Cellulosic biofuel is a liquid fuel or feedstock produced from lignocellulose, a structural material that comprises much of the mass of plants, including grasses, wood and municipal/agricultural waste.

Most companies use some combination of heat (including gasification), enzymes and chemicals to break down complex cellulosic materials into simple sugars (for fermentation into ethanol) and other marketable products such as bio-crude and renewable power.

According to the Sandia National Lab, the U.S. could produce 75 billion gallons per year of cellulosic biofuels without displacing food and feed crops (the U.S. consumed ~134 billion gallons of gasoline in 2011). The U.S. advanced biofuels industry is ramping up to compete in the $2.5 trillion global clean energy marketplace. Compliance with the federal Renewable Fuel Standard (RFS) is forecasted to create up to 800,000 jobs by 2022.

The RFS was amended to include cellulosic biofuels just 5 years ago. Despite the global recession, the cellulosic biofuels industry now has facilities and projects under development in more than 20 U.S. states representing billions of dollars in private investment. Enzyme costs are down 80% in the last decade, and cellulosic biofuels are being produced for $2.00 per gallon or less today. The cellulosic biofuels industry has reached the commercial deployment phase. However, high capital risk from OPEC-induced price distortions, constrained blending markets and policy uncertainty continues to slow the rate of deployment. The federal policies that put the United States at the global forefront of the development of the cellulosic biofuels industry are at risk. How U.S. policymakers address these challenges will determine whether the country leads or falls behind in the global race to produce next generation bio-based fuels and products.

This report provides a detailed snapshot of advances made toward the commercial deployment of cellulosic biofuels. The report profiles cellulosic biofuel production facilities and projects in roughly 20 U.S. states, several provinces in Canada, as well as China, Denmark, Italy, Germany and Spain. All companies profiled are working toward developing production capacity in the United States to meet the federal RFS.

The Fuel
- Cellulosic biofuel is a liquid fuel or feedstock produced from lignocellulose, a structural material that comprises much of the mass of plants, including grasses, wood and municipal/agricultural waste.

The Technology
- Most companies use some combination of heat (including gasification), enzymes and chemicals to break down complex cellulosic materials into simple sugars (for fermentation into ethanol) and other marketable products such as bio-crude and renewable power.

The Opportunity
- According to the Sandia National Lab, the U.S. could produce 75 billion gallons per year of cellulosic biofuels without displacing food and feed crops (the U.S. consumed ~134 billion gallons of gasoline in 2011). The U.S. advanced biofuels industry is ramping up to compete in the $2.5 trillion global clean energy marketplace. Compliance with the federal Renewable Fuel Standard (RFS) is forecasted to create up to 800,000 jobs by 2022.

Industry Progress
- The RFS was amended to include cellulosic biofuels just 5 years ago. Despite the global recession, the cellulosic biofuels industry now has facilities and projects under development in more than 20 U.S. states representing billions of dollars in private investment. Enzyme costs are down 80% in the last decade, and cellulosic biofuels are being produced for $2.00 per gallon or less today.

The Challenge
- The cellulosic biofuels industry has reached the commercial deployment phase. However, high capital risk from OPEC-induced price distortions, constrained blending markets and policy uncertainty continues to slow the rate of deployment. The federal policies that put the United States at the global forefront of the development of the cellulosic biofuels industry are at risk. How U.S. policymakers address these challenges will determine whether the country leads or falls behind in the global race to produce next generation bio-based fuels and products.

Disclaimer: This report provides a commercial deployment update for a number of first movers in the cellulosic biofuels sector. The report does not profile all cellulosic biofuel projects under development in the U.S. and abroad, and does not cover other advanced biofuel sectors.
COMPANY PROFILE

Abengoa Bioenergy is a worldwide leader in the development of biofuels for transportation, as well as in chemical bioproducts which use biomass as raw material. Abengoa Bioenergy owns and operates 14 bioethanol facilities throughout the United States, Europe and Brazil with a total production capacity of 842 million gallons per year.

PILOT FACILITY
LOCATION: York, NE
FEEDSTOCK: Wheat Straw, Corn Stover
PRODUCTS: Cellulosic Ethanol
CAPACITY: 20,000 GPY
PLANT PROFILE: Completed and first cellulosic ethanol produced in September 2007

DEMONSTRATION FACILITY
LOCATION: Salamanca, Spain
FEEDSTOCK: Wheat and barley straw
PRODUCTS: Cellulosic Ethanol
CAPACITY: 1.3 MGy
PLANT PROFILE: Construction completed and first cellulosic ethanol produced in 2009.

PATH TO COMMERCIAL DEPLOYMENT

The Abengoa Bioenergy Hugoton Biorefinery will utilize the company’s proprietary technology to produce 25 million gallons of cellulosic ethanol per year. The plant will utilize approximately 1,100 dry tons of agricultural waste per day for the ethanol production process. The residue of that process (approximately 300 tons per day of lignin) will be combusted to produce 20 megawatts of electricity. This will allow the facility to be fueled entirely by biomass.

Abengoa Bioenergy Partners

Private Equity: Abengoa Bioenergy equity
Strategic: None; contracted with professional biomass harvesting and removal firms
Public/Government: Selected for $97MM Section 932 Cost Share Grant (DOE) in 2007; awarded $133MM EPAct 2005 loan guarantee in 2011 for development of the Abengoa Bioenergy commercial facility in Hugoton, Kansas
American Process & AVAPCO Partners

**Green Power+ Strategic**:
- ArborGen
- Decorative Panels International
- Green Tech America
- Metso

**Green Power+ Public/Government**:
- U.S. Department of Energy ($18MM grant to Alpena Biorefinery)
- Michigan Economic Development Corporation ($4MM grant to Alpena Biorefinery)

**AVAPCO Strategic**:
- ArborGen
- Green Tech America
- Metso
- Novozymes

**AVAPCO Public/Government**:
- Private investment

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**AVAP TECHNOLOGY**

AVAP is a greenfield technology that fractionates any biomass via the proprietary, patented use of SO2 and ethanol into cellulose, lignin and hemicelluloses. The cellulose and hemicelluloses are then converted into sugars. Resultant sugars are high purity and low cost, making them an ideal feedstock for downstream conversion into bio-based chemicals and biofuels. The lignin is burned as fuel in the boiler.

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**GREEN POWER+ TECHNOLOGY**

GREEN POWER+ is a cellulosic technology that co-locates with biomass power plants. The hemicelluloses are selectively extracted and hydrolyzed into monomer sugars. The resulting sugars are fermented into cellulosic ethanol. The process configuration enables Green Power+ to convert the hemicelluloses to higher value added products: cellulosic ethanol and renewable chemicals.

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**PATH TO COMMERCIAL DEPLOYMENT**

- **2008**
- **2009**
- **2010**
- **2011**
- **2012**
- **2013**
- **2014**
- **2015**

- **Estimated Startup**
- **2013**

**GREEN POWER+ DEMONSTRATION FACILITY**

**LOCATION**: Alpena, MI

**FEEDSTOCK**: Mixed hardwood

**PRODUCTS**: Cellulosic ethanol, Potassium acetate

**CAPACITY**: 700,000 Gpy per product

**JOBS**: ~25 operational, including biomass logistics

**PLANT PROFILE**: The plant is co-located with the Decorative Panels International (DPI) hardboard manufacturing facility. Plant construction began April 2011; commissioning occurred in June 2012. The plant is in startup mode.

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**AVAP TECHNOLOGY**

**AVAP DEMONSTRATION FACILITY**

**LOCATION**: Thomaston, GA

**FEEDSTOCK**: Variety of biomass – up to 10 tons/day

**PRODUCTS**: Cellulosic sugars, Ethanol, Cellulose

**CAPACITY**: Up to 300,000 Gpy Cellulosic Ethanol

**JOBS**: ~30 operational, including biomass logistics

**PROJECT PROFILE**: Plant will begin startup in Q1/2013. Thomaston will be the site of AVAPCO’s supply chain integrated alliances with downstream sugar converters to chemicals, fuels and materials. AVAPCO was an affiliate of American Process, Incorporated. AVAPCO was created in 2011 in order to commercialize the AVAP technology developed by American Process. AVAPCO owns the Thomaston, GA AVAP Demonstration Facility.

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**GREEN POWER+ & AVAPCO Partners**

**American Process Green Power+ Demo Facility**

Based in Atlanta, American Process Inc. was founded in 1994 as a consulting practice serving the forest products industry. Since 2005, the company has been developing technologies for the conversion of biomass into cellulosic sugars to be used in the production of biofuels and bio-based chemicals. American Process now owns two patented cellulosic technologies, Green Power+ and AVAP.
Beta Renewables is a $350 million joint venture formed from the Chemtex division of Gruppo Mossi & Ghisolfi and TPG. The M&G Group (~$3b USD annual revenue) brings over 60 years of success in process development and plant commercialization worldwide. The joint venture has invested over $200 million in the development of its advanced PROESA™ cellulosic biofining technology.

**Beta Renewables Partners**

**Private Equity:** Over $200 million invested in PROESA technology development by M&G’s Chemtex division. Beta Renewables formed as $350 million joint venture by Chemtex and TPG.

**Strategic:** GraalBio, Colbiocel, Novozymes, Genomatica, Gevo, Codexis, Amyris, Biofuels Center of North Carolina

**Public/Government:** USDA, $99M loan guarantee for Project Alpha in North Carolina, plus $4M BCAP award

**U.S. COMMERCIAL FACILITY UNDER DEVELOPMENT: PROJECT ALPHA**

**LOCATION:** Sampson County, NC

**STATUS:** $99M conditional loan guarantee awarded August 2012

**FEEDSTOCK:** Dedicated energy feedstock crops; $3.9M BCAP award

**PRODUCTS:** Cellulosic Ethanol, Bio-based Chemicals

**CAPACITY:** 20 MGy

**JOBS:** 300+ direct and indirect jobs

**PROJECT PROFILE:** Project Alpha to use Chemtex PROESA technology; $3.9M Biomass Crop Assistance Program (BCAP) grant to facilitate the establishment of over 4,000 acres of energy crop development across eleven counties in North Carolina, with expected additional revenues to exceed $4.5M annually for local biomass producers

**PATH TO COMMERCIAL DEPLOYMENT**
COMPANY PROFILE
BlueFire was established to deploy the Arkenol Process Technology for the conversion of cellulosic waste materials into renewable fuels and other products. BlueFire is the exclusive North America licensee of the technology, which converts widely available, inexpensive, organic materials such as agricultural residues, wood residues, municipal solid wastes and purpose grown energy crops into renewable end products. BlueFire also operates SucraSource, which converts cellulose into intermediate sugars for the production of bio-chemicals and other products.

BLUEFIRE COMMERCIAL SITE

COMMERCIAL FACILITY
LOCATION: Fulton, MS
STATUS: Site Preparation Completed. Pending financing for facility construction, recipient of $87.5MM Dept of Energy grant
FEEDSTOCK: Forestry residues and other cellulosic wastes
PRODUCTS: Cellulosic Ethanol, Gypsum, Lignin and Protein Cream
CAPACITY: 19 MGy
JOBS: 750 peak construction jobs. Over 100 for plant operation and handling of biomass and products
PROJECT PROFILE: All permits for construction obtained, long-term contracts for all of feedstock and products complete. Turn-key EPC contract completed.

PATH TO COMMERCIAL DEPLOYMENT

Licensed technology with over 30,000 hours of pilot plant activity
Secured 340 MM grant under the Biomass Program of Farm Bill
Began developing Fulton, MS facility
Increased grant to $87.5MM total under ARRA
Began site clearing and pre Perez in November
Completed site preparation and detailed engineering for Fulton facility
Began due diligence on future sites
Launched SucraSource to market cellulose to sugar technology
Completed financing for 79 MMGPY Fulton, MS Facility
SucraSource signed agreement with GS Caltex to build cellulose to sugar plant in Korea
Began Fulton Facility Construction Early 2013
Finished construction of Fulton, MS Facility and start production

COMMERCIAL SITE

BLUEFIRE COMMERCIAL SITE

COMMERCIAL SITE

BLUEFIRE COMMERCIAL SITE

DEMONSTRATION FACILITY
LOCATION: Anaheim, CA
FEEDSTOCK: Various wood and paper wastes, MSW, bagasse
PRODUCTS: Cellulosic Sugars
CAPACITY: 200 lbs per day
PLANT PROFILE: Pilot testing complete; now utilized for production of cellulosic sugars for sale to companies developing processes to convert sugar to bio-products.

BLUEFIRE DEMONSTRATION FACILITY

BLUEFIRE DEMONSTRATION FACILITY

SucraSource, a wholly owned subsidiary of BlueFire Renewables, signed agreements in 2012 with GS Caltex, a Korean petroleum company, to build a cellulose to sugar plant in Korea. The facility will process 2 tons of construction and demolition debris per day into cellulosic sugar, which will be converted into a high-value chemical by GS Caltex. The facility will be owned and operated by GS Caltex with SucraSource providing the process design package, equipment procurement and technical and engineering support.

Bluefire Partners
Private Equity: Quercus Trust, Arkenol Inc., ARK Energy Inc.
Strategic: Feedstock Contract with Cooper Marine Timberlands, OF-Take Agreement with Tenaska Biofuels, EPC contract with MasTec North America, Applied Power Concepts
Project Development: Launched SucraSource, a wholly-owned subsidiary constructing a cellulosic sugar facility in South Korea for development of sugar to chemicals process. Designing cellulose to fuels plant with China Huadian Engineering Co and Sinbioway - Both out of Beijing, China

BLUEFIRE PROCESS DESIGN

BLUEFIRE PROCESS DESIGN

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Downloaded from https://www.flownow.com/bluefire.html on 2023-11-02
**COMPANY PROFILE**
Clariant, headquartered in Muttenz near Basel, Switzerland, is an internationally active specialty chemical company with $8 billion in annual turnover and over 22,000 employees worldwide. Clariant has over 100 group companies and production sites in 44 countries including the United States. The Clariant Biotech and Renewables Center is based in Munich and Straubing, Germany, and is focused exclusively on the development and commercial deployment of renewable technology solutions.

**RESEARCH FACILITY**
**LOCATION:** Munich, Germany  
**FEEDSTOCK:** Various ligno-cellulosic feedstocks  
**PRODUCTS:** Cellulosic Ethanol, Cellulosic Sugars, Biobased Chemicals  
**CAPACITY:** 2 tons per year  
**PLANT PROFILE:** Plant utilized to test and improve the sunliquid® technology across several different lignocellulosic feedstocks.

**Clariant Partners**
- **Private Equity:** No funding was requested from Private Equity for the demonstration plant. Funding sources for the first commercial plant will be evaluated.
- **Strategic:** No funding was requested from Strategic Partners for the demonstration plant. Funding sources for the first commercial plant will be evaluated.
- **Public/Government:** The Bavarian State Government and the German Federal Ministry of Education and Research have each funded 5 million euros into the demonstration plant for research relating to the project. Funding sources for the first commercial plant will be evaluated.

**CLARIANT COMMERCIAL STRATEGY**
- **STATUS:** Clariant is in the process of evaluating site locations for the first commercial sunliquid® production plant in the U.S., EU, Brazil and Canada.
- **FEEDSTOCK:** Agricultural residues  
- **PRODUCTS:** Cellulosic Ethanol, Cellulosic Sugars, Biobased Chemicals  
- **CAPACITY:** Feedstock dependent; ranges between 18-60 MGy  
- **JOBS:** To be determined

**PATH TO COMMERCIAL DEPLOYMENT**
- **2008:** B&D started on sunliquid® technology in 2008  
- **2009:** Sunliquid® research/pilot plant built and operating  
- **2010:** Operational efficiency achieved at sunliquid® pilot plant  
- **2011:** Agreement in place to build demonstration plant  
- **2012:** Construction begins on demonstration plant  
- **2013:** Continue to prove out sunliquid® technology at pilot/research plant  
- **2014:** Produce first commercial gallons at Straubing demonstration plant  
- **2015:** Demonstrate and improve performance of sunliquid® technology at demo scale  
- **2016:** Identify site for first commercial sunliquid® plant  
- **2017:** Produce first gallons at first commercial sunliquid® plant
**COMPANY PROFILE**
Headquartered in Montreal, Canada, Enerkem employs 140 employees in the U.S. and Canada. Enerkem builds modular, copy-exact and scalable 10 million gallon per year biorefineries that utilize its proprietary thermochemical conversion technology to produce advanced ethanol and bio-chemicals from municipal solid waste (MSW). Founded in 2000, Enerkem started piloting its technology in 2003.

**U.S. COMMERCIAL STRATEGY**
**SUMMARY:** Enerkem has identified dozens of potential sites in the United States to deploy its modular, copy-exact 10 MGy biorefineries.

**FIRST PROJECT:** Pontotoc, MS

**FEEDSTOCK:** MSW, wood residues

**PRODUCTS:** Syngas, Biomethanol, Acetates, Cellulosic Ethanol

**STATUS:** Under development

**ENHERKEM COMMERCIAL PROJECT**
**LOCATION**: Edmonton, AB, Canada

**STATUS:** Phase 1 Completion in 3Q 2013

**FEEDSTOCK:** MSW from the City of Edmonton

**PRODUCTS:** Syngas, Biomethanol, Acetates, Cellulosic Ethanol

**CAPACITY:** 10 MGy

**PLANT PROFILE:** Enerkem has a 25-year agreement with the City of Edmonton to build and operate a plant that will produce next-generation biofuels from non-recyclable, non-compostable municipal solid waste (MSW). It is the world’s first major collaboration between a metropolitan centre and a waste-to-biofuels producer to turn MSW into methanol and ethanol. The plant will produce 2.5% RFS-eligible cellulosic biofuels and enable Edmonton to increase its residential waste diversion rate to 90 percent.

**ENHERKEM PRODUCTION PROJECT**
**LOCATION**: Westbury, QC, Canada

**STATUS:** phase 1 Completion in 3Q 2013

**FEEDSTOCK:** MSW, wood residues

**PRODUCTS:** Syngas, Biomethanol, Cellulosic Ethanol

**CAPACITY:** 1.3 MGy

**PROJECT PROFILE:** Enerkem’s Westbury facility is the first plant in the world to utilize used electricity poles (a negative-cost and heterogeneous material) to produce ethanol and methanol. The plant, co-located with a saw mill that recycles wood from utility poles, utilizes the portion of the pole that cannot be reclaimed. The plant began producing conditioned syngas in 2009, methanol in 2011, and cellulosic ethanol in 2012.

**PATH TO COMMERCIAL DEPLOYMENT**

**2008**
- Announced Edmonton commercial project with the government of Alberta
- Launched U.S. business development strategy in wake of BFS
- Westbury Demo: gasification island mechanically complete

**2009**
- Announced plan to enter the US with Pontotoc, MS project
- Awarded funding agreement from DOE for MS project (up to $50 million)
- Westbury Demo: gasification island commissioned, plant startup

**2010**
- Strategic Partner: Secant Waste Management
- Groundbreaking ceremony for Edmonton commercial project and project federal permitting for Pontotoc, MS requirements rest (NEPA)
- Westbury Demo: construction of syngas-to-methanol island

**2011**
- Strategic Partner: Secant Waste Management
- Completed $100M in private financing
- Awarded $33M loan guarantee by SBA for MS Project
- Westbury Demo: completion of methanol production island
- Fast Company named Enerkem one of World’s 50 Most Innovative Companies (10)

**2012**
- Westbury Demo: full-scale ethanol production underway
- Announced of Vancover commercial project & $27M grant funding
- Entered non-binding agreements to sell proprietary systems to Waste Management & Valero for new U.S. projects

**2013**
- Full-scale Edmonton project to begin operations
- Construction of methanol-to-ethylene island in Edmonton
- Mussina project construction to start
- Start development of new projects in North America and overseas

**2014**
- Edmonton full-scale facility construction complete

**2015**
- Mussina full-scale facility construction complete

**Enerkem Partners**


**Strategic:**
- Waste Management (upstream: feedstock), Valero (downstream: blending), GreenField Ethanol (distributor: largest traditional ethanol producer in Canada)
- Government/Public: up to $50 MM cost-share (DOE) and $80MM loan guarantee (USDA) to support construction full-scale commercial facility in Pontotoc, MS; $18MM CAD grant (Quebec: Ministry of Natural Resources and Wildlife) and $9 MM loan (Investissement Quebec) for commercial facility in Varennes, Quebec; $23MM CAD (Alberta Innovates and Alberta Energy) for full-scale facility in Edmonton, Alberta; Natural Resources Canada, Sustainable Development Technology Canada

**SUMMARY:**
- Enerkem has identified dozens of potential sites in the United States to deploy its modular, copy-exact 10 MGy biorefineries.
- **FIRST PROJECT:** Pontotoc, MS
- **FEEDSTOCK:** MSW, wood residues
- **PRODUCTS:** Syngas, Biomethanol, Acetates, Cellulosic Ethanol
- **STATUS:** Under development

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- **STATUS:** Under development
Fiberight is a privately held company founded in 2007 with current operations in Virginia, Maryland and Iowa. Fiberight applies its proprietary technology to refine municipal solid waste (MSW) and waste fiber pulp into cellulosic sugars that can be further processed into cellulosic biofuels. Fiberight demonstrated the ability to produce commercial scale batches of cellulosic ethanol at its Iowa plant in 2010. Fiberight is targeting rapid expansion of its prototype commercial plants in population dense municipalities with high-stranded trash costs or landfill limitations.

**Reference Commercial Facility**

**Location:** Lawrenceville, VA

**Feedstock:** Municipal solid waste, commercial waste, energy crops

**Products:** Cellulosic Ethanol/biofuels, Cellulosic Sugars, Bio-chemicals

**Capacity:** 1 MGy

**Plant Profile:** Utilized to test core business and technology platforms since 2007; upgraded in 2011 to be fully integrated MSW-to-biofuels reference commercial plant; operations commenced in 2012 with 20+ employees.

**Fiberight Partners**

**Private Equity:** Confidential Private Equity Fund, SEC Reg. D offering completed in 2012 - $15M

**Strategic:** Novozymes

**Government/Public:** Iowa Power Fund - $2.9M, USDA Loan Guarantee - $25M

**Commercial Facility**

**Location:** Blairstown, IA

**Status:** Existing Facility To Be Modified in 2013

**Feedstock:** Municipal Solid Waste, Non-Food Wastes

**Products:** Cellulosic Ethanol, Bio-chemicals

**Capacity:** 6 MGy

**Jobs:** 55 Full-time Operational Positions

**Project Profile:** Facility is a retro-fitted former corn ethanol plant within 30 miles of well over 1,000 tons per day of MSW.

**Path to Commercial Deployment**


- Lab scale research continues
- Pilot scale testing in Lawrenceville
- Purchase of Blairstown commercial ethanol facility
- Engineering and design completed for full-scale demo testing in Blairstown
- Equity funding for reference commercial plant secured
- Design & engineering for Lawrenceville reference commercial plant
- USDA loan guarantees secured
- Lawrenceville reference commercial plant processing begins
- Novozymes partnership formalized
- Fiberight to help put MSW-to-cellulosic ethanol EPA pathway approved
- Blairstown commercial facility constructed, operations commence
- 2-4 Commercial plants constructed in Mid-Atlantic, Iowa Expansion
- Additional 3-5 plants in Mid-Atlantic Region
Fulcrum BioEnergy is headquartered in Pleasanton, California. The company operates a process demonstration unit in Durham, North Carolina that converts synthesis gas to ethanol. Fulcrum is ready to begin construction on a commercial-scale advanced biofuels facility, the Sierra BioFuels Plant, that will convert municipal solid waste (MSW) into ethanol. Sierra is located near Reno, Nevada.

**Fulcrum Partners**

**Private Equity:** Raised $93 million of capital in 2011 from investors such as US Renewables Group, Rustic Canyon and Waste Management.

**Strategic:** Fulcrum has partnered with Waste Connections and Waste Management, two of the nation’s largest waste companies, for long-term feedstock supply and joint development activities. These agreements give Fulcrum the ability to produce more than 700 million gallons of ethanol per year throughout the United States.

**Government/Public:** Fulcrum received a $105 million conditional commitment for a USDA loan guarantee in August 2012. The final terms are currently being negotiated with the USDA.

**Sierra BioFuels Commercial Project**

- **Location:** McCarran, Storey County, NV
- **Status:** Initial site preparation work completed. Construction will begin once the USDA loan guarantee is closed
- **Feedstock:** Municipal solid waste contracted with Waste Connections and Waste Management
- **Products:** Advanced Ethanol
- **Capacity:** 10 MGy
- **Jobs:** 430 engineering and construction jobs; 53 permanent jobs

**Project Profile:** Located at the Tahoe-Reno Industrial Center approximately 20 miles east of Reno, Nevada, Sierra will be one of the first projects of its kind to be built in the United States. Designed to produce approximately 10 MMT of low-carbon, renewable transportation fuel annually, the project will combine new, innovative technology with existing commercial systems.

**Estimated Completion: 2014**

**Path to Commercial Deployment**

- **2008**
  - Acquired development rights for Sierra; entered into technology licensing and development agreements; executed MSW feedstock agreement for Sierra

- **2009**
  - Engineered, constructed and commissioned operations of Alcohol Synthesis PDU; demonstrated at full-scale Fulcrum’s proprietary process for the conversion of synthesis gas to alcohol

- **2010**
  - Signed EPC contract with Fluor Corporation

- **2011**
  - Completed engineering phase of Sierra BioFuels

- **2012**
  - Sierra BioFuels received conditional commitment for a $105MM USDA loan guarantee

- **2013**
  - Completed engineering phase of Sierra BioFuels

- **2014**
  - Commercial operations to begin at Sierra BioFuels Plant

- **2015**
  - Construction of additional commercial scale projects to begin
Inbicon began pioneering biomass conversion technology in the late 1990s. Using steam, enzymes, and yeast, Inbicon turns soft lignocellulose (e.g. wheat straw, corn stalks, energy grasses) into cellulosic ethanol, as well as renewable lignin and industrial sugar molasses for power and bio-chemicals. Inbicon is a subsidiary of DONG Energy, Denmark’s largest energy company with 6,000 employees and $9.8 billion in revenues (2011). DONG Energy has invested over $100 million to develop and commercialize Inbicon technology, which is licensed worldwide.

**Commerical Project**

**Location**: Maahyng, Denmark  
**Status**: Engineering and Permitting  
**Feedstock**: Wheat Straw (50 Tons per hour)  
**Products**: Cellulosic Ethanol, Biogas, Renewable Electricity, Renewable Fertilizer, rainfall biofuel  
**Capacity**:  20 MGy (Cellulosic Ethanol); 1.7 Billion Cubic Feet (Biogas); Renewable Electricity for 25,000 households, 56,000 TPY of renewable fertilizer; 56,000 TYP of solid biofuel for power stations  
**Project Profile**: Integrates 6 Danish technolgies on a 247-acre site in northwestern Jutland, to utilize 400,000 tons of wheat straw and 770,000 tons of livestock waste annually.

**Marketing**: Inbicon is working with the Danish Export Fund (EKF) to bring loan guarantees to its North American projects.

**Enzyme**: Novozymes; DuPont Genencor

**Project Finance**: Inbicon is working with the Danish Export Fund (EKF) to bring loan guarantees to its North American projects.

Inbicon Partners

**Marketing**: Leifmark, LLC is the independent Inbicon partner authorized to license Inbicon Biomass Refinery technology in North America. Leifmark has developed a pipeline of U.S. projects, including the Fair Oaks (IN) and Spiritwood (ND) projects.

**U.S. Engineering**: To assure quality control for U.S. projects, Inbicon has certified three American firms to perform engineering for U.S. projects: Harris Group (Seattle, WA); Pöyry (Appleton, WI); and, APS (Richmond, VA).

**Enzyme**: Novozymes; DuPont Genencor

**Project Finance**: Inbicon is working with the Danish Export Fund (EKF) to bring loan guarantees to its North American projects.

**Cellulosic ethanol produced at the Inbicon Kalundborg plant is currently sold at almost 500 Station fueling stations in Denmark in E5 blends (5% cellulosic ethanol, 95% gasoline)**

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COMPANY PROFILE
INEOS Bio is a BioEnergy company producing advanced biofuels and renewable power from a wide range of low-cost carbon materials. The company’s highly innovative technology provides an alternative to waste disposal for communities around the globe. INEOS Bio is one of the global businesses in INEOS.

IFEEDSTOCK STORAGE AT INEOS FACILITY

RESEARCH AND DEVELOPMENT FACILITY
LOCATION: Fayetteville, AR
FEEDSTOCK & PRODUCTS: Synthesis Gas, Ethanol, Other
CAPACITY: 1.5 tons per day
PLANT PROFILE: INEOS Bio utilizes its integrated pilot plant to test, prove and optimize its proprietary technology. INEOS Bio’s pilot plant and research and development facility represents a vitally important step on the road to commercialization. The company will continue to operate its pilot plant in parallel with its commercial and licensed facilities. Experience has shown that continued development and research with an integrated pilot plant supports an overall continuous improvement process that benefits our licensees and operating facilities.

INEOS Partners
Marketing: JV Project between INEOS Bio and New Planet BioEnergy
Strategic: (Project) AMEC, Air Products, VogelBusch, Emerson, CDM-Smith
Public/Government: $50MM (DOE) grant, $75MM (USDA) loan guarantee, $2.5MM (State of Florida) grant

The INEOS Bio technology is a combined thermo-chemical and bio-chemical process that efficiently converts a wide range of organic materials, including municipal solid waste, yard, forestry and agricultural waste into ethanol and renewable energy. This flexibility allows facilities to be built anywhere in the world, providing jobs and locally sourced renewable energy for urban and rural communities.

INEOS VERE BEACH COMMERCIAL FACILITY
LOCATION: Vero Beach, FL
STATUS: Commissioning Stage
FEEDSTOCK: Vegetative and Yard waste; MSW
PRODUCTS: Cellulosic ethanol and renewable power
CAPACITY: 8 MGY; 6MW (gross) electricity generation
JOBS: 400 direct and indirect jobs, 60 full time
PLANT PROFILE: The site, adjacent to the Indian River County landfill, ensures flexibility and long-term feedstock availability.

PATH TO COMMERCIAL DEPLOYMENT

The INEOS Bio technology is tested, proven and optimized at fully integrated pilot plant scale.
Awarded $50MM DOE Grant through IBA program
First DOE awarded facility to move to construction phase
Groundbreaking on first commercial scale plant in Florida, USA
Selected/trial USDA Loan Guarantee
Completion of construction/ commissioning and operations of Florida plant
Additional INEOS Bio Licensed & Operating Facilities
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ESTIMATED STARTUP 2012
COMPANY PROFILE
Since Iogen’s founding in the late 1970s, more than $425 million has been invested in Iogen’s cellulosic ethanol technology, including more than $75 million in the Iogen demonstration plant in Ottawa. Investors include Royal/Dutch Shell, Goldman Sachs, Petro Canada, and Volkswagen. The company, based in Ottawa, has produced more than 560,000 gallons of cellulosic ethanol to date and holds more than 250 patents. Iogen also operates a thriving business making enzymes that digest fiber.

DEMONSTRATION FACILITY
LOCATION: Ottawa, ON, Canada
FEEDSTOCK: Cereal Straw, Bagasse, Corn Stover, Grasses
PRODUCTS: Cellulosic Ethanol
CAPACITY: 1 MGY
PLANT PROFILE: Fully integrated plant with all key unit options; started ethanol production in 2005. Has undergone regular upgrades and improvements resulting from learnings of integrated 24x7 operation and technology improvements from R&D.

Iogen Partners
Private Equity: $425 million aggregate investment through partners including: Royal Dutch/Shell Group, Goldman Sachs & Co., Volkswagen and Petro-Canada.

Strategic: Iogen is currently working closely with Raízen, Brazil’s largest sugar and ethanol producer and a 50:50 JV between Royal/Dutch Shell and Cosan.

Government/Public: $20MM from Government of Canada, of which $10MM (Technology Partnership Canada) was for Ottawa demonstration facility.

PATH TO COMMERCIAL DEPLOYMENT

IOGEN DEMO PLANT FUEL PRODUCTION

<table>
<thead>
<tr>
<th>Year</th>
<th>Ethanol (Liters)</th>
<th>Cumulative Production (Liters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>129,547</td>
<td>279,416</td>
</tr>
<tr>
<td>2006</td>
<td>16,811</td>
<td>236,229</td>
</tr>
<tr>
<td>2007</td>
<td>2,598</td>
<td>238,827</td>
</tr>
<tr>
<td>2008</td>
<td>244,526</td>
<td>445,162</td>
</tr>
<tr>
<td>2009</td>
<td>510,442</td>
<td>956,594</td>
</tr>
<tr>
<td>2010</td>
<td>588,781</td>
<td>1,575,375</td>
</tr>
<tr>
<td>2011</td>
<td>371,016</td>
<td>1,646,811</td>
</tr>
<tr>
<td>2012</td>
<td>219,090</td>
<td>1,865,901</td>
</tr>
</tbody>
</table>

*To July 31, 2012
KiOR is a next-generation renewable fuels company that has developed a unique two-step proprietary technology platform to convert abundant and sustainable biomass resources into cellulosic gasoline, diesel, jet fuel and fuel oil. KiOR’s cellulosic biofuels may be transported using existing distribution networks and are suitable for use in vehicles on the road today. KiOR strives to help ease dependence on foreign oil, reduce lifecycle greenhouse gas emissions and create high-quality jobs and economic benefit across rural communities.

KiOR has developed a proprietary technology platform to convert sustainable, low-cost biomass into a hydrocarbon-based renewable crude oil. The platform combines proprietary catalyst systems with a process based on existing Fluid Catalytic Cracking (fCC) technology, a standard process used for over 60 years in oil refining. KiOR processes its renewable crude oil in a conventional hydrotreater into gasoline and diesel blendstocks that can be combined with existing fossil-based fuels used in vehicles on the road today.

KiOR Partners
Private Equity/Investment: Initial public offering proceeds were approximately $148.6 million. Major stock ownership: Class A&B shares - 57.2 million/Khosla Ventures; 17.5 million/Artis Capital Management; 8.5 million/Alberta Investment Management Corporation. Class C shares 3.0 million – Khosla Ventures.

Public/Government: Mississippi Development Authority loan for $75 million, and significant support from other state departments as well as local economic development teams.

**KiOR Commercial Project in Columbus, MS**

**Estimated Startup**
4Q 2012

**Estimated Completion**
2014

**Location**: Columbus, MS

**Status**: Operational

**Feedstock**: Forestry Residuals

**Products**: Cellulosic Gasoline & Diesel

**Capacity**: 40 MGY

**Jobs**: ~60 direct; several hundred indirect

**Project Profile**: $350 million investment; flagship commercial project serving as logistical hub for production and delivery; construction beginning early 2013 with ~600 construction employees.

**Path to Commercial Deployment**


- **“Proof of concept” achieved at Pilot Plant in Pasadena**
- **Validated technical feasibility of proprietary process by successfully converting biomass into an intermediate renewable crude oil that can be refined into cellulosic gasoline**
- **Continued work on technical feasibility, R&D & commercialization**
- **Demonstration unit installed in Pasadena (10X scale up from pilot plant), capable of producing up to 15 barrels of product per day**
- **Site selection for first commercial facility**
- **Broke ground at Columbus commercial plant (50X scale up from demo plant), capable of producing up to 13 million gallons of cellulosic biofuels per year**
- **Signed off take agreements with Hunt Refining, Catchlight Energy and FedEx**
- **Initial public offering (IPO) successful**
- **Second additional financing**
- **Completed construction of Columbus commercial plant & commencement operations**
- **Received Title 79 Registration from EPA for sale of cellulosic gasoline and diesel**
- **Due diligence on next facility started**

**2nd Commercial Project Under Development**

**Location**: Natchez, MS

**Feedstock**: Forestry Residuals

**Products**: Cellulosic Gasoline & Cellulosic Diesel

**Capacity**: 40 MGY

**Jobs**: 60-70 direct; several hundred indirect

**Project Profile**: $350 million investment; flagship commercial project serving as logistical hub for production and delivery; construction beginning early 2013 with ~600 construction employees.
**COMPANY PROFILE**

Founded in 2005 LanzaTech offers a fully integrated sustainable fuels and chemicals platform that uses available waste resources to produce fuels such as ethanol and chemicals such as 2,3Butanediol (2,3BDO) at high selectivity and yield. Since 2008, the company has been operating a 15,000 gallon per year waste-gas to ethanol facility in New Zealand and this year scaled its platform to a 100,000 gallons per year demo facility in Shanghai, China. LanzaTech is headquartered in Chicago, IL and has additional offices in New Zealand, China and India.

**LANZATECH PARTNERS**

**Private Equity:** LanzaTech has raised more than $100 million in private equity and debt financing. Investors include Khosla Ventures, Orang Venture Partners, KWI, Malaysian Life Sciences Capital Fund, Western Technology Investment, PETRONAS Technology Ventures Sdn Bhd, Dialog Group

**Strategic:** PETRONAS, INVISTA, Baosteel, Capital Steel, Virgin Atlantic


LanzaTech’s gas fermentation technology converts carbon containing gases produced by industries such as steel manufacturing and oil refining, as well as gases generated from forestry and agricultural residues, municipal waste, and coal, into valuable fuel and chemical products.

**PATH TO COMMERCIAL DEPLOYMENT**

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>Pilot Plant becomes operational in NZ</td>
</tr>
<tr>
<td>2009</td>
<td>First Plant operating at 15,000 gal/year capacity</td>
</tr>
<tr>
<td>2010</td>
<td>LanzaTech successfully produces 2,3-Butanediol in key biocatalytic block used to make polymers, plastics and hydrocarbon fuels</td>
</tr>
<tr>
<td>2011</td>
<td>Construction begins on Baosteel demonstration facility</td>
</tr>
<tr>
<td>2012</td>
<td>First Demo facility becomes operational</td>
</tr>
<tr>
<td>2013</td>
<td>Full Commercial scale plant to be constructed with Baosteel</td>
</tr>
<tr>
<td>2014</td>
<td>Production at Freedom Pines Commercial Biorefinery begins</td>
</tr>
<tr>
<td>2015</td>
<td>Second Commercial facility operating in China (Shougang)</td>
</tr>
</tbody>
</table>

LanzaTech’s gas fermentation technology converts carbon containing gases produced by industries such as steel manufacturing and oil refining, as well as gases generated from forestry and agricultural residues, municipal waste, and coal, into valuable fuel and chemical products.
Mascoma Corporation, founded in 2005, is a renewable fuels company that has developed an innovative, highly adaptable technology for the low-cost conversion of abundant biomass into cellulosic ethanol and renewable chemicals. Using its proprietary consolidated bioprocessing (CBP) technology platform, Mascoma has also developed bioengineered yeasts and other microorganisms to reduce costs and improve yields in the production of renewable fuels and chemicals. The company operates a demonstration facility in Rome, New York to evaluate new technologies and conduct large-scale process demonstration runs. Mascoma also operates a research and development laboratory in Lebanon, New Hampshire and maintains offices in Waltham, Massachusetts and Toronto, Canada.

**Mascoma Partners**

**Private Equity:** Raised $120MM in four rounds of financing (Khosla Ventures, Flagship Ventures, General Catalyst Partners, Kleiner Perkins Caufield & Byers, Pinnacle Ventures, VantagePoint Partners, Jeremy Grantham, Valero Energy Corporation, Marathon Petroleum Company, General Motors Ventures).

**Commercial:** Lallemand Inc., a global developer, producer and marketer of yeast, bacteria and related products, to commercialize the TransFerm yeast product, which is the first commercial application of Mascoma’s proprietary consolidated bioprocessing (CBP) technology platform.

**Public/Government:** Cooperative agreement with DOE for up to $80MM to assist in the design, construction and operation of a commercial-scale hardwood cellulosic ethanol facility in Kinnos, Michigan; $20MM in R&D assistance (DOE) for Kinnos, MI project; $20MM grant agreement with the Michigan Economic Development Corporation for Kinross, MI facility; $20MM grant agreement with the NY State Energy Research and Development Authority to assist building and operation of demonstration plant in Rome, New York.

**Demonstration Facility**

**Location:** Rome, NY
**Feedstock:** Multiple feedstock (biomass)
**Products:** Cellulosic ethanol, biochemicals
**Capacity:** 200,000 Gpy
**Plant Profile:** Ground breaking, December 2007; first fermentation, June 2008. Currently employs 15 operations staff. Completed 1,000 hour extended validation run using Mascoma’s hardwood CBP microorganisms.

**Commercial Project**

**Location:** Kinross, MI
**Status:** Final Engineering, Closing Financing
**Feedstock:** Wood pulp and chips
**Products:** Cellulosic ethanol
**Capacity:** 20 MGY
**Jobs:** 150 construction jobs; 60 permanent operations jobs, up to 500 indirect jobs according to State of Michigan
**Project Profile:** First-of-its-kind 20 million gallons per year cellulosic ethanol facility utilizing proprietary CBP technology, agreement in place for hardwood pulpwood feedstock to be sourced from Michigan counties located within a 150-mile radius area of the site.

**Path to Commercial Deployment**

- 2008
  - 1st gallon of cellulosic ethanol produced at Rome, NY demonstration facility
  - Initiated complete cellulosic ethanol process validation runs at Rome, NY demonstration facility
  - AWARD: Awarded $20MM grant from Michigan Economic Development Corporation (MEDC) for Kinnos, MI project
  - AWARD: $20MM grant from DOE for construction of an industrial scale fermentation system and development of integrated cellulosic ethanol plant
  - Acquired SunOpta Biosystems, a company that provides pretreatment equipment and process solutions for biomass conversion
  - Awarded up to $80MM in funding from DOE to assist in development of a commercial-scale cellulosic ethanol facility in Kinnos, MI
  - Demonstrated $2.00/gallon cash operating cost and hardwood to ethanol conversion yield of 71 gallons per bone dry ton at NY demonstration facility
  - Received contract bids for Kinross, MI facility and conducted final engineering design work
  - Ground breaking at Kinnos, MI commercial facility
  - Ground breaking at 2nd commercial-scale cellulosic ethanol facility in Drayton Valley, Alberta
  - Target: 2013/14 timeframe

- 2015
  - Construction completed, first gallons produced at Kinross, MI commercial facility
  - Construction completed, first gallons produced at Alberta commercial facility
  - Target: 2015/16 timeframe
COMPANY PROFILE

POET-DSM Advanced Biofuels, LLC is a 50/50 joint venture between Royal DSM and POET, LLC. Based in Sioux Falls, SD, the joint venture utilizes a proprietary technology to convert corn crop residue into cellulosic bio-ethanol. POET-DSM’s first commercial-scale plant, dubbed Project LIBERTY, will produce 20 MGY of cellulosic bio-ethanol. Based on this plant the JV plans to license globally an integrated technology package for the conversion of corn crop residue to cellulosic bio-ethanol.

POET-DSM PARTNERS

Strategic: JV between DSM (enzymes and yeast) POET (process, feedstock procurement). Each party to contribute ~ 50% of the value to the JV. DSM will contribute $150MM in equity and debt financing. POET will contribute the existing Project LIBERTY, including secured grants from the U.S. Department of Energy and the State of Iowa.

Public/Government: $100MM in grants from U.S Department of Energy; $14.8MM grant from State of Iowa for biorefinery construction, engineering and feedstock acceleration activities; $5.25MM in credits from State of Iowa for tax and training.

PROJECT LIBERTY

LOCATION: Scotland, SD
FEEDSTOCK: Corn Crop Residue
PROJECTS: Ethanol, Biogas
CAPACITY: 30,000 GPY

PLANT PROFILE: POET’s pilot/demo cellulosic ethanol plant has been crucial to improving the process for commercial-scale production. Preliminary harvests by Iowa farmers are helping solidify the feedstock pipeline for Project LIBERTY.

BEGAN OPERATIONS 2008

PATH TO COMMERCIAL DEPLOYMENT


POET pilot plant becomes operational, second round of biomass harvested testing
DSM starts extensive enzyme development program for cellulosic ethanol
Significant cost reductions at pilot facility, 12,000 acres of biomass harvested
Commercial biomass stackyard completed. First commercial biomass harvest (56,000 tons)
DSM identifies enzyme system effective at breaking down lignin-cellulose to component sugars at increased thermal stability
Site work started on commercial-scale biorefinery
Second commercial biomass harvest (40,000 tons)
DSM acquires C5 Yeast Company from NovoBioscience
Joint venture formed with Royal DSM
Third commercial biomass harvest (50,000 tons)
Anticipated completion of construction at commercial-scale facility
Validate technology at commercial scale
Validate technology at commercial scale

COMMERCIAL FACILITY

LOCATION: Emmetsburg, IA
STATUS: Under Construction
FEEDSTOCK: Corn Crop Residue
PROJECTS: Ethanol, Biogas
CAPACITY: 20 MGY, later growing to 25 MGY
JOBS: 37 biorefinery jobs, 309 direct construction jobs

PROJECT PROFILE: Located adjacent to current POET grain ethanol plant; 22-acre biomass storage site is complete, biorefinery construction underway with anticipated completion in 4Q 2013; continuing to ramp-up farmer contracts for biomass harvesting forecast goal of 285,000 tons per year.
COMPANY PROFILE
Incorporated in 2002, ZeaChem Inc. is headquartered in Lakewood, Colorado. The company operates a research and development laboratory facility in Menlo Park, California, and a 250,000 gallon per year demonstration biorefinery in Boardman, Oregon. ZeaChem has developed a cellulose-based biorefinery platform capable of producing advanced biofuels and bio-chemicals.

DEMONSTRATION FACILITY
LOCATION: Boardman, OR
FEEDSTOCK: Poplar Trees, Wheat Straw
PRODUCTS: Cellulosic Ethanol, Bio-Chemicals
CAPACITY: 250,000 GPy
PLANT PROFILE: Construction completed on schedule and significantly under budget; created 50 construction jobs and employs 35 full-time operations staff in the region. Phase 1: high-value bio-chemicals for paints and lacquers. Phase 2: cellulosic ethanol and bio-chemicals by YE12. Phase 3: cellulosic jet and diesel (’13).

ZEAChem Partners
Strategic: Chrysler Group LLC (fuels), P&G (bio-chemicals).
Government/Public: $25MM (DOE) cooperative agreement to support construction of demonstration facility; $40MM (USDA) cooperative agreement with Univ. of Washington and others to expand the demo plant for bio-based jet and diesel production; $17MM Biomass Crop Assistance Program (BCAP) grant from the USDA to GreenWood Resources, ZeaChem’s primary feedstock supplier to establish and maintain 7,000 acres of intercropped poplar trees for the demo and 1st commercial facilities; $232.5MM (USDA) conditional loan guarantee to support the financing of the 1st commercial plant.

PATH TO COMMERCIAL DEPLOYMENT
Raised $34MM Series B
Selected as one of 19 advanced biotech projects for USDA Integrated Bioenergy Cooperative Agreement ($25MM)
Proved technology at pilot scale
Established partnerships with Chrysler and P&G
Begun operations at demonstration biorefinery, cellulosic ethanol production by YE12
Selected for USDA conditional loan guarantee for 1st commercial plant
Estimated start of production of cellulosic jet and diesel fuel at demo scale
Anticipated start of construction on 1st commercial biorefinery
Anticipated start of production at 1st commercial biorefinery

ZeacHem Commercial Facility Site
COMMERCIAL FACILITY
LOCATION: Boardman, OR
STATUS: USDA Conditional Loan Guarantee Awarded
FEEDSTOCK: Poplar Trees, Wheat Straw
PRODUCTS: Cellulosic Ethanol, Bio-Chemicals
CAPACITY: 25+ MGy
JOBS: 200 direct construction jobs; 65 full-time operations jobs; 250 indirect jobs for construction and full-time operations
PLANT PROFILE: Located adjacent to ZeaChem’s demo plant; agreements in place for 100% of the required feedstock from GreenWood Resources and local agricultural residue processors.

ZeaChem utilizes a hybrid process of biochemical and thermochemical processing that preserves the best of both approaches from yield and economic perspectives.