patented Illumesis™ lighting and growth platform is accelerating the potential application of indoor agriculture/aquaculture for the food, beverage, nutraceutical, cosmetic and other industries.

**Technology:** Allophycocyanin (APC) is a highly soluble fluorescent phycobiliprotein isolated from the cyanobacteria *Arthrospira platensis*. R-Phycoerythrin (R-PE).



# GENOMATICA

San Diego, CA

Number of employees: ~100

GENOMATICA, INC IS PRODUCING 1,4-BUTANEDIOL, BUTADIENE, HEXAMETHYLENEDIAMINE, CAPROLACTAM AND ADIPIC ACID.



Above: Adria, Italy Plant

**About:** Genomatica delivers new manufacturing processes that enable its partners to produce the world's most widely-used chemicals from alternative feedstocks, with better economics and greater sustainability than petroleum-based processes.

**Product applications:** BDO is used in plastics, solvents, electronic chemicals and elastic fibers for the packaging, automotive, textile, and sports and leisure industries. Butadiene is a key raw material for tires, engineering polymers and latex products.

**Potential market size:** The 1,4-Butanediol market will be worth \$8.96 billion by 2019. Hexamethylenediamine, caprolactam and adipic acid have a total market of over \$18 billion per year.

**Technology:** Guided by a genome-scale metabolic model, we engineered the *E. coli* host to enhance anaerobic operation of the oxidative tricarboxylic acid cycle. The organism produced BDO from glucose, xylose, sucrose and biomass sugar streams.



## KEY FACTS

- + Adria, Italy
- + 30 kilotons per year
- + **Feedstock:** Strategic relationships with Tate & Lyle for dextrose sugar, M&G for sugars from cellulosic biomass, and Waste Management for C1s.
- + Genomatica and DuPont Tate & Lyle Bio Products Company, LLC (DT&L) produced more than 5 million pounds (over 2,000 metric tons) of BDO by direct fermentation using conventional sugars as feedstock in 2012.

## PARTNERSHIPS AND FINANCING

Under a joint venture agreement, Novamont is converting an existing facility in Adria, Italy to use Genomatica's BDO process to produce approximately 40 million pounds of BDO per year. In April 2013, Versalis and Genomatica announced an agreement to create a joint venture for butadiene. In December 2013, Braskem and Genomatica announced a joint development agreement for butadiene. Braskem anticipates funding Genomatica's development work; will allocate Braskem R&D resources; and fund the construction of pilot and demonstration-scale plants.



# GEVO

Englewood, CO

Number of employees: 91

GEVO IS PRODUCING ISOBUTANOL, ETHANOL  
AND HIGH-VALUE ANIMAL FEED.

Above: Luverne, MN Plant

## KEY FACTS

- + Luverne, MN
- + 20 billion gallons per year
- + Feedstock: Corn
- + Gevo currently operates a biorefinery in Silsbee, Texas, in collaboration with South Hampton Resources Inc., to produce renewable jet fuel, octane, and ingredients for plastics like polyester.

## PARTNERSHIPS AND FINANCING

Gevo has a marquee list of partners including The Coca-Cola Company, Toray Industries Inc. and Total SA, among others.

**About:** Gevo® is a leading renewable chemicals and advanced biofuels company. We are developing biobased alternatives to petroleum-based products using a combination of synthetic biology and chemistry.

**Product applications:** Isobutanol has broad market applications as a solvent and a gasoline blendstock that can help refiners meet their renewable fuel and clean air obligations.

**Potential market size:** The global isobutanol market is expected to reach \$1.18 billion by 2022. The feed additives is projected to reach \$21.8 billion by 2020.

**Technology:** Gevo's proprietary integrated fermentation technology platform (GIFT®), which has been designed to produce low-cost renewable isobutanol, consists of two elements: A proprietary yeast biocatalyst, which converts sugars derived from multiple renewable feedstocks into isobutanol, and a proprietary separation unit which is designed to bolt onto existing ethanol facilities.



# GF BIOCHEMICALS

Milan, Italy

Number of employees: 50

GF BIOCHEMICALS AMERICAS IS PRODUCING LEVULINIC ACID DERIVATIVES, LIKE ESTERS AND KETALS.



Above: Golden Valley, MN Plant

**About:** GFBiochemicals is the main producer of levulinic acid at commercial scale directly from biomass.

**Product applications:** Pharma, personal care, flavors and fragrances, resins and coatings, cleaners, plasticizers, nylon, fuel additives.

**Potential market size:** \$40 billion annually.

**Technology:** Thanks to its proprietary technology, levulinic acid is produced through a one-step process directly from a wide range of cellulosic feedstock and GFBiochemicals offers a combination of high product yields, high productivity, concentrated process streams and efficient recovery. Produced at an industrial scale levulinic acid is cost competitive and can also successfully address many performance-related issues attributed to petroleum-based chemicals and materials. Levulinic acid was recognized by the US Department of Energy as one of the top biobased platform chemicals of the future.

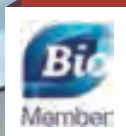
## KEY FACTS

- + Golden Valley, MN
- + Caserta, Italy
- + 3 million lbs per year
- + Commercial under development, potentially at Laskin Energy Park in Hoyt Lakes, MN.

## PARTNERSHIPS AND FINANCING

GFBiochemicals is owned by private investors.





# GREEN BIOLOGICS

Ashland, VA.

Number of employees: 78 (in U.S. operations)

GREEN BIOLOGICS IS PRODUCING 100 PERCENT BIOBASED, RENEWABLE N-BUTANOL AND ACETONE.

Above: Little Falls, MN Plant

## KEY FACTS

- + Little Falls, MN  
30,000 tonnes per year  
Feedstock: Corn
- + Emmetsburg, IA.  
40,000 liter demonstration

## PARTNERSHIPS AND FINANCING

GBL was founded in Oxford, England in 2003 and moved to its current location in Milton Park near Abingdon in 2005. On January 1, 2012, GBL merged with Butylfuel™ Inc., a Gahanna, Ohio company founded in 1991.

GBL has raised well over \$100 million in equity financing from investors and venture capital firms including Sofinnova Partners, Swire Pacific Limited, Capricorn Venture Partners, Oxford Capital Partners, ConVergInce Holdings, the Carbon Trust and Morningside Group.

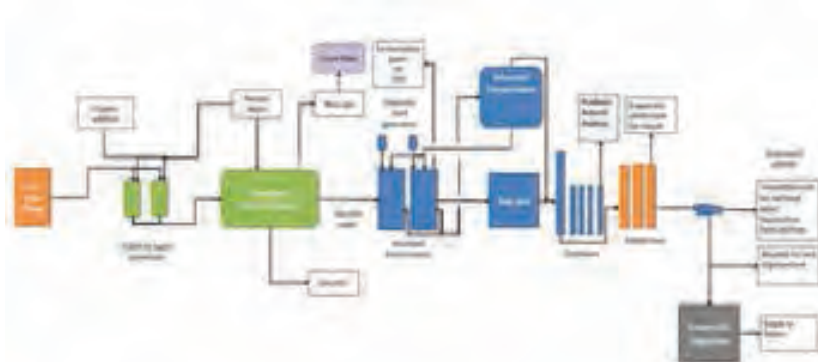
Additional venture debt financing was provided by Tennenbaum Capital Partners (TCP). In 2014, GBL received a \$500,000 grant from the Minnesota Agricultural Department to support the engineering for repurpose of their advanced fermentation facility in Little Falls, MN. [www.greenbiologics.com](http://www.greenbiologics.com)

**About:** Green Biologics Ltd (GBL) is developing and commercializing technologies to produce renewable chemicals that reduce GHG emissions, create rural jobs and deliver a sustainable value chain for a global green economy.

**Product applications:** n-Butanol is used in paints and coatings, and as an intermediate in the production of household, institutional, and industrial products as well as plasticizers, esters and amines. Acetone is used extensively as a solvent in paints, coatings, adhesives, inks, plastics and polymers, personal care and food applications.

**Potential market size:** The global market for n-butanol was estimated at 3,802.5 kilotons in 2012. According to Markets to Markets consultancy, the global n-butanol market is expected to reach \$9.4 billion by 2018, with year-over-year growth exceeding 4.4 percent.

**Technology:** We use microbial engineering and synthetic biology tools to continually expand our robust library of Clostridium microbial strains, which are used as biocatalysts as part of our Advanced Fermentation Process (AFP)™.



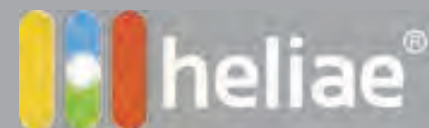


# HELIAE

Gilbert, AZ

Number of employees: ~130

HELIAE IS CURRENTLY PRODUCING HIGH-VALUE PRODUCTS DERIVED FROM MICROALGAE. HELIAE PRODUCES SUPPLEMENT GRADE ASTAXANTHIN AND A NUMBER OF AGRICULTURAL PRODUCTS AT COMMERCIAL SCALE.



Above: Gilbert, AZ Plant

**About:** Heliae® is a platform technology company using sunlight and low-cost carbon feedstocks to produce a wide range of high-value products from microalgae and similar emerging biological systems, with a long term vision of producing a sustainable source of high-quality, low-cost protein, materials, and related products.

**Product applications:** Human and animal health, agriculture, aquaculture, materials and technology services.

**Potential market size:** The current market value of commercially used carotenoids (such as astaxanthin) is estimated at nearly \$1.5 billion (2014) and is projected to reach \$1.8 billion in 2019 at a CAGR of 3.9 percent. The soil treatment market is valued at \$24.1 billion and is estimated to grow at a CAGR of 8.5 percent through 2020. The biological products in agriculture market was estimated at \$3 billion in 2013 with a 3-year CAGR of 15 percent. Nutritional chemicals for the animal health market are estimated to reach nearly \$4 billion in 2016, with a CAGR between 3.2 and 4 percent. By 2020, the aquaculture feed market is expected to reach \$381.9 million. The global biomaterials market is forecast to grow to an estimated \$130.57 billion by 2020 at a CAGR of 16 percent.

**Technology:** While experts in phototrophic microalgae production, Heliae's mixotrophic algae production platform sets it apart from the industry. Mixotrophy is a hybrid of known phototrophic and heterotrophic models, which decreases capital costs, improves contamination control and increases productivity and product optionality.

## KEY FACTS

- + Gilbert, AZ
- + 1 billion gallon per year
- + Feedstock: Microalgae and other underdeveloped biological platforms
- + Heliae offers technology and facility development services, contract research and manufacture, and maintains a robust pipeline of materials and human/animal health products.

In an effort to support the growth of algae as a sustainable resource, Heliae provides a full range of facility development services around the world. Such projects may range in scope, scale and production potential.

## PARTNERSHIPS AND FINANCING

Heliae led a joint venture – named Alvita Corp. – with Japan-based Sin-cere Corporation, a waste management and recycling company, in the development of a commercial algae production facility in Saga City, Japan. Construction of the facility began in 2015 and Alvita's astaxanthin product is targeted for market in Japan by the end of 2016. Heliae continues research partnerships with Schott glass, Evodos Separation Technology, and a number of universities and companies.

Heliae is privately held.



# ITACONIX

Stratham, NH

Number of employees: 15

ITACONIX CORPORATION PRODUCES A GROWING LINE OF NOVEL POLYMERS THAT UTILIZE THE UNIQUE FUNCTIONALITY OF ITACONIC ACID TO MEET CUSTOMER NEEDS FOR SAFER CHEMICALS.



## KEY FACTS

- + Stratham, NH
- + In 2009, we established a large-scale production facility.
- + Feedstock: Corn

## PARTNERSHIPS AND FINANCING

In 2009, Itaconix, in partnership with the University of Maine and UMass Lowell, received a \$1.8 million research grant from the U.S. Department of Energy and U.S. Department of Agriculture through the Joint Biomass Research and Development Initiative.

In 2014, Itaconix received a Phase II SBIR grant from the National Science Foundation for the development of bio-based latex resins.

In 2015, Itaconix signed a collaboration agreement with a leading chemical company for the development and worldwide marketing of certain Itaconix polymers.

**About:** Itaconix Corporation is a bio-based specialty chemicals company developing highly functional polymers from itaconic acid that achieve three essential objectives – safety, performance and sustainability.

**Product applications:** Itaconix® DSPT™ for hard water conditioning in consumer, agricultural, and industrial uses; Itaconix® VELASOFT™ for skin/hair conditioning in shampoos and skin products; Itaconix® XDP™ for dispersing minerals; Itaconix® ZINADOR™ for odor neutralization; Itaconix® TSI™ for anti-scaling; Itaconix® CHT™ for spotting/filming prevention in automatic dishwashing; Itaconix® BIOBIND™ for binding in coatings and adhesives; Itaconix® SAP for adsorption in diapers and feminine care.

**Potential market size:** The estimated U.S. market for current Itaconix products is \$16 billion.

**Technology:** Itaconix's PURITAC™ technology platform covers processes, compositions, and applications for polymers of itaconic acid. Itaconic acid is produced by fermentation with *Aspergillus terreus* using carbohydrates such as corn. The initial technology was developed by Dr. Yvon Durant, the company's CTO and co-founder, while at the University of New Hampshire.

# JOULE UNLIMITED

Bedford, MA

JOULE UNLIMITED IS PRODUCING ETHANOL, DIESEL.



Above: Hobbs, NM plant

**About:** Joule has pioneered a CO<sub>2</sub>-to-fuel production platform, effectively reversing combustion through the use of solar energy. The company's platform applies engineered catalysts to continuously convert waste CO<sub>2</sub> directly into renewable fuels such as ethanol or hydrocarbons, for diesel, jet fuel and gasoline.

**Product applications:** Fuel.

**Potential market size:** Over \$1 trillion.

**Technology:** Each module of the SolarConverter system contains Joule's tailored catalysts (a modified cyanobacterium), non-potable water and micronutrients. Waste CO<sub>2</sub> is pumped in from an industrial emitter or pipeline. The CO<sub>2</sub> keeps the catalysts in motion, maximizing their exposure to sunlight to drive photosynthesis. Charged from the sunlight, the catalysts consume the CO<sub>2</sub> and continuously produce and secrete the fuel or chemical molecules into the liquid medium. The medium circulates through a separator that filters the end product, which is sent to a central plant for final separation and storage. The process occurs continuously for numerous weeks before the module is flushed and reinoculated on a staggered basis.

## KEY FACTS

- + Hobbs, NM
- + Feedstock: CO<sub>2</sub>, sunlight

## PARTNERSHIPS AND FINANCING

Joule is privately held and has raised approximately \$200 million in funding to date. The company was founded within Flagship VentureLabs™.

COMMERCIAL

DEMONSTRATION

PILOT

BIOREFINERY CLASSIFICATION: DEMONSTRATION PLANT



# LANZATECH

Chicago, IL

Number of employees: 140

LANZATECH IS PRODUCING ETHANOL, 2,3-BUTANEDIOL, 1,3-BUTADIENE, ACETIC ACID, ISOPROPANOL, AND ISOBUTYLENE.

## KEY FACTS

- + LanzaTech Freedom Pines Biorefinery, Soperton, GA
- + Feedstock: Biomass (including MSW) synthesis gas, industrial waste gases, biogas



## PARTNERSHIPS AND FINANCING

Led by Mitsui & Co., in 2014, the \$112 million Series D round included new investors New Zealand Superannuation Fund, Siemens Venture Capital, CICC Growth Capital Fund I, L.P. and Khosla Ventures, Qiming Venture Partners, K1W1 and the Malaysian Life Sciences Capital Fund. LanzaTech has global partnerships across multiple sectors and along the supply chain, from steel, chemicals, aviation and banking.

**About:** LanzaTech's biological carbon recycling technology opens up new resources for making low-carbon chemicals and fuels. LanzaTech presents a 'carbon smart' future where you can choose where the carbon in your products comes from.

**Product applications:** Styrene-butadiene rubber, plastics, textiles, resins, polyurethane, adhesives, solvents, coatings, paints, fuels, de-icers, cosmetics, pharmaceuticals, personal care, and food.

**Potential market size:** The global butadiene market is over 12 million megatons per year (MTA). The global acetic acid market is ~16 million MTA. The global IPA market is ~2 million MTA, with a value of \$2.5 - \$3.5 billion.

**Technology:** Using microbes (*Clostridium autoethanogenum*) that ferment gases (rather than sugars), carbon-rich waste gases and residues are transformed into useful liquid commodities.



# MANUS BIO

Cambridge, MA

Number of employees: 10

MANUS BIO'S FIRST CHASSIS PRODUCES TERPENOIDS.



Above: Cambridge, MA lab.

**About:** Manus Bio recreates plant processes in microorganisms to produce natural ingredients through fermentation. Manus Bio's microbial platform has been optimized to convert inexpensive sugar sources into rare and expensive products, providing a low-cost, sustainable, and environmentally friendly source for many ingredients used in our daily lives.

**Product applications:** Flavors, fragrances, food ingredients, sweeteners, nutraceuticals, cosmetic actives, biopesticides, agrochemicals, and pharmaceuticals.

**Potential market size:** Flavors and fragrances (\$2 billion), sweeteners (\$2 billion), biopesticides (\$4 billion), nutraceuticals (\$1.5 billion), cosmetic actives (\$2.2 billion), agrochemicals (\$100 billion), and pharmaceuticals (\$60 billion).

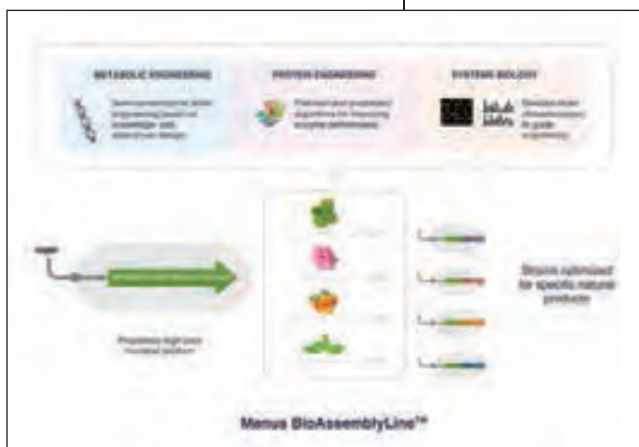
**Technology:** Manus Bio merges three core disciplines – metabolic engineering, protein engineering, and systems biology – in order to quickly and efficiently generate microbes that produce a variety of plant-based ingredients. The patented microbial platform has been optimized for high yield of a common precursor pathway, thus making it simple to pursue new products. The use of modular, reconfigurable, and plug-and-play tools and components further shortens the path to commercialization for new ingredients. In essence, Manus Bio has created an efficient BioAssemblyLine™ for the low-cost and sustainable production of an array of high value natural products.

## KEY FACTS

+ Feedstock: Glucose and glycerol

## PARTNERSHIPS AND FINANCING

\$25 million in non-dilutive funding from early adopting customers, NSF SBIR Phase I grant (\$150,000) in January 2013, NSF STTR Phase I grant (\$225,000) in June 2014, NSF SBIR Phase I grant (\$225,000) in June 2016.





# MATRIX GENETICS

Seattle, WA

Number of employees: 29

MATRIX GENETICS IS PRODUCING ENHANCED PRODUCTS FROM SPIRULINA.

## KEY FACTS

- + South Lake area near Seattle, WA
- + Feedstock: Cyanobacteria

## PARTNERSHIPS AND FINANCING

Matrix has announced two partnerships, one with a multinational energy company for biofuels research and one with Proterro in the area of enhanced nutrition. Avista Development is the venture arm of Avista Corp., an energy company involved in the production, transmission and distribution of energy as well as other energy-related businesses.

**About:** Matrix Genetics, LLC is a biotechnology company focused on producing high value products from algae. Our state-of-the-art, synthetic biology platform is the most cost-efficient method to create customized organisms with a range of traits to meet the needs of the fuel, food and feed industries.

**Product applications:** Pigments, feed enzymes, vaccines, fuels.

**Potential market size:** Matrix is pursuing multiple markets, from the \$100 million blue pigment market to the billion dollar feed enzyme market.

**Technology:** Matrix has developed world-class capabilities in directing carbon flux in algae to products of interest, including pigments, proteins, oils, anti-oxidants and specialty chemicals. Matrix is also the first to develop tools to precisely modify the genome of Spirulina, one of the few algae grown commercially at large scale. Spirulina has Generally Recognized as Safe (GRAS) status, allowing quick access to product opportunities in the food, beverage and enhanced nutrition categories. This ability to engineer strains to produce products of interest is the basis of the Company's technology and differentiates us from our competitors.





# MBI

Lansing, MI

Number of employees: 11

MBI INTERNATIONAL IS COMMERCIALIZING AFEX (AMMONIA FIBER EXPANSION), A TRANSFORMATIONAL BIOTECHNOLOGY THAT SUSTAINABLY EXPANDS OUR CAPACITY TO SUPPLY BOTH FOOD AND ENERGY WHILE IMPROVING ECONOMIC RESILIENCE FOR RURAL COMMUNITIES AROUND THE WORLD.



Above: AFEX Pilot Plant, Lansing, MI

**About:** Established in 1981, MBI is closely affiliated with Michigan State University (MSU) and a wholly owned subsidiary of the MSU Foundation. MBI serves as a biotech hub, a technology development and commercialization partner for promising bio-based technologies.

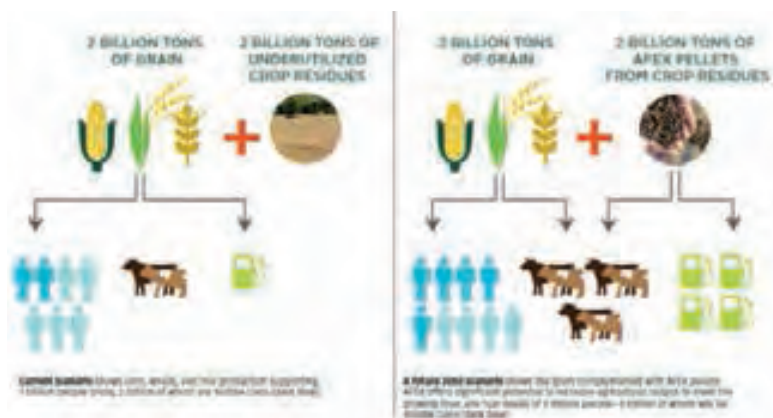
**Technology:** MBI is also licensing patented technologies for the production of bio-based fumaric and succinic acid.

## KEY FACTS

- + AFEX Pilot Plant
- + Lansing, MI
- + Feedstock: Corn stover, wheat straw, rice straw, switchgrass

## PARTNERSHIPS AND FINANCING

MBI and MSU have been collaborating under a strategic framework through which MBI serves as a technology development and commercialization partner for promising bio-based technologies.





# MEREDIAN BIOPLASTICS

## Bainbridge, GA

Number of employees: 70

MEREDIAN IS PRODUCING NODAX™ MEDIUM-CHAIN-LENGTH POLYHYDROXYALKANOATES (MCL-PHA).

## KEY FACTS

- + Bainbridge, GA
- + 20,000 liters
- + Feedstock: Fatty acid feedstocks
- + In late March, 2014, Tate & Lyle validated the replication of the proprietary process.

## PARTNERSHIPS AND FINANCING

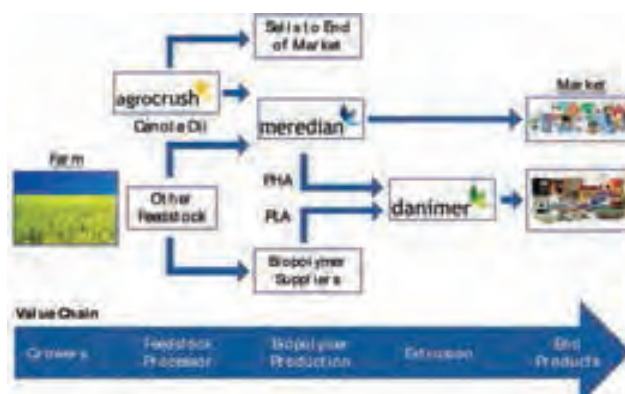
Working in partnership with sister companies Danimer Scientific and AgroCrush, Meredian creates bioplastic feedstock from cold pressed canola oil. U.S. government loan programs for businesses, such as those offered by the USDA-Rural Development and the U.S. Department of Treasury-New Market Tax Credit programs.

**About:** Meredian Bioplastics, a subsidiary of Meredian Holdings Group, makes commercial grade PHA using world-class production systems, offering a scalable, durable, and cost effective material that reduces manufacturing dependence on non-renewable, diminishing resources.

**Product applications:** In March, 2014, NODAX™ received FDA approval for food contact applications. The PHA produced at MHG is also Vinçotte Certified to biodegrade within 12 to 18 weeks in 6 different mediums including anaerobic, soil, freshwater, marine, industrial and home composting.

**Potential market size:** PHA market consumption will grow from an estimated 10,000 megatons (MT) in 2013 to 34,000 MT by 2018, with a CAGR of 27.7 percent from 2013 to 2018.

**Technology:** Meredian purchased the intellectual property that forms the basis of its bioplastic technology from Procter & Gamble in 2007, and has continued to improve the patent portfolio with key international and North American patents.





# METABOLIX

Woburn, MA

Number of employees: 70

METABOLIX, INC IS PRODUCING  
POLYHYDROXYALKANOATE POLYMERS (PHAS).



Above: PHA copolymer material

**About:** Metabolix, Inc. is an innovation-driven specialty materials company focused on delivering high-performance biopolymer solutions to customers in the plastics industry.

**Product applications:** Developmental film grades based on amorphous-PHA ( $\alpha$ -PHA) modified PLA. PHA additives in PVC systems improve permanence in durable applications. Biobased paper coatings based on PHA possess excellent barrier properties to water and grease and are compatible with the re-pulping operations typically used to recycle paper and corrugated cardboard. Plastic microbeads with PHA biopolymer materials that are biobased and marine degradable.

**Potential market size:** According to the Freedonia Group, the total additives market for PVC is approximately 7 million metric tons per annum. The property modifier and process aid segment of the current global PVC market is approximately 3.5 billion pounds and an aggregate market value of approximately \$6 billion annually.

**Technology:** Metabolix has developed proprietary microbial strains to produce target PHA co-polymers. We have also developed fermentation technology and a novel recovery process to recover high purity specialty PHA biopolymers.

## KEY FACTS

- + Contract production
- + 50,000 pounds per month
- + Feedstock: Industrial sugars

## PARTNERSHIPS AND FINANCING

Metabolix is working with customers across a range of applications for specialty PHA applications. We are targeting PHA to improve performance and/or reduce costs in material systems such as PVC and PLA, and in applications requiring improved performance, biocontent, biodegradability and other attributes where PHAs can provide unique functional benefits.





# MICROMIDAS

Sacramento, CA

Number of employees: 31

MICROMIDAS IS PRODUCING FURANS.

Above: Sacramento, CA Plant

## KEY FACTS

- + Sacramento, CA
- + 500 kilograms per day
- + Feedstock: Waste paper, cardboard, wood chips

## PARTNERSHIPS AND FINANCING

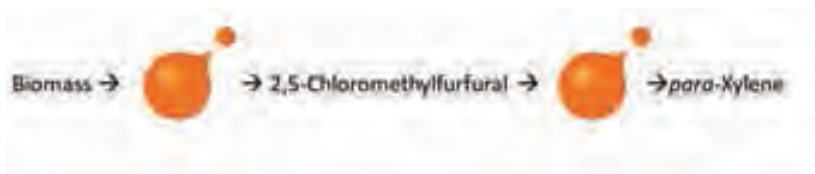
Micromidas has raised \$40 million to date.

**About:** Micromidas is building a chemical platform to produce both existing and new furanic and aromatic chemicals, polymers and resins using a wide variety of cellulosic biomass and carbohydrates, including wood and wood refuse, pulp and paper sludge, corn, corn by-products, corn stover, sugar cane bagasse, empty palm fruit bunches and other glucan sources.

**Product applications:** Furans are readily derivatized to produce monomers, plasticizers, or renewable (but chemically identical) variants of commodity chemicals such as paraxylene.

**Potential market size:** Globally, 35 million metric tons of paraxylene are consumed each year, mostly used to make polyester for fabric. It is a \$50 billion global market.

**Technology:** The Micromidas process is a non-fermentation, non-gasification, chemical-only process that selectively produces a furan intermediate from any feedstock containing cellulose or hemicellulose.





# MODULAR GENETICS

Woburn, MA

Number of employees: 6

MODULAR GENETICS, INC IS PRODUCING  
AN ACYL GLUTAMATE SURFACTANT.

**About:** Modular Genetics, Inc. is a sustainable chemistry company utilizing advanced technology in synthetic biology to produce specialty chemicals that are cost competitive, provide superior performance and are environmentally friendly.

**Product applications:** Detergents, wetting agents, emulsifiers and foaming agents.

**Potential market size:** The global surfactants market is estimated to register a CAGR of 5.4 percent by volume and 5.8 percent by value from 2014 to 2019. The global surfactants market is projected to reach 22,802 kilotons by volume and \$40,286 million by 2019.

**Technology:** Modular Genetics, Inc.'s automated gene engineering system, CombiGenix™, can synthesize, modify and recombine genes to create novel recombinant DNA molecules by the thousands. By linking CombiGenix™ to sophisticated, proprietary protein design tools and high-throughput screening, Modular has created an automated platform for the evolution of proteins with enhanced functions. Modular has engineered *Bacillus subtilis* strains to convert cellulosic sugar into a surfactant consisting of a fatty acid linked to an amino acid.



Above: Biorefinery, bacillus strain, electronic circuit, flasks (clockwise from top left).

## KEY FACT

+ **Feedstock:** Sugar from corn or woody material

## PARTNERSHIPS AND FINANCING

Modular Genetics has shown that its surfactant can be produced from sugar derived from rice hulls — a byproduct of rice production. This technology was funded through the NSF Small Business Innovation Research Program. Unilever is testing the new surfactants.

BIOREFINERY CLASSIFICATION: PILOT PLANT

PILOT

DEMONSTRATION

COMMERCIAL



# MYRIANT CORPORATION

Quincy, MA

Number of employees: 150

MYRIANT CORPORATION IS PRODUCING SUCCINIC ACID (1,4-BUTANEDIOIC ACID), ACRYLIC ACID, LACTIC ACID, MUCONIC ACID, AND FUMARIC ACID.

Above: Lake Providence, LA Plant

## KEY FACTS

- + Lake Providence, LA
- + 30 million pounds of bio-succinic acid
- + Feedstock: Sorghum grain and sorghum grits
- + With our partner ThyssenKrupp Uhde, we successfully scaled and achieved commercial production of bio-succinic acid at Uhde's biotech commercial validation facility in Leuna, Germany.

## PARTNERSHIPS AND FINANCING

Myriant is a subsidiary of PTT Global Chemical Public Company Limited, Thailand's largest and Asia's eighth largest chemical company. Our Lake Providence Commercial Facility is partially funded through a \$50 million cost sharing award from the United States Department of Energy (DOE), and a \$25 million Business and Industry (B&I) Loan Guarantee from the United States Department of Agriculture (USDA). Myriant has partnered with Johnson Matthey - Davy Technologies (JM Davy) to demonstrate that our bio-succinic acid can be utilized in JM Davy's process as a direct replacement for maleic anhydride.

**About:** Myriant is a global leader innovating and commercializing bio-based chemical intermediates.

**Product applications:** Plastics, textile fibers, coatings. Myrifilm® Zero-VOC Coalescing Solvent.

**Potential market size:** Succinic acid represents a \$7.1 billion market.

**Technology:** Myriant uses a single-step, anaerobic fermentation process that enables higher productivity and yield than other bio-production processes. Our team of scientists and researchers accomplishes this by developing proprietary biocatalysts—microorganisms, including *E. coli*, *Bacillus*, *Streptomyces*, *Corynebacterium*, and yeast, with altered metabolic pathways—designed to produce our target bio-chemicals from a variety of feedstocks.



# NATUREWORKS, LLC

Minnetonka, MN

Number of employees: 130

NATUREWORKS, LLC IS PRODUCING POLYLACTIC ACID (PLA).

**About:** NatureWorks is the first to offer a family of commercially available biopolymers derived from 100 percent annually renewable resources with cost and performance that compete with petroleum-based packaging materials and fibers.

**Product applications:** Polymer — food service, packaging, textiles, apparel, durable goods. Ingeo bioplastic

**Potential market size:** According to a report by Markets and Markets, by 2020 the Lactic Acid Market will be worth \$3.82 billion and the Polylactic Acid Market will be worth \$5.16 billion.

**Technology:** Microorganisms convert the sugar into lactic acid through fermentation. A two-step process transforms the lactic acid molecules into rings of lactide. The lactide ring opens and links together to form a long chain of polylactide polymer. This is the process of polymerization.

Above: Blair, NE Plant

## KEY FACTS

- + Blair, NE
- + 300 million pounds (150,000 metric tons) of Ingeo biopolymer
- + Feedstock: Corn

## PARTNERSHIPS AND FINANCING

NatureWorks is an independent company invested in by Cargill and PTT Global Chemical, who recently announced a \$150 million investment in NatureWorks.



# NEOL BIO

Granada, Spain

Number of employees: 35

NEOL BIO IS PRODUCING TAILOR-MADE MICROBIOIL, OLEOCHEMICALS.

Above: Neol Bio's Pilot Plant

## KEY FACTS

- + Aoiz, Navarra, Spain, Center for Second Generation Biofuels (CB2G) of CENER, the Spanish National Renewable Energy Centre.
- + Neol Bio has developed the process and the microorganisms to produce high-value, tailor-made oils in its R&D centers in Granada, Spain, and validated on a large scale at demonstration plants.

## PARTNERSHIPS AND FINANCING

Neol Bio is a company listed at the Spanish Alternative Market.

**About:** Neol Bio develops economically viable bioprocesses, reducing the use of chemical contaminants and assessing agricultural and industrial waste, thus using advanced techniques in molecular biology, bioprocess engineering and industrial microbiology.

**Product applications:** Very long chain fatty acids (arachidonic, erucic, gondoic and nervonic) have a wide industrial use in cosmetics, lubricants and as additives for plastics.

**Potential market size:** The global market for oleochemicals is valued at around \$30,000 million per year with an estimated annual growth of 6 percent.

**Technology:** MicroBioil™ is a platform to produce high added value oils and microbial derived oleochemicals from renewable sources. MicroBioil™ facilitates the production of oils through sustainable processes, using industrial by-products (such as crude glycerin) or organic residues (such as wheat straw or sugarcane bagasse).

All processes and micro-organisms used have been fully developed by Neol Bio and are protected by world-wide patents.



# NEWLIGHT TECHNOLOGIES

Costa Mesa, CA

NEWLIGHT TECHNOLOGIES IS USING GREENHOUSE GAS TO PRODUCE AIRCARBON™ POLYHYDROXYALKANOATE (PHA) THERMOPLASTIC.



Above: Newlight California Facility

**About:** Newlight is a sustainable materials company dedicated to using carbon sequestration technology to produce clean, high-performance materials that reduce cost, maintain or improve performance, and capture carbon on a market-driven basis.

**Product applications:** AirCarbon™ can be used in extrusion, blown film, cast film, thermoforming, fiber spinning, and injection molding applications, replacing fossil-fuel based polypropylene, polyethylene, ABS, polystyrene, and TPU.

**Technology:** First, concentrated greenhouse gas emissions such as biogas are directed into Newlight's patented conversion reactor. Next, those carbon emissions are combined with air and Newlight's biocatalyst, which pulls oxygen out of air and carbon and hydrogen out of methane. Finally, carbon, oxygen, and hydrogen are re-assembled to form a long chain thermopolymer.



## KEY FACTS

+ **Feedstock:** Air and captured methane-based farm carbon emissions.

## PARTNERSHIPS AND FINANCING

In June 2016, Newlight signed a 20-year master off-take agreement with Vinmar International, Ltd.

Under the terms of the off-take agreement, Vinmar will initially purchase and Newlight will sell 1 billion pounds of AirCarbon PHA, including 100 percent of AirCarbon PHA from Newlight's planned 50 million pound per year production facility for 20 years. The contract will also cover 100 percent of the output from a 300 million pound per year AirCarbon production facility and a 600 million pound per year AirCarbon production facility for a total of up to 19 billion pounds over 20 years.

In October 2016, Newlight signed a supply, collaboration, and production license with IKEA, wherein IKEA will use Newlight's AirCarbon technology to produce up to 10 billion pounds of AirCarbon for use in IKEA home furnishings.



# NOVOMER

Waltham, MA

Number of employees: 50

NOVOMER HAS TWO TECHNOLOGY PLATFORMS AND IS PRODUCING ACRYLIC ACID, OTHER C3 AND C4 DROP-IN CHEMICALS AND CONVERGE® POLYPROPYLENE CARBONATE (PPC) POLYOLS.

Above: Houston, TX Plant

## KEY FACTS

- + Houston, TX
- + 2,000 megatons per year
- + Feedstock: Waste CO<sub>2</sub>, propylene oxide, waste CO and ethylene oxide
- + Novomer has scaled up the production of Converge polyols using a contract manufacturer in Houston, Texas.

## PARTNERSHIPS AND FINANCING

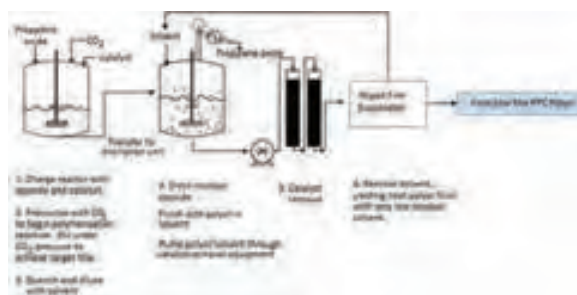
Novomer has numerous industry partnerships and a broad array of financial and strategic investors. The company received a three year \$25 million U.S. Department of Energy Award in 2010. The DOE Advanced Manufacturing Office awarded the company an additional \$5 million grant. Novomer received \$400,000 from the NSF to make CO<sub>2</sub> based polymers and \$475,000 from NYSERDA to support development of a continuous production process for CO<sub>2</sub> polyols.

**About:** Novomer is a leading materials company commercializing a family of low-cost, high-performance, sustainable polymers and chemicals.

**Product applications:** Rigid and flexible foams, coatings, adhesives, sealants, elastomers, diapers, paints and high-performance plastics.

**Potential market size:** Novomer estimates these product markets represent more than \$40 billion per year.

**Technology:** Novomer is commercializing two platforms, one that uses waste CO<sub>2</sub> as a raw material to produce a family of polyols for use in polyurethane applications and another that uses waste CO to produce C3 and C4 drop-in chemicals (acrylic acid). The foundation for these platforms results from catalyst research completed at Cornell University. The CO<sub>2</sub> technology platform combines waste CO<sub>2</sub> with commodity Epoxides (currently Propylene Oxide (PO)) to form a family of novel polymers that contain up to 50 percent by weight CO<sub>2</sub>.





# NOVOZYMES, NA

Franklinton, NC

Number of employees: 1,326

AT NOVOZYMES IT BEGINS WITH ENZYMES  
AND MICROORGANISMS.



Above: Franklinton, NC Plant

**About:** Rethink Tomorrow: Novozymes is the world leader in biological solutions. Together with customers, partners and the global community, we improve industrial performance while preserving the planet's resources and helping build better lives. As the world's largest provider of enzyme and microbial technologies, our bioinnovation enables higher agricultural yields, low-temperature washing, energy-efficient production, renewable fuel and many other benefits that we rely on today and in the future.

**Technology:** Enzymes are proteins that act as catalysts. When one substance needs to be transformed into another, nature uses enzymes to speed up the process. Our customers use enzymes as catalysts in the manufacture of a wide variety of products, including ethanol, sugar, beer and bread, where the enzymes are not part of the end product. Enzymes are also used directly in products such as laundry detergents, where they help remove stains and enable low-temperature washing.

Like enzymes, many microorganisms have natural properties that can be put to use in a variety of processes. In our strategic BioAg Alliance, Novozymes is working on microorganisms that will give the world's farmers a new biological toolkit for increasing yields and protecting crops.



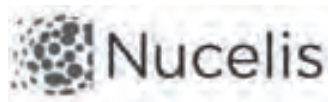
## KEY FACTS

- + Milwaukee, WI (Production, Marketing, Sales since 2011)
- + Franklinton, NC (Production, Administration since 1979)
- + Houston, TX (Production, Marketing, Sales since 2012)
- + Davis, CA (R&D since 1992)
- + Ottawa, Canada (Production, Marketing, Sales since 2013)
- + Salem, VA (R&D, Production since 2001)
- + Watertown, SD (Production, Marketing, Sales since 2013)
- + Saskatoon, Canada (R&D, Marketing, Manufacturing since 2007)
- + San Francisco, CA (R&D since 2013)
- + Blair, NE (Production since 2009)

## PRODUCT LAUNCHES 2015:

- Pulp and paper xylanase  
Novozymes Secura®
- Protease for automatic dishwashing  
Novozymes Liquozyme® LpH
- Novozymes Extenda®
- Novozymes Avantec® Amp

BIOREFINERY CLASSIFICATION: COMMERCIAL PLANT



# NUCELIS, LLC

San Diego, CA

Number of employees: 20

NUCELIS LLC IS PRODUCING SQUALANE,  
ERGOSTEROL, VITAMIN D2.

Above: San Diego, CA Plant

## KEY FACTS

- + San Diego, CA
- + 400 liters of fermentation capacity
- + Feedstock: Sugar

## PARTNERSHIPS AND FINANCING

Cibus Global, Ltd., a cutting-edge technology firm and leader in the area of gene editing, acquired Nucelis LLC in January 2014. Nucelis, which had been established as an independent entity in December 2010, is now an independent operating unit of Cibus.

**About:** Nucelis, LLC is a leading metabolic engineering company leveraging its proprietary precision gene editing technology and integrated fermentation development platform (RTDS™), to develop and deliver premium, bio-based and sustainable specialty products for the personal care, food ingredients, and flavor and fragrance markets.

**Product applications:** Squalane is a high value, clear oil compound used in cosmetics, pharmaceuticals, and specialty lubricants. Ergosterol is a provitamin to vitamin D2. Vitamin D2 has a variety of applications as a food supplement.

**Potential market size:** The squalene and squalane market is expected to grow to \$177.06 million at a CAGR of 10.3 percent in terms of value from 2014 to 2019.

**Technology:** Nucelis has leveraged the versatility of its Rapid Trait Development System (RTDS™) platform for the production of its lead product, Vitamin D2. Nucelis' Vitamin D2 represents a non-animal source with unmatched purity and performance, at price points that make it the obvious source for all Vitamin D2-based formulations. Nucelis Vitamin D2 is currently for sale, with commercial samples available upon request. In addition, Nucelis is commercializing a high purity squalane product, and a unique formulation of squalene and natural oils for use in personal care products.

One key feature of the RTDS platform is its flexibility in optimizing any existing fermentation-based production process. Nucelis can customize a solution for all partners seeking to improve production efficiencies. For those partners who participate in GM-sensitive markets, Nucelis can engineer valuable improvements while maintaining the non-GM status of the production strain. The impact is a clear path to improved process productivity and increased economic value.

# PHYCAL

Highland Heights, OH

Number of employees: 50

PHYCAL IS PRODUCING ALGAL OIL.



Above: Wahiawa and Kalaheo, HI Plant

**About:** Phycal, Inc. is developing an integrated system for producing renewable biofuels and their co-products from algae. The bio-fuels include renewable “green” drop-in jet fuel and diesel, straight vegetable oil, fuel oil blends (e.g. for industrial boilers), and others. Co-products could include proteins, methane, hydrogen, animal or human nutritional products, and others.

**Product applications:** Fuels.

**Potential market size:** \$99 billion in 2014.

**Technology:** Heteroboost™ is an algae “feedlot” that uses mature algae from the open ponds and increases lipid content by introducing fixed carbon in a closed system, such as inedible sugar and glycerol, which dramatically increases algal productivity.



## KEY FACTS

- + St. Louis, MO research facility
- + Feedstock: Algae

## PARTNERSHIPS AND FINANCING

The Department of Energy has awarded Phycal more than \$27.2 million in federal funding for the further exportation of algae based biofuel. As part of its program to promote beneficial reuse of carbon dioxide, the Department of Energy awards companies funding to create green solutions to carbon dioxide problems.



# PHYTONIX

Asheville, NC

Number of employees: <10

PHYTONIX CORPORATION IS PRODUCING N-BUTANOL.

Above: Black Mountain, NC lab

## KEY FACTS

- + Black Mountain, NC
- + Feedstock: Carbon dioxide

## PARTNERSHIPS AND FINANCING

Phytonix has several strategic partnerships, including: Uppsala University (Sweden) and South Dakota State University.

**About:** Phytonix Corporation ("Phytonix" or "Px") is an industrial biotechnology company producing sustainable chemicals directly from carbon dioxide. Phytonix's objective is to be the global leader in bio-safe, direct solar chemicals and fuel production utilizing carbon dioxide as the sole feedstock and energy from the Sun.

**Product applications:** Industrial chemical market and fuels.

**Potential market size:** Biobutanol is a valuable industrial chemical intermediate with a existing \$10 billion global market growing at 13 percent CAGR.

**Technology:** Phytonix has developed engineered cyanobacterial species that secrete n-butanol in a significantly carbon-negative, photosynthetic process. Phytonix commercial facilities will be a modular and scalable system consisting of soft-sided vessels called phytoconverters™, where the cyanobacteria will grow.



# POET

Sioux Falls, SD

Number of employees: 1,500

POET IS PRODUCING INVIZ™ ZEIN AND VOILA™ CORN OIL.

**About:** POET, one of the world's largest ethanol producers, is a leader in biorefining through its efficient, vertically integrated approach to production.

**Product applications:** Films, packaging, adhesives, edible coatings and glazes, plastics, rubber, asphalt paving additives, and high-energy additive to feed rations.

**Technology:** Our patented raw starch hydrolysis process, named BPX, converts starch to sugar with a proprietary blend of enzymes, while other ethanol producers use a jet cooker to break down starch with heat. BPX reduces energy use in the plant by 8 to 15 percent and increases yield by 0.10 to 0.15 gallons per bushel. After years of development, we brought the process to commercial scale production in 2004 and it is now deployed in all of our biorefineries.

Above: Project Liberty, Emmetsburg, IA

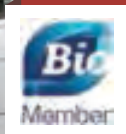
## KEY FACTS

- + POET Footprint: 27 corn ethanol biorefineries, 1 cellulosic ethanol biorefinery
- + Total capacity: 1.7 billion gallons per year
- + Feedstock: Corn, corn stover



## PARTNERSHIPS AND FINANCING

In partnership with Royal DSM of the Netherlands, POET-DSM Advanced Biofuels opened a commercial-scale ethanol plant in Emmetsburg, Iowa – dubbed “Project LIBERTY” – in September of 2014. Project LIBERTY’s feedstock is corn crop residue – cobs, leaves, husk and some stalk.



# PROTERRO

Bronxville, NY

PROTERRO, INC IS PRODUCING INDUSTRIAL AND FOOD GRADE SUGARS, ORGANIC ACIDS AND AMINO ACIDS.

Above: Orlando, FL Plant

## KEY FACTS

- + Orlando, FL
- + Feedstock: CO<sub>2</sub>, sunlight, water and nutrients

## PARTNERSHIPS AND FINANCING

Proterro was founded in 2008 and is backed by Battelle Ventures, Braemar Energy Ventures, Cultivian Sandbox Ventures and Middleland Capital.

**About:** Proterro is a biotechnology company that converts waste CO<sub>2</sub> into valuable products under license agreements with our partners. Our technology utilizes cyanobacteria in a patented, fully integrated production system to produce cost-competitive products for partners in the global food, feed, and energy industries.

**Product applications:** Fermentation to fuels and other chemicals; food and nutritional ingredients.

**Potential market size:** \$44 billion.

**Technology:** Proterro's patented two-step technology platform provides maximum flexibility in creating products that are tailored to our partners' needs. We modify cyanobacteria to produce molecules designed to our partner's specifications. Then we efficiently produce high-yield organisms in a unique solid state bioreactor.

# PROVIVI

Santa Monica, CA

Number of employees: 8

PROVIVI, INC IS PRODUCING OLEFINS.



**About:** We are developing biopesticides for agriculture, commercial, household, and public health pest management.

**Product applications:** Chiral pesticides.

**Potential market size:** The global agrochemical market is predicted to reach \$223 billion in 2015.

**Technology:** Included in our arsenal of biocatalysts are ones that catalyze the transfer of carbenes, nitrenes, and oxenes to olefins and carbon-hydrogen bonds, thus installing important functional groups (e.g. cyclopropanes, amines, alcohols, epoxides, sulfoxides, sulfoximines, and ethers) that feature in various chiral pesticides. For example, we have developed the most active catalyst ever reported for olefin cyclopropanation, a key reaction in the synthesis of a variety of pesticides. Provivi has an exclusive license from Caltech for this technology platform.

## KEY FACTS

+ Santa Monica, CA

## PARTNERSHIPS AND FINANCING

Provivi was founded in 2013 based on biocatalysis technology developed at the California Institute of Technology (Caltech) which has since become a licensor, shareholder, and research collaborator.

In September 2014, Provivi signed an enzyme distribution agreement with Strem Chemicals, Inc., a manufacturer of specialty chemicals for research and development, granting Strem distribution rights for research quantities of Provivi's carbene/nitrene transferase enzymes that will feature in the new C/N Transferase Screening Kit.

COMMERCIAL

DEMONSTRATION

PILOT

BIOREFINERY CLASSIFICATION: PILOT PLANT



# PUREVISION TECHNOLOGY

Fort Lupton, CO

PUREVISION TECHNOLOGY IS PRODUCING CELLULOSIC SUGAR.

Above: Hemp feedstock at Ft. Lupton, CO Plant

## KEY FACTS

- + Ft. Lupton, CO
- + Half-ton per day
- + Feedstock: Hemp

## PARTNERSHIPS AND FINANCING

PureVision Technology LLC is targeting to raise \$10 million in an A-round equity financing during 2015. Use of proceeds include working capital to advance and complete three pre-commercialization programs (corn stover, wheat straw and industrial hemp), intellectual property development, patent filings, and pre-development costs to support PureVision's first commercial demonstration biorefinery. A-Round investors are entitled to a preferred return on their investment.

**About:** PureVision Technology is a biorefining R&D company developing and licensing technology packages for the lowest cost production of sugars, lignin and pulp from diverse non-food biomass to industries manufacturing biobased products.

**Product applications:** Fermentation to fuels and other chemicals

**Potential market size:** TechNavio's analysts forecast the global cellulosic ethanol market to grow at a CAGR of 53.3 percent over the period 2013-2018.

**Technology:** PureVision's latest technology breakthrough rapidly converts diverse cellulosic biomass into fermentable sugars in less than one hour without the use of enzymes or concentrated acids. The company's rapid hydrolysis technique has the flexibility of producing separated or mixed concentrated sugars. Experimental proof-of-concept of the company's rapid hydrolysis chemistry has been completed successfully at the Ft. Lupton laboratories.

# RENEWABLE ENERGY GROUP, INC.

## REG LIFE SCIENCES, LLC

Ames, IA; South San Francisco, CA

Number of REG employees: >700

REG LIFE SCIENCES LLC IS DEVELOPING  
HIGH-VALUE FATTY ACID DERIVATIVES.



Above: REG Life Sciences Biorefinery, Okeechobee, FL

**About:** REG Life Sciences is a wholly-owned subsidiary of Renewable Energy Group established in 2014 to harness the power of industrial biotechnology to produce renewable chemicals, fuels and other products.

**Product applications:** Fragrances, polymers, and surfactants.

**Potential market size:** The global market for natural fatty acids reached \$18.3 billion in 2014 and is expected to grow at a compound annual growth rate of 7.1 percent to \$25.7 billion for 2014-2019. The global market for fragrances was worth roughly \$11 billion in 2015. Sales of polymers reached \$112 billion in 2015 in the US, up 3 percent from 2014. The global market for surfactants was \$25-30 billion in 2015, with a volume of around 15 million megatons, expected to grow at a CAGR of approximately 5 percent through 2020 to \$32-40 billion.

**Technology:** Combining the natural efficiency of microbial fatty acid metabolism with novel engineered biosynthetic pathways, REG Life Sciences engineers industrial microorganisms to selectively convert renewable feedstocks to target end-product compounds. These products range from difficult-to-produce “drop in” and value-add replacement compounds to completely new structures with diverse chemical functionalities and applications. The flexibility of the platform technology and ability to design, construct, and evaluate processes efficiently from lab to commercial scale has enabled a growing pipeline of renewable chemical products.

### KEY FACTS

- + REG Life Sciences Biorefinery, Okeechobee, FL
- + Feedstock: Corn sugars, crude glycerin, cane sugars and biomass hydrolysate

### PARTNERSHIPS AND FINANCING

REG Life Sciences has partnered with ExxonMobil for the development of cellulosic sugars as a fermentation feedstock for biofuel production.



# RENMATIX

King of Prussia, PA

Number of employees: ~85

RENMATIX IS PRODUCING CELLULOSIC SUGARS,  
OMNO POLYMERS AND CRYSTALLINE CELLULOSE

Above: Integrated Plantrose Complex (IPC), Kennesaw GA

## KEY FACTS

- + Integrated Plantrose Complex (IPC), Kennesaw, GA
- + 3 dry tons of biomass to sugar per day
- + Feedstock: Woody biomass, agricultural residues, energy crops, municipal solid waste, and additional plant material
- + Renmatix acquired a 56,000 square foot manufacturing facility in Rome, NY. The new Feedstock Processing Facility (FPF) opened on April 20, 2015, as the third U.S. location for Renmatix. This move creates a secure supply for Renmatix and its development partners at the IPC in Kennesaw, GA, where the second step in production of Plantro® sugars is performed.

## PARTNERSHIPS AND FINANCING

Renmatix has publicly disclosed joint development agreements with BASF, UPM, and Total. As announced in 2015, Total will utilize Renmatix's proprietary Plantrose process with specific feedstocks to extract sugar for use in production of biobased products of strategic interest to Total. Existing Renmatix investors, including BASF and Kleiner Perkins Caufield & Byers, joined Total in the initial tranche of a Series D fundraise.

**About:** Renmatix's proprietary Plantrose® Process pioneers the use of supercritical hydrolysis to break down non-food biomass quickly, using no significant consumables.

**Product applications:** Fermentation or catalytic conversion to biochemicals and biofuels or direct utilization of coproducts as produced.

**Potential market size:** TechNavio's analysts forecast the global cellulosic ethanol market to grow at a CAGR of 53.3 percent over the period 2013-2018.

**Technology:** The water-based Plantrose® Process consists of two core steps. The first is fractionation of biomass and separation of the remaining solids, which contain cellulose and lignin. The second is cellulose hydrolysis of the pretreated solids under elevated conditions utilizing supercritical water, or water at higher temperatures and pressures, as the primary solvent. The company won the 20th Annual Presidential Green Chemistry award in 2015 for its work in harnessing water as a new solution to the difficult problem of economically extracting cellulosic sugar from biomass.





# RENNOVIA

Santa Clara, CA

Number of employees: ~50

RENNOVIA, INC.'S FIRST TARGETS ARE GLUCARIC ACID, ADIPIC ACID, 1,6-HEXANEDIOL, HEXAMETHYLENEDIAMINE (HMD).

Above: Stockton, England Plant

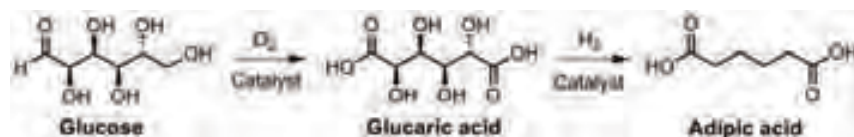
**About:** Rennovia Inc. is a specialty chemical company focused on breakthrough catalysts and processes for the cost-advantaged production of chemicals from renewable feedstocks.

**Product applications:** Nylon-6,6, polyurethanes, and specialty chemicals.

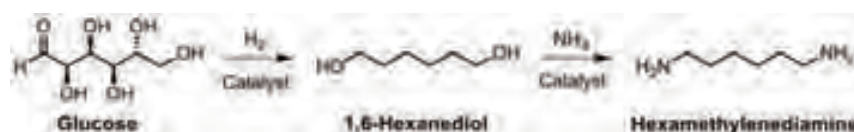
**Potential market size:** Nylon-6,6 engineering polymers and fibers markets are approximately 2.5 million metric tons (5.5 billion pounds) per year, predicted to grow at 3 to 4 percent CAGR to 2022. Global polyurethane markets for adipic acid, HMD, and 1,6-HDO total approximately 900,000 metric tons (2 billion pounds) per year, predicted to grow at about 4 to 5 percent CAGR to 2020. Additional addressable markets for glucaric acid are predicted to be greater than 350,000 metric tons (770 million pounds) per year.

**Technology:** Rennovia employs its high-throughput catalyst synthesis and screening technology infrastructure to identify new heterogeneous catalysts for cost advantaged production of bio-based specialty chemicals:

## Rennovia's glucaric and adipic acid production from glucose



## Rennovia's 1,6-HDO and HMD production from glucose



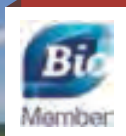
## KEY FACTS

- + Stockton, England
- + Feedstock: Sugars
- + In July 2015, Johnson Matthey Process Technologies and Rennovia announced the on time start-up of the first phase of an integrated mini-plant for production of glucaric acid from glucose, using jointly developed technology. Construction of the second phase or production of adipic acid from glucaric acid is ongoing.

Operation of the mini-plant will provide the engineering data for the design of commercial scale manufacturing plants. The mini-plant is located at the Johnson Matthey Process Technologies R&D Center in Stockton, England.

## PARTNERSHIPS AND FINANCING

Rennovia strategic partners and investors include Archer Daniels Midland (ADM) – the #1 global corn processor, leading sugar feedstock supplier and established manufacturer of bio-based ADM Evolution Chemicals™ — and Johnson Matthey — a \$10 billion global catalyst and process technology and catalyst development partner and commercial catalyst supplier for the Rennovia glucaric and adipic acid process.



# REVERDIA

Geleen, Netherlands

Number of employees: 40

REVERDIA IS PRODUCING SUSTAINABLE SUCCINIC ACID.

Above: Cassano Spinola, Italy Plant

## KEY FACTS

- + Cassano Spinola, Italy
- + 10,000 tonnes per year
- + Feedstock: Glucose

## PARTNERSHIPS AND FINANCING

**Business Model:** Reverdia captures value through product sales and technology licensing.

Reverdia is a joint venture between Royal DSM, the global Life Sciences and Materials Sciences company, and Roquette Frères, the global starch and starch-derivatives company. Reverdia has many partnerships in place, including: (i) distributor partnerships with Helm and Omnia, (ii) co-development partnerships with Provion and Covestro, (iii) consortia like BioSuccInnovate. Many other partnerships exist but have not been published in the public domain.

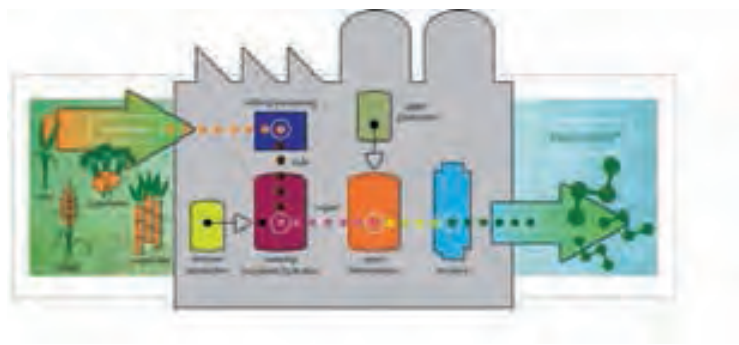
**About:** Reverdia is dedicated to be the global leader in the market for sustainable succinic acid, focusing on market development by establishing partnerships with direct and indirect customers, building on customer needs and Reverdia's strengths.

**Product applications:** Bio-polymers (e.g. Polybutylene succinate, PBS), polyurethanes, coatings.

**Potential market size:** The global market for succinic acid is expected to grow from ~40 kilotons in 2015 to ~700 kilotons in 2025 and will be mainly driven by bio-succinic acid for new bio-based polymer and material applications.

**Technology:** Reverdia uses low pH yeast technology rather than bacteria to produce bio-based succinic acid.

Reverdia's low pH yeast fermentation process has best-in-class carbon performance as demonstrated by the published cradle-to-gate LCA by the University of Utrecht.



# RIVERTOP RENEWABLES

Missoula, MT

Number of employees: 33

RIVERTOP RENEWABLES, INC IS PRODUCING SODIUM GLUCARATE.



Above: Rivertop's production facility at DTI, Danville, VA

**About:** Merging proven science with renewable resources, Rivertop is improving the performance, sustainability and cost of end-products with innovative, new-to-market solutions.

**Product applications:** Chelants and corrosion inhibitors for consumer products (like detergents) and industrial uses (water treatment & road deicing).

**Potential market size:** \$50 billion. \$9 billion for detergent ingredients. \$2.8 billion for cooling towers.

**Technology:** Rivertop's oxidation platform utilizes all of the carbon atoms from the glucose feedstock and adds oxygen weight, resulting in more pounds of product than feedstock input. This improved process enables the mass production of versatile, high-value renewable chemicals, including sodium salts of glucaric acid. The technology was first developed at the University of Montana.



## KEY FACTS

- + Rivertop's production facility at DTI, Danville, VA
- + 9 million dry pounds [18 million pounds wet] of sodium glucarate.
- + Feedstock: Sugars, sugar and alcohols
- + Commercial production at DTI: Riase® detergent builder, a sugar-derived chelant that meets high performance standards and enables lower total formulation cost for dishwasher and laundry detergents. Waterline™ corrosion inhibitors and descaling agents designed to be high-performing, low-cost alternatives to phosphates for water treatment. Headwaters® biodegradable inhibitors that enable highway departments to reduce the costly corrosive impacts of de-icing brines to roads, bridges and vehicles.

## PARTNERSHIPS AND FINANCING

Rivertop partnered with DTI to design, construct & operate a biorefinery in Danville, VA. In April 2014, Rivertop Renewables announced that it had raised \$26 million in its Series B investment round from Cargill, First Green Partners and existing investors.



# ROYAL DSM

Heerlen, Netherlands

Number of employees: 25,000

ROYAL DSM IS MASTERING MICROBES AND ENZYMES  
TO CREATE SUSTAINABLE SOLUTIONS.

## KEY FACTS

- + DSM Biotechnology Center, Delft, Netherlands, and Shanghai, China
- + Feedstock: Biomass

## PARTNERSHIPS AND FINANCING

In January 2012, DSM announced the POET-DSM Advanced Biofuels, LLC, joint venture with US-based POET to commercially demonstrate and license cellulosic ethanol derived from corn crop residue.

In May 2011, DSM and the French company Roquette Frères formed the Reverdia joint venture to build a commercial scale plant for the production of bio-based succinic acid, the first non-fossil feedstock derived chemical building block for a broad range of applications, from packaging to footwear.

**About:** Royal DSM is a global science-based company active in health, nutrition and materials. By connecting its unique competences in life sciences and materials sciences, DSM is driving economic prosperity, environmental progress and social advances to create sustainable value for all stakeholders simultaneously.

**Product applications:** Biofuels, food and nutrition, advanced materials.

**Technology:** DSM uses its biological sciences competences to find, make, and apply microbes and enzymes to create more sustainable processes, ingredients and building blocks for new products. These competences specifically help to engineer and characterize enzymes and microbial strains in detail up to the molecular level; to assess their performance under application conditions; and to develop data and computation-driven model systems for building efficient “design-build-test-learn” engineering cycles.



# SAPPHIRE ENERGY

San Diego, CA

Number of employees: 150

SAPPHIRE ENERGY IS PRODUCING ALGAE NUTRITIONAL OILS.

**About:** Sapphire's world-leading technology uses sunlight, CO<sub>2</sub>, seawater, non-arable land, nutrients, and novel strains of algae in outdoor ponds to produce biomass for processing into a range of consumer products. Sapphire's clean technology is presently undergoing expansion to a variety of global sites ideally suited for high productivity and maximal environmental sustainability.

**Product applications:** Fuel, feed, food, dietary supplements and pharmaceuticals.

**Potential market size:** Varies by market.

**Technology:** Developed at the University of California, San Diego.



Above: Las Cruces, NM Plant

## KEY FACTS

- + Las Cruces, NM
- + 100 acre algae farm; modules at strategic global sites
- + Feedstock: Algae

## PARTNERSHIPS AND FINANCING

Sapphire Energy is supported by a world-class syndicate of investors, including a recent funding round from a Chinese investor and previous investments from ARCH Venture Partners; The Wellcome Trust; Cascade Investment, LLC; Venrock; and Monsanto. Sapphire has relationships with a variety of academic and industrial partners for commercialization such as MATRIC (Mid-Atlantic Technology, Research and Innovation Center) in West Virginia.



# SENOMYX

San Diego, CA

Number of employees: 90

SENOMYX, INC IS PRODUCING COMPLIMYX® BRAND OF FLAVOR INGREDIENTS, WHICH INCLUDE SWEETMYX, SAVORYMYX®, AND BITTERMYX® OFFERINGS.

Above: San Diego, CA Plant

## KEY FACTS

- + San Diego, CA
- + Senomyx flavors and flavor boosters are produced in accredited food manufacturing facilities using the highest quality ingredients.

## PARTNERSHIPS AND FINANCING

PepsiCo funds research to identify and develop novel sweet taste ingredients, including both boosters and natural sweeteners. PepsiCo has exclusive licensed rights in non-alcoholic beverages on a worldwide basis during the research funding period. Firmenich has collaborated with Senomyx and continues to provide research funding in the area of sweet taste for use in food products on a global basis. Ajinomoto, Co., Inc. currently markets products in several Asian markets that contain a Senomyx savory ingredient. Nestlé has commercialized a Senomyx flavor ingredient in Southeast Asia.

**About:** Senomyx is using proprietary taste science technologies to discover, develop, and commercialize new flavor ingredients that have benefits for consumers and consumer products manufacturers.

**Product applications:** Flavoring.

**Potential market size:** The global flavor and fragrance market is rising with an annual growth rate from 5 to 6 percent valued at an estimated \$23.9 billion in 2013.

**Technology:** With an advanced understanding of human taste bud science, precise screening platforms and taste testing, Senomyx has developed a process that mimics the natural function of the taste bud and enables discovery of new flavors that boost the taste of sweeteners and other flavors in foods and allow for the reduction of sugar and high fructose corn syrup.

# SIRRUS, INC.

Loveland, OH

Number of employees: 15

SIRRUS IS COMMERCIALIZING 1,1-DISUBSTITUTED ALKENE MONOMERS.



**About:** Sirrus advances manufacturing technology through chemistry relating to the synthesis, stabilization, activation and formulation of a unique and reactive class of monomers commonly known as methylene malonates.

**Product applications:** Adhesives, sealants, coatings and resins.

**Potential market size:** The global demand for reactive intermediates is valued at greater than \$1 billion, with formulated reactive intermediates valued at > \$200 billion.

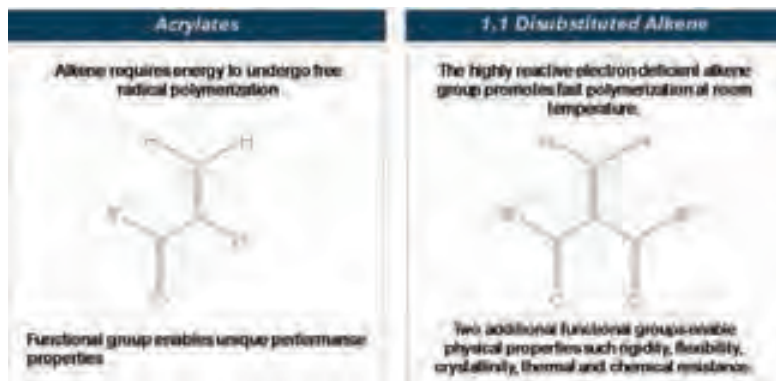
**Technology:** Sirrus has developed a novel intermediate chemical platform based on 1,1-disubstituted alkene monomers that will allow many current manufacturing processes to be completed faster with less energy and reduced solvent. Chemilium products have one alkene group with the potential to have a wide variety of substituent terminal or functional groups that can be used to make tunable molecular weight polymers. Forza products contain multiple alkene groups allowing cross-linking for the development of polymers exhibiting high strength as well as thermal and chemical resistance.

## KEY FACTS

- + Loveland, OH
- + 5 kilogram per hour
- + Feedstock: Malonic acid, formaldehyde

## PARTNERSHIPS AND FINANCING

Sirrus has announced agreements with Elmer's Products, Inc. and Sun Chemical. Additionally, Sirrus has four additional unannounced partnerships drawing on Sirrus' unique technology to provide benefits in coating and adhesive application. Sirrus has raised more than \$35 million from blue chip investors including Braemar Energy Ventures and Arsenal Ventures and strategic investors including General Motors Venture and Mitsui Ventures.





# SOLEGEAR

Vancouver, BC, Canada

Number of employees: 12

SOLEGEAR IS PRODUCING PROPRIETARY BIOPLASTIC MATERIALS: POLYSOLE® & TRAVERSE®.

Above: Vancouver, BC Plant

## KEY FACTS

- + Vancouver, BC
- + Feedstock: Sugar cane, non-food grade corn, and/or sugar beets
- + Commercialization-focused business model:
  - Proprietary Formulation – value we can build on.
  - Collaborative R&D – benefit from the highest expertise.
  - Outsourced supply chain and tolled manufacturing – lowers costs, increases flexibility.
  - Pull-based sales and inventory – customer demand drives development.

## PARTNERSHIPS AND FINANCING

Solegear works in partnership with major brands, retail customers and innovative plastic manufacturers. Partnerships include r-pac international, Columbia Plastics, Ex-Tech Plastics and TEQ.

Since going public in 2015, the Company has raised over \$3.5 million in equity and receives ongoing research funding from the Government of Canada.

**About:** Solegear is an advanced materials firm that develops, produces and distributes high-performance bioplastics – plastics made from plants, not petroleum.

**Product applications:** Consumer goods and packaging.

**Potential market size:** \$35 billion.

**Technology:** Green Chemistry – Proprietary biopolymer with maximum bio-based content and no hazardous chemicals.





# SUCCINITY GMBH

Düsseldorf, Germany

SUCCINITY GMBH IS PRODUCING SUCCINIC ACID.



Above: Montmelo, Spain Plant

**About:** Succinity is a joint venture between BASF and Corbion Purac for the production and commercialization of biobased succinic acid with the name Succinity®.

**Product applications:** Bio-polymers (e.g. Polybutylene succinate [PBS]), polyurethanes, coatings.

**Potential market size:** The global market for succinic acid was around 40 kilotons in 2015 and is expected to grow with >10 percent CAGR in the coming years.

**Technology:** Feedstock is fermented based on the bacterium *Basfia succiniciproducens*. *Basfia* has a naturally high yield for the production of succinic acid and allows the flexible usage of various feedstocks, such as glycerol and C5/C6 sugars. Using an innovative closed-loop downstream process, Succinity GmbH is able to produce high-quality biobased succinic acid efficiently, without major waste streams. The result is a highly pure product that is an attractive alternative to petrochemically derived succinic acid and an attractive raw material for several applications, such as bioplastics.



## KEY FACTS

- + Montmelo, Spain
- + 10,000 metric tons
- + Feedstock: Glycerol, glucose, sucrose
- + The plant is located at the Corbion Purac Montmelo site.

## PARTNERSHIPS AND FINANCING

BASF and Corbion Purac have been conducting research on biobased succinic acid under a joint development agreement since 2009, before registering Succinity GmbH in August 2013.

Projected market growth will be driven partially by legislative initiatives and partially by brand owners reacting to changed consumer needs with differentiated products that focus on improved ecological footprints.



# SWEETWATER ENERGY

Rochester, NY

Number of employees: 29

SWEETWATER ENERGY IS PRODUCING CELLULOSIC SUGAR.

Above: Rochester, NY Plant

## KEY FACTS

- + Rochester, NY
- + 2 megaton feedstock input per day
- + Feedstock: Mixed hardwoods
- + The company's first commercial facility will be constructed in Northern Minnesota and will produce hardwood-derived cellulosic sugar and clean lignin that will then be fully processed into final market-ready products: 4.1 million gallons of industrial alcohol, 550,000 gallons of sub-fuel grade alcohol, and over 6,000 metric tons of industrial activated carbon. Sweetwater's wood-based industrial alcohol and activated carbon compete directly on price with the incumbent feedstocks.

## PARTNERSHIPS AND FINANCING

Sweetwater has received a \$30 million loan guarantee and incentives package from the State of Minnesota for our first commercial project (total project CAPEX of \$54 million) and is currently actively in their Series B to raise an additional \$100 million to cover the remaining capital for the first two commercial facilities.

**About:** Sweetwater Energy owns ground-breaking, patented technology that will be economically disruptive for the chemicals, fuels and advanced materials industries.

**Product applications:** Biochemicals, biofuels, bioplastics and advanced packaging and construction materials.

**Potential market size:** \$105 billion.

**Technology:** Sweetwater's technology efficiently processes low-cost, sustainable biomass, such as wood and agricultural residues, into two platform products: highly fermentable cellulosic sugar and clean lignin fiber. Sweetwater's technology converts 95 percent of available sugar in biomass feedstocks, including all C5 and C6 sugars. The technology that we now own significantly outperforms each of the previous systems that we thoroughly tested in terms of sugar yield, inhibitor profile, ethanol yield, clean lignin that can actually be processed into something beyond fuel. Further, our highly scalable hardware has been reliably proven in heavy industrial duty in multiple industries worldwide.



# SYNGULON

Liege, Belgium

Number of employees: 3

SYNGULON IS DEVELOPING BACTERIOCIN TECHNOLOGY.



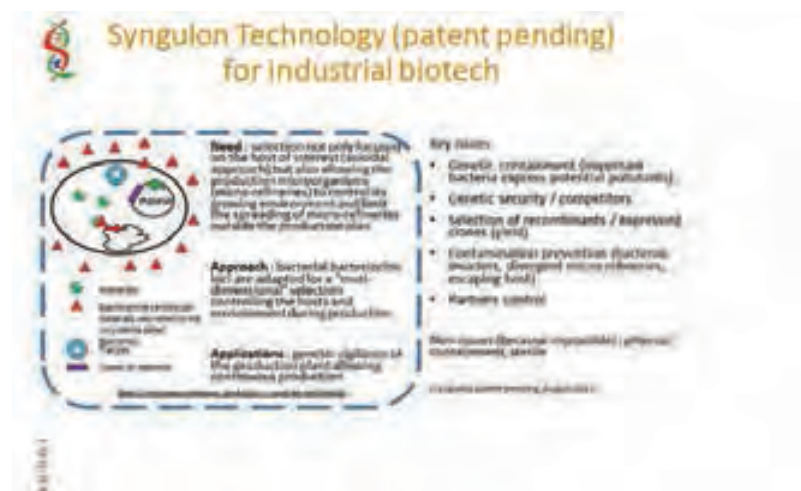
**About:** Syngulon is developing original genetic technologies to improve the efficiency of microorganisms (also called microrefineries) involved in industrial bioproduction.

**Product applications:** Green chemical production organisms.

**Technology:** A pressing concern with microbial systems is that re-engineered microbes may escape and produce undesirable effects on the environment. To address this biosafety issue, multiple mechanisms for constraining microbial replication and horizontal gene transfer have been proposed, including the use of host-construct dependencies such as selection using toxin-antitoxin pairs, conditional plasmid replication or the requirement for a specific metabolite for bacterial function. A need for efficient genetic firewall design is presented including new selection genetic circuit using bacteriocins gene platform. Syngulon proposes an innovative genetic firewall to boost fermentation.

## PARTNERSHIPS AND FINANCING

Syngulon is a start-up, founded in 2013, incubated by Walloon incubator for engineering sciences (WSL). Syngulon is part of a Horizon 2020 consortium financed by the EU on the industrial applications of the microalgae.





# SYNTHETIC GENOMICS

Number of employees: >200

SYNTHETIC GENOMICS, INC SERVES THREE DISTINCT  
END MARKETS: RESEARCH, BIOPRODUCTION,  
AND APPLIED PRODUCTS.

+ SGI's Research offerings, commercialized through its subsidiary SGI-DNA, are revolutionizing biotechnology with next-generation genomic solutions, including the world's first DNA printer.

- + Bioproduction expertise extends across various production hosts: phototrophic, heterotrophic, viral, mammalian and fully synthetic.
- + Applied Products include vaccines, biologics and therapeutics, human nutrition, biofuels and bio-based chemicals, crops.

SGI develops its applied products, typically in strategic partnerships with leading global organizations, across a variety of industries. Examples include algae based biofuels (with ExxonMobil), sustainable crops (with Monsanto), nutritional supplements (with ADM to commercialize Omega-3 DHA oil from algae), vaccines (with GlaxoSmithKline and Sequiris), non-GMO food proteins, and transplantable organs (with United Therapeutics).

**About:** Synthetic Genomics (SGI) is a leader in the field of synthetic biology, an emerging science that is at the intersection of biology and engineering, requiring the integration of evolutionary, molecular, and systems biology, biophysics, machine learning, and genetic engineering. SGI utilizes its foundational intellectual property in this rapidly evolving field in combination with expertise in core disciplines such as bio-discovery, -informatics, and -processing, software engineering, analytical chemistry, fermentation, and advanced cell engineering, to design and build biological systems to solve global sustainability challenges.

**Technology:** Synthetic Genomics combines advanced genomics capabilities, such as Gibson Assembly Method, and proprietary microbial cell lines obtained through worldwide discovery to develop bio-based, consumer friendly products that are sustainable and economically advantaged.





# TERRAVIA

South San Francisco, CA

Number of employees: ~200

TERRAVIA HOLDINGS, INC IS PRODUCING  
ALGAE-BASED OILS AND INGREDIENTS.



**About:** TerraVia™ is a next-generation food, nutrition and specialty ingredients company that harnesses the power of algae, the mother of all plants and earth's original superfood, to deliver much needed innovation and sustainable solutions to the food industry.

**Product applications:** Food, aquaculture, animal nutrition and personal care.

**Potential market size:** Signed \$200 million multi-year deal with Unilever for algae-based oils in 2016.

**Technology:** TerraVia's algae-based platform is transforming our food system by bringing together better nutrition and great taste, along with economic and environmental sustainability. The company has spent over a decade unlocking the power of algae to find and develop vital food, nutrition, and specialty ingredients: healthy oils and fats, proteins, fibers and micronutrients. The company also manufactures a range of specialty personal care ingredients for key strategic partners.

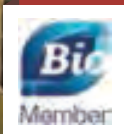
Above: Solazyme Bunge Renewable Oils, Sao Paulo State, Brazil

## KEY FACTS

- + Peoria, Illinois and Sao Paulo State, Brazil
- + Feedstock: Dextrose and sucrose
- + Solazyme Bunge Renewable Oils began commercial production in Brazil in May 2014. The facility has some of the world's largest aerobic fermenters and a nameplate capacity of 100,000 metric tons of oil per year.

## PARTNERSHIPS AND FINANCING

TerraVia formed a joint venture with Bunge Limited in 2012 that established the production facility as well as multiple jointly funded developed programs. In 2015, they expanded the JV to commercialize algae-based oils and ingredients globally. TerraVia also has a history of collaboration with Unilever in order to produce sustainable oils for personal care products. In 2016, the two companies announced a multi-year supply agreement for algae-based oils.



# VERDEZYNE

Carlsbad, CA

Number of employees: 65

VERDEZYNE, INC IS DEVELOPING TECHNOLOGY TO PRODUCE DODECANEDIOIC ACID (DDDA), ADIPIC ACID, SEBACIC ACID.

Above: Carlsbad, CA Plant

## KEY FACTS

- + Malaysia
- + 30 million pounds per year of diacids
- + Feedstock: Fatty acids isolated from soy, palm kernel, coconut and other plant-based oils
- + Drop in renewable replacements for petrochemicals

## PARTNERSHIPS AND FINANCING

Verdezyne has raised ~\$66 million in equity capital, plus MYR \$250 million in project finance to fund construction of a plant in Bio-XCell's premier biotechnology and ecosystem park in southern Malaysia. With construction scheduled to commence in 2016, the plant will be capable of producing approximately 30 million pounds of diacids per year.

**About:** Verdezyne is a privately owned industrial biotechnology company that is leveraging the power of biology to produce chemicals from renewable, non-food sources.

**Product applications:** Nylon or other polymers for use in a variety of applications including: engineering resins, automotive parts, athletic apparel, carpeting and toothbrush bristles.

**Potential market size:** DDDA for nylon 6,12, is a \$200 million per year market growing 5.4 percent annually. Sebaccic acid for nylon 6,10 is a \$400 million per year market growing 5.5 percent annually. Adipic acid for nylon 6,6 and thermoplastic polyurethanes is a \$6 billion annual market growing 4.6 percent annually.

**Technology:** Verdezyne has developed a proprietary platform that uses engineered yeast to metabolize multiple non-food-based renewable feedstocks and isolate a number of widely-used, high-value chemicals. The industrially robust production yeast used has two chromosome copies (diploid), which provides the stability of genetic redundancy compared with bacterial systems which have one chromosome (haploid).



# VIRENT

Madison, WI

Number of employees: 37

VIRENT IS PRODUCING DIRECT REPLACEMENT  
FUELS AND CHEMICALS.



Above: Madison, WI Plant

**About:** Using patented catalytic chemistry, Virent converts soluble biomass-derived sugars into products identical to those made with petroleum, including gasoline, diesel, jet fuel, and chemicals used for plastics and fibers.

**Product applications:** Fuels, aromatic chemicals.

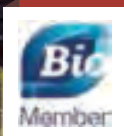
**Technology:** Virent's BioForming® process provides a true biorefinery capable of producing multiple products from various feedstocks using heterogeneous catalysts common to the petroleum and catalyst industry. Virent's products are drop-in equivalents to their petroleum counterparts, but with a significantly reduced carbon footprint. The Virent catalytic process is similar to processes in the refining and petrochemical industry and is more readily scalable than other types of bio-based technologies. The flexible product slate allows for optimization in response to shifting market opportunities between fuels and chemicals production. Virent's process can work with a variety of feedstocks including ethanol, sugars, and lignocellulosic materials from wood, corn and bagasse.

## KEY FACTS

- + Madison, WI
- + 10,000 gallons per year
- + Feedstock: Beet sugars
- + Several products have been produced at demonstration scale and validated with industrial leaders including renewable gasoline, jet fuel and diesel fuel; bio-paraxylene for polyester beverage packaging and fibers.

## PARTNERSHIPS AND FINANCING

Partnerships with Cargill, Royal Dutch Shell, Honda, Tesoro, and Coca-Cola Company. In 2011, Virent received up to \$13.4 million from the Department of Energy to convert corn stover to jet fuel.



# XF TECHNOLOGIES

Albuquerque, NM

Number of employees: 16

XF TECHNOLOGIES IS PRODUCING FUROATES.

## KEY FACTS

- + Albuquerque, NM
- + 10,000 gallons/year
- + Feedstock: Biomass feedstock agnostic (compatible with cellulosic biomass, sugars and starches). Alcohol feedstock flexible (process utilizes ethanol, methanol, butanol, diols, polyols, etc).

## PARTNERSHIPS AND FINANCING

xF is seeking customers interested in testing and commercially utilizing its products.

xF is a venture backed company interested in strategic investment or additional venture capital.

**About:** xF Technologies Inc. is a renewable products company that has developed a proprietary process to convert biomass into novel petrochemical replacements.

**Product applications:** Solvents, anti-microbial inhibition agents, plasticizers for polymers and bioplastics, fragrance carriers for personal care, coalescing aids for coatings; gasoline and diesel oxygenates.

**Potential market size:** The global solvents market has been estimated to be worth \$35 billion according to a 2014 report by Markets and Markets.

**Technology:** xF Technologies has created a chemical platform that combines a biomass derived intermediary with an alcohol or a diol to create a broad range of high value renewable chemicals. It is a two-step, low cost thermochemical process that first generates a sugar derivative called CMF (5-chloromethyl furfural) followed by a catalytic step to convert the CMF into a finished product. In the first step, hydrochloric acid (HCl) is used to break down the feedstock into C6 sugars that are subsequently converted into CMF. This reaction occurs via a non-catalytic proprietary process that operates at about 100°C and 7 atm of pressure.





# ZEACHEM

Lakewood, CO

Number of employees: 26

ZEACHEM IS PRODUCING ACETIC ACID,  
ETHYL ACETATE, ETHANOL.



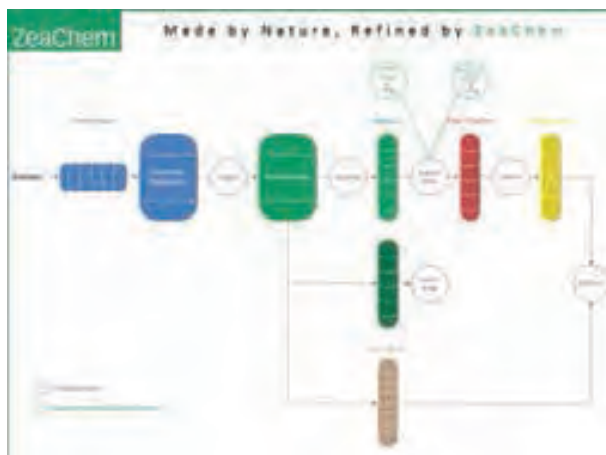
Above: Boardman, OR Plant

**About:** ZeaChem Inc. develops biorefineries capable of producing advanced chemicals and fuels, using its own proprietary technology as well as that of its partners.

**Product applications:** ZeaChem's two and three carbon based products are the chemical building blocks in many applications including paints, solvents, PET, pharmaceuticals, food preservatives, and absorbents.

**Potential market size:** \$1 trillion.

**Technology:** ZeaChem's C2 Platform uses a combination of fermentation and conventional chemical synthesis pathways to produce acetic acid, acetate esters, and ethanol. Its C3 Platform changes the microorganism used for fermentation, resulting in a slate of analogous three-carbon products such as propionic acid, propionate esters, propanol, propylene, and propylene derivatives.



## KEY FACTS

- + Boardman, OR
- + 1,500 megatons per year (MTPY) of acids from 5,000 dry MTPY of ligno cellulosic woody biomass or 20,000 MTPY acids from 132,000 MTPY of sugar beets
- + Feedstock: Feedstock flexible. Lignocellulosic feedstocks demonstrated to date include hardwoods, softwoods, wheat straw, corn stover, sugar cane bagasse, rye grass, banagrass, and sugar beet pulp. Advanced feedstocks demonstrated to date include sugar beet and corn syrup.
- + ZeaChem's commercialization plan includes an expansion of the existing assets to enable commercial volume production at the same location.

## PARTNERSHIPS AND FINANCING

Privately funded. Investors include Firelake Capital Management, PrairieGold Ventures, Sustainable Conversion Ventures, and Leaf Resources Limited. ZeaChem currently operates its demonstration biorefinery as a technology institute. Third parties who come and work at the demo plant are able to accelerate scale up of their technology at a fraction of the cost to building a new plant.

COMPANY	PRODUCT
AB ENZYMES GMBH	Enzymes
ADM	Citric Acid; Ethanol; 2,5-Furandicarboxylic Acid (FDCA); Glycerin; Lecithin; Polyols; Propylene Glycol (1,2-propanediol); Sorbitol; Soy Methyl Ester; Starches; Sugars; Vegetable Oils (Canola, Cottonseed, Linseed, Soybean); Xanthan; Waxes
ADVANCED BIOCATALYTICS CORPORATION	Surfactants
AGRIVIDA, INC	Enzymes
AJINOMOTO	Amino Acids; Isoprene
AKZO NOBEL	Acetic Acid; Acetone; n-Butanol; Epichlorohydrin; Fatty Acids
AMERICAN PROCESS	Cellulosic Sugar; Nanocellulose
AMYRIS, INC	Farnesene; Isoprene
ANELLOTECH, INC	Benzene; Toluene; Xylene
ARBIOM	Glucose; Lignin; Xylose
ARKEMA	Fatty Acids and Esters; Polyamides; Polyphthalamide (PPA)
ARZEDA	1,3-Butadiene; Enzymes; Levulinic Acid
AVA BIOCHEM	2,5-Furandicarboxylic Acid (FDCA); 5-Hydroxymethylfurfural (5-HMF)
AVANTIUM	Alkoxyethyl-Furfural; Furandicarboxylic Acid (FDCA); Methyl Levulinate; Mono-Ethylene-Glycol (MEG)
BARENTZYMES	Enzymes
BASF ENZYMES LLC	1,4-Butanediol (1,4-BDO); Enzymes; Polytetrahydrofuran (PolyTHF®)
BIOAMBER	Adipic Acid; 1,4-Butanediol (1,4-BDO); Succinic Acid
BIOBASED TECHNOLOGIES	Polyols
BIOBTX	Terephthalic Acid
BIO-CAT/BIO-CAT MICROBIAL	Enzymes
BIOCATALYSTS	Enzymes
BIO-ON	Polyhydroxyalkonate (PHA)
BIORESOURCE INTERNATIONAL, INC	Enzymes
BIOSYNTHETIC TECHNOLOGIES	Biosynthetic Oils
BLUE MARBLE BIOMATERIALS	Acetic Acid; Acrylic Acid; Butyric Acid; Caproic Acid; Butyl Butyrate; Dimethyl Sulfide; Ethyl Butyrate; Ethyl Thioacetate; Ethyl Thiobutyrate; Ethyl Thiopropionate; Lactic Acid; 3-Mercapto-Butanone; 3-Mercapto-Pentanone; 5-Methyl Furfuryl Mercaptan; Methyl Thioacetate; Methyl Thiobutyrate; Propionic Acid; S-Propyl Acetate; Propyl Butyrate; Propyl Hexanoate; Propyl Propionate; Propyl Thioacetate; Thiobutyric Acid; Thiopropionic Acid; Thioacetic Acid
BORREGAARD	Ethanol; Cellulosic Sugars; Lignin
BRASKEM	Butadiene; Ethanol; Ethylene; Isoprene; Propylene; Polyethylene; Polypropylene
CALYSTA	Lactic Acid; Methane

COMPANY	PRODUCT
<b>CARGILL</b>	Citric Acid; Ethanol; Glucaric Acid; Glycerin; 3-Hydroxypropionic Acid; Isoprene; Lactic Acid; Itaconic Acid; Lecithins; Maltodextrins; Palm Oils; Polyols; Sorbitol; Sugars; Starches; Triglycerides; Xanthan Gum
<b>CATHAY INDUSTRIAL BIOTECHNOLOGY</b>	DC11 (Undecanedioic Acid); DC12 (Dodecanedioic Acid); DC13 (Brassylic Acid); DC14 (Tetradecanedioic Acid); DC15 (Pentadecanedioic Acid); DC16 (Hexadecanedioic Acid); 1,5-Pentamethylene Diamine
<b>CELANESE</b>	Cellulose Diacetate
<b>C-LECTA</b>	Enzymes
<b>CELLANA LLC</b>	Biodiesel; Omega-3-Oils
<b>CELLUCOMP</b>	Cellulose Nano-Fibers
<b>CODEXIS</b>	Enzymes
<b>COOL PLANET ENERGY SYSTEMS</b>	Biocarbon; Hydrocarbon
<b>CORBION</b>	2,5-Furandicarboxylic Acid (FDCA); Lactic Acid; Polylactic Acid (PLA); Succinic Acid
<b>COVESTRO</b>	Pentamethylene Diisocyanate; Waterborne Polyurethanes
<b>CRODA</b>	Ethylene Oxide; Non-ionic Surfactants
<b>DEINOVE</b>	Carotenoids; Muconic Acid
<b>DUPONT</b>	Enzymes; 2,5-Furandicarboxylic Acid (FDCA); Isoprene; Polyesters
<b>DUPONT TATE &amp; LYLE BIOPRODUCTS</b>	1,3 Propanediol
<b>EARTH ENERGY RENEWABLES</b>	Fatty Acids (C2-C8)
<b>EASTMAN CHEMICAL COMPANY</b>	Cellulose Acetate; Cellulose Acetate Butyrate; Cellulose Acetate Propionate; n-Butanol
<b>ECOSYNTHETIX</b>	Starch Vinyl Emulsions; Starch-Vinyl Polymers
<b>EDENIQ</b>	Cellulosic Sugars
<b>ELEVANCE RENEWABLE SCIENCES, INC</b>	Ethylene; C10+ Hydrocarbons from Olefin Metathesis; Esters from Olefin Metathesis
<b>EMERY OLEOCHEMICALS</b>	Aliphatic Esters; Polyols
<b>ENERKEM</b>	Ethanol; Methanol
<b>EPYGEN</b>	Enzymes
<b>EVOLVA</b>	Nootkatone; Resveratrol; Saffron; Stevia; Vanillin
<b>EVONIK</b>	Amino Acids; Enzymes
<b>FORELIGHT</b>	Astaxanthin; Omega-3s; Phycocyanin
<b>GENOMATICA, INC</b>	Adipic Acid; Butadiene; 1,4-Butanediol (BDO); Caprolactam; Hexamethylenediamine
<b>GEVO</b>	iso-Butanol; Butene; Ethanol; Isooctane; p-Xylene
<b>GFBIOCHEMICALS</b>	Levulinic Acid
<b>GLOBAL BIOENERGIES</b>	Butadiene; Isobutene; Propylene
<b>GLYCOSBIO</b>	Isoprene; Lactic Acid; Omega 3 Fatty Acid; Triglycerides
<b>GRAIN PROCESSING CORPORATION</b>	Corn Syrup; Maltodextrins; Starches
<b>GREEN BIOLOGICS</b>	Acetone; n-Butanol

COMPANY	PRODUCT
GREEN LIFE CAN, LLC	Polyalphaolefins; Polyolesters
GREENLIGHT BIOSCIENCES	Fatty Acids; Pyrimidines; Ribose
HELIAE	Astaxanthin; Proteins
INGREDION	Corn Oil and Proteins; Dextrose; Maltodextrins; Polyols; Starches
INTREXON	1,4-Butanediol; iso-Butanol; Farnesene; Isoprene
INVISTA	Adipic Acid; Adiponitrile (ADN); 1,3-Butadiene; 2,3-Butanediol (BDO); Polyamide (Nylon 6,6)
ITACONIX CORPORATION	Itaconic Acid; Polymers of Itaconic Acid
JOULE UNLIMITED	Diesel; Ethanol
KIVERDI	Citrus Oil; Omega-7 Oils; Sugars
KRATON PERFORMANCE POLYMERS (ARIZONA CHEMICAL)	Fatty Acids; Pine Oils; Pine Pitch; Rosin Acids; Sulphate Turpentine; Tall Oil
LANZATECH	Acetic Acid; 1,3-Butadiene; iso-Butylene; 2,3-Butanediol, Ethanol; iso-Propanol
LEAF RESOURCES LTD	Cellulosic Sugars
LOGOS TECHNOLOGIES	Rhamnolipids
LYGOS	Malonic Acid
MANGO MATERIALS	Polyhydroxyalkonate (PHA)
MANUS BIOSYNTHESIS	Terpenoids
MATRIX GENETICS	Spirulina Derived Products
MBI INTERNATIONAL	Fumaric Acid; Succinic Acid
MERCURIUS BIOREFINING	Ethyl Formate; Ethyl Levulinate; Formic Acid; Furfural
MEREDIAN BIOPLASTICS	Medium Chain Length Polyhydroxyalkanoates (MCL-PHA)
METABOLIC EXPLORER	Glycolic Acid; L-Methionine; 1,2 Propanediol; 1,3 Propanediol
METABOLIX, INC	Acrylic Acid; Gamma-Butyrolactone; Butanediol; Polyhydroxyalkanoates (PHAS)
MICROMIDAS	Aromatics; Furans
MODERN MEADOWS, INC	Collagen
MODULAR GENETICS, INC	Acyl Glutamate Surfactant
MYRIANT CORPORATION	Acrylic Acid; Fumaric Acid; Lactic Acid; Muconic Acid; Succinic Acid
NATUREWORKS, LLC	Polylactic Acid (PLA)
NEOL BIOSOLUTIONS SA	Arachidonic Acid; Erucic Acid; Gondoic Acid, Nervonic Acid
NESTE	Isoalkanes; Propane; Vegetable Oils
NEWLIGHT TECHNOLOGIES	Polyhydroxyalkanoates (PHA)
NOVOMER	Acrylic Acid; Butanediol; Polypropylene Carbonate Polyols; Succinic Acid
NOVOZYMES	Enzymes
NUCELIS LLC	Squalane; Ergosterol; Vitamin D

## APPENDIX A. RENEWABLE CHEMICAL COMPANIES

COMPANY	PRODUCT
OAKBIO INC	n-Butanol; Polyhydroxyalkanoate (PHA)
PHOTANOL	Erythritol
PHYCAL	Algae Oils; Biodiesel
PHYTONIX CORPORATION	n-Butanol
PLAXICA	Lactic acid
POET	Cellulosic Ethanol; Corn Oil Byproducts; Sugar
PRAJ MATRIX	Lignin; Pentose and Hexose Sugars
PROTERRO, INC	Amino Acids; Sugars
PROVIVI, INC	Olefin Chiral Pesticides
PTT GLOBAL CHEMICAL (PTGC)	Butanediol; Lactic Acid; Polylactic Acid; Succinic Acid,
PUREVISION TECHNOLOGY	Cellulosic Sugar
RENEWABLE ENERGY GROUP, REG LIFE SCIENCES LLC	Fatty Acids
RENMATIX	Cellulosic Sugars
RENNOVIA	Adipic Acid; Glucaric Acid; 1,6-Hexanediol; Hexamethylenediamine
REVERDIA	Succinic Acid
RIVERTOP RENEWABLES, INC	Sodium Glucarate
RHO RENEWABLES, INC	Trans-Cinnamic Acid; Methylcyclohexane; 3-Methylanisole; Styrene; Toluene; p-Xylene
ROQUETTE	Gluconic Acid; Isosorbide; Isosorbide Polymers; Sodium Gluconate; Starch; Succinic Acid; Proteins
ROYAL DSM	Alkyd Resins; Cellulosic Ethanol; Carotenoids; Enzymes; Polyamides; Polyester Elastomer (Castor Oil Based); Succinic Acid
SABIC	Polyethylene (PE); Polypropylene (PP)
SAPPHIRE ENERGY	Algae Nutritional Oils
SENOAMYX, INC	Artificial Flavors
SIRRUS	1,1-Disubstituted Alkene Monomers
SOLEGEAR	Polylactic Acid (PLA)
SOLIX ALGREDIENTS	Astaxanthin
SOLVAY	Acetone; n-Butanol; Cellulose Acetate; Epichlorohydrin; Glycerin; Guar Gum; Surfactants; Vanillin
STORA ENSO	Lignin; Sugars
SUCCINITY GMBH	Succinic Acid
SWEETWATER ENERGY	Cellulosic Sugars
SYLVATEX	Micro-emulsion Additive for Inverse Micelles
SYNTHEZYME	Enzymes; (omega) Hydroxy Fatty Acids; Polyesters; Surfactants
SWISSAUSTRAL BIOTECH SA	Enzymes; Microbial Biobank

COMPANY	PRODUCT
TATE & LYLE	Corn Syrup, Starch, and Oil; Citric Acid and Other Acids; Distiller Grain; Ethanol, Gluten; Waxy Corn
THE COCA-COLA	Polyethylene Terephthalate (PET)
THE DOW CHEMICAL COMPANY	Ethanol; Plasticizers; Polyols
TERRAVIA	Algae Oils for Specialty Applications
UNITED CATALYST, LLC	Sugars from Cellulose Hydrolyzing Imprinted Polymers (CHIPs)
VERDEZYNE, INC	Adipic Acid; Dodecanedioic Acid (DDDA); Sebacic Acid
VIRENT	Aromatic Mixtures; Benzene; p-Xylene
WHITE DOG LABS	Acetone; iso-Butanol; n-Butanol; Butyrate; iso-Propanol
XF TECHNOLOGIES	5-Chloromethyl Furfural; Furoate Esters
ZEACHEM	Acetic Acid; Ethanol; Ethyl Acetate; Ethylene Glycol
ZUCHEM	Mannitol; Monosaccharides; Oligosaccharides for Pharmaceutical and Nutritional; Xylitol

## APPENDIX B. STRAIN DEVELOPMENT TECHNOLOGY COMPANIES

COMPANY	PRODUCT
AEQUOR INC	Engineered Marine Microbe for Antifouling and Antibiofilm
CARIBOU BIOSCIENCE	Precision Cell Engineering
CHAIN BIOTECHNOLOGY LTD	Develops Microbial Hosts (chassis) for Engineering Anaerobic Bacteria
DNA2.0	Gene Synthesis – Tools Provider
ENEVOLV, INC	Engineers Microbes: Bacteria, Yeast, Algae
GEN9	Gene Synthesis
GINKGO BIOWORKS	Engineers Microorganisms
GREENLIGHT BIOSCIENCES	Cell-Free Bioprocessing Technology
MOLECULAR ASSEMBLIES	DNA Synthesis
MUSE BIOTECHNOLOGIES INC	Strain Engineering
OLIGOS BIOTECH	Engineering Fungus
PARETO BIOTECHNOLOGIES	Polyketide Pathways
SYNGULON	Bacteriocin Engineering
SYNPROMICS	Synthetic Promoters for Gene Expression
SYNTHETIC GENOMICS	Advanced Genomics – Microbial Cell Lines; DHA Omega-3; Astaxanthin
TESELAGEN	Combinatorial Gene Design and Editing
TWIST BIOSCIENCE	Gene Synthesis on Silicon
ZYMERGEN	Strain Improvement

## BIO Industrial & Environmental Section Member Companies

Aequor, Inc., Oceanside, CA	Epygen Labs FZ LLC, Dubai, United Arab Emirates	Phytonix Corp., Black Mountain, NC
Agrivida, Inc., Medford, MA		Poet, LLC, Sioux Falls, SD
Amyris, Inc., Emeryville, CA	Evolva, Allschwil, Switzerland	POET-DSM Advanced Biofuels LLC, Elgin, IL
Anellotech, Inc., Pearl River, NY	Genencor® A Danisco Division, Palo Alto, CA	Praj Matrix - The Innovation Center, Pune, Maharashtra, India
Arzeda, Seattle, WA	Genomatica, Inc., San Diego, CA	Primordial Genetics Inc., San Diego, CA
BASF Corp., Florham Park, NJ	GranBio, Sao Paulo, Brazil	ProteoNic BV, Leiden, Netherlands
Bayer Corporation, Tarrytown, NY	Green Biologics, Gahanna, OH	Proterro, Inc., Ewing, NJ
Biobased Technologies®, LLC, Rogers, AR	Green Life Can LLC, Las Vegas, NV	Renmatix, King Of Prussia, PA
BioFiber Solutions International, Inc., Seal Beach, CA	Heliae, Gilbert, AZ	Rennovia, Inc., Santa Clara, CA
Biosynthetic Technologies, Irvine, CA	Intrexon Corp., Germantown, MD	Reverdia, Geleen, Netherlands
Calysta, Menlo Park, CA	Itaconix Corp., Stratham, NH	RHO Renewables, Inc., Oakland, CA
Cellana LLC, Kailua Kona, HI	LanzaTech, Skokie, IL	Sapphire Energy, Inc., San Diego, CA
ChemDiv, Inc., San Diego, CA	Matrix Genetics, Seattle, WA	Succinity GmbH, Düsseldorf, Germany
Corbion, Amsterdam, Netherlands	MBI International, Lansing, MI	Syngulon, Gosselies, Belgium
DEINOVE, Grabels, France	Metabolix, Inc., Cambridge, MA	Synthetic Genomics, Inc., La Jolla, CA
DNA2.0, Newark, CA	Modular Genetics, Inc., Woburn, MA	TerraVia, South San Francisco, CA
DSM, NV, Heerlen, Netherlands	Monsanto Co., Saint Louis, MO	The Coca-Cola Co., Atlanta, GA
DuPont Corp., Wilmington, DE	Muse Biotechnologies, Inc., Boulder, CO	The Dow Chemical Co., Midland, MI
Earth Energy Renewables, LLC, Bryan, TX	NatureWorks, LLC, Minnetonka, MN	Verdezyne, Inc., Carlsbad, CA
Elevance Renewable Sciences, Inc., Woodridge, IL	NexSteppe, South San Francisco, CA	XFTechnologies, Albuquerque, NM
Enevolv, Inc., Cambridge, MA	Novozymes, Bagsvaerd, Denmark	ZeaChem, Inc., Lakewood, CO
	Nucelis LLC, San Diego, CA	

## BIO Industrial & Environmental Section Governing Board

Alan Shaw, PhD – I&E Section Chair President & Chief Executive Officer Calysta	Mark Jones, PhD Executive External Strategy & Communications Director Dow Chemical Company	Joseph Shaulson President & Chief Executive Officer Metabolix, Inc.	Stephan B. Tanda Managing Board Royal DSM
Tjerk de Ruiter – I&E Section Vice Chair Chief Executive Officer Corbion	Eli Ben Shoshan Director – Strategy, Business Development, Mergers & Acquisitions DuPont Industrial Biosciences	Adam Monroe President, Novozymes Americas Regions Novozymes	Jamie Levine Chief Executive Officer Sapphire Energy, Inc.
John Melo President & Chief Executive Officer Amyris, Inc.	Neil Goldsmith Chief Executive Officer Evolva	Anna Rath President & Chief Executive Officer Nexsteppe, Inc.	Roger Wyse, PhD (non-voting) Founder Spruce Capital Partners
Markus Pompejus, PhD VP White Biotechnology Research North America BASF Corporation	Jennifer Holmgren, PhD Chief Executive Officer Lanzatech	Doug Berven Vice President, Corporate Affairs Poet, LLC	Jonathan S. Wolfson Chief Executive Officer TerraVia
			Miki Knutzen Global Program Director, PlantBottle The Coca Cola Company

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