



POET-DSM's Project LIBERTY in Emmetsburg, Iowa, celebrated its grand opening on September 3, 2014. Cost-shared funding from the Bioenergy Technologies Office contributed to the construction of this pioneer-scale plant, which will produce 25 million gallons of cellulosic ethanol per year—enough to avoid approximately 210,000 tons of CO₂ emissions annually. *Photo: POET*

Integrated Biorefineries: Reducing Investment Risk in Novel Technologies

Achieving national energy and climate goals will require a large, economically viable, and environmentally sustainable U.S. bioeconomy. The U.S. goal to build a diverse, robust, and resilient energy sector creates an urgent need to bridge the gap between promising research and pioneering large-scale production of advanced biofuels.

Developing the U.S. bioeconomy requires building many integrated biorefineries capable of converting a broad range of biomass feedstocks into affordable biofuels, bioproducts, and biopower. Integrated biorefineries are similar to conventional refineries in that they produce a range of products to optimize production economics and the use of feedstocks. The novel technologies needed to operate biorefineries require significant investments in research, development, demonstration, and deployment to reduce costs to a level competitive with fossil fuels.

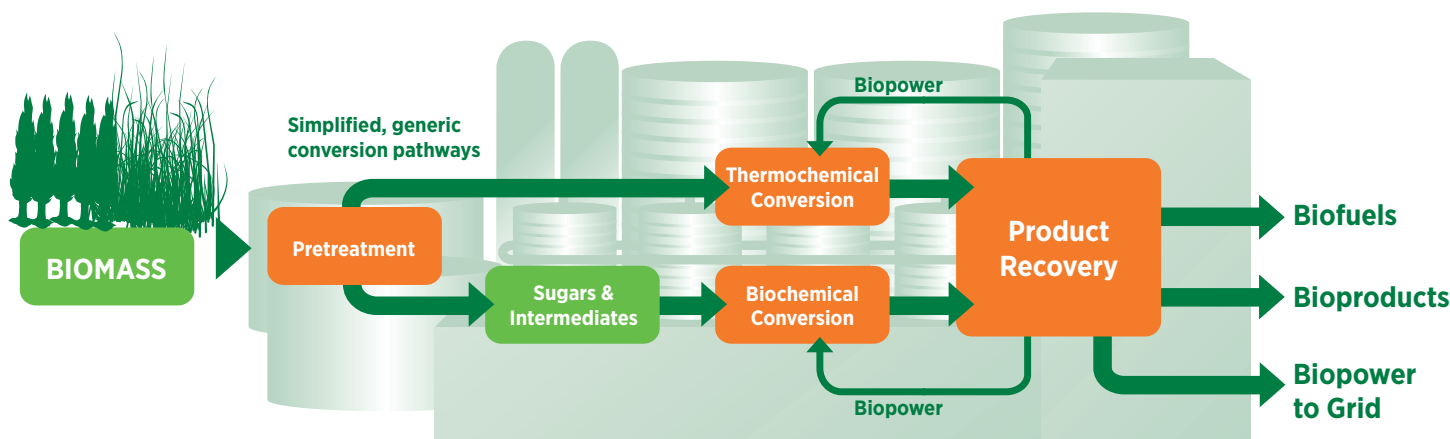
The U.S. Department of Energy's Bioenergy Technologies Office works in partnership with industry to develop, build, and operate integrated biorefineries at various scales (pilot, demonstration, and pioneer). These projects are located around the country and use a range of non-food feedstocks and conversion technologies.

Federal support for these first-of-a-kind, integrated biorefineries is necessary to validate their performance and significantly reduce the technical and financial risks associated with new technology deployment. These investments support the goals of the President's Climate Action Plan and the national "all-of-the-above" strategy to develop diverse domestic energy sources—reducing costs to consumers, improving energy security, and maintaining our economic vitality.

"The Energy Department's investments in projects like the LIBERTY biorefinery are helping to bring innovative, cost-cutting biofuel technologies online and diversify our transportation fueling options."

– Energy Secretary Ernest Moniz
on the start of production at the Project LIBERTY facility,
September 2014

Typical Conversion Pathways in Biorefineries



Researchers are exploring and improving a variety of conversion technologies to increase the efficiency and lower the cost of producing sustainable biofuels from diverse biomass feedstocks.

Key Challenges:

There are currently a number of technical and non-technical barriers to the large-scale implementation of highly efficient integrated biorefinery facilities.

- **Financing New Technologies:** In order to reduce technical risks, government financial assistance in projects aimed at proving performance at the pilot, demonstration, and pioneer scales can be a key enabler.
- **End-to-End Process Integration:** The biorefinery concept encompasses a wide range of technical issues related to collecting, storing, transporting, and processing diverse feedstocks, as well as addressing the complexity of integrating new and adapted process steps not yet demonstrated at scale.
- **Risk of First-of-a-Kind Technology:** The number and complexity of new process steps implemented in pilot- and demonstration-scale projects have been shown to be strong predictors of future commercial performance shortfalls.
- **Inadequate Supply Chain Infrastructure:** Feedstock variability and lack of feedstock infrastructure increases the uncertainty associated with a sustainable feedstock supply chain.
- **Offtake Agreements:** Many financial institutions need to balance the large capital expenses and long payback periods of biorefineries with certainty about future production levels and market demand. The inability of many biorefineries to arrange long-term contracts for product offtake increases the

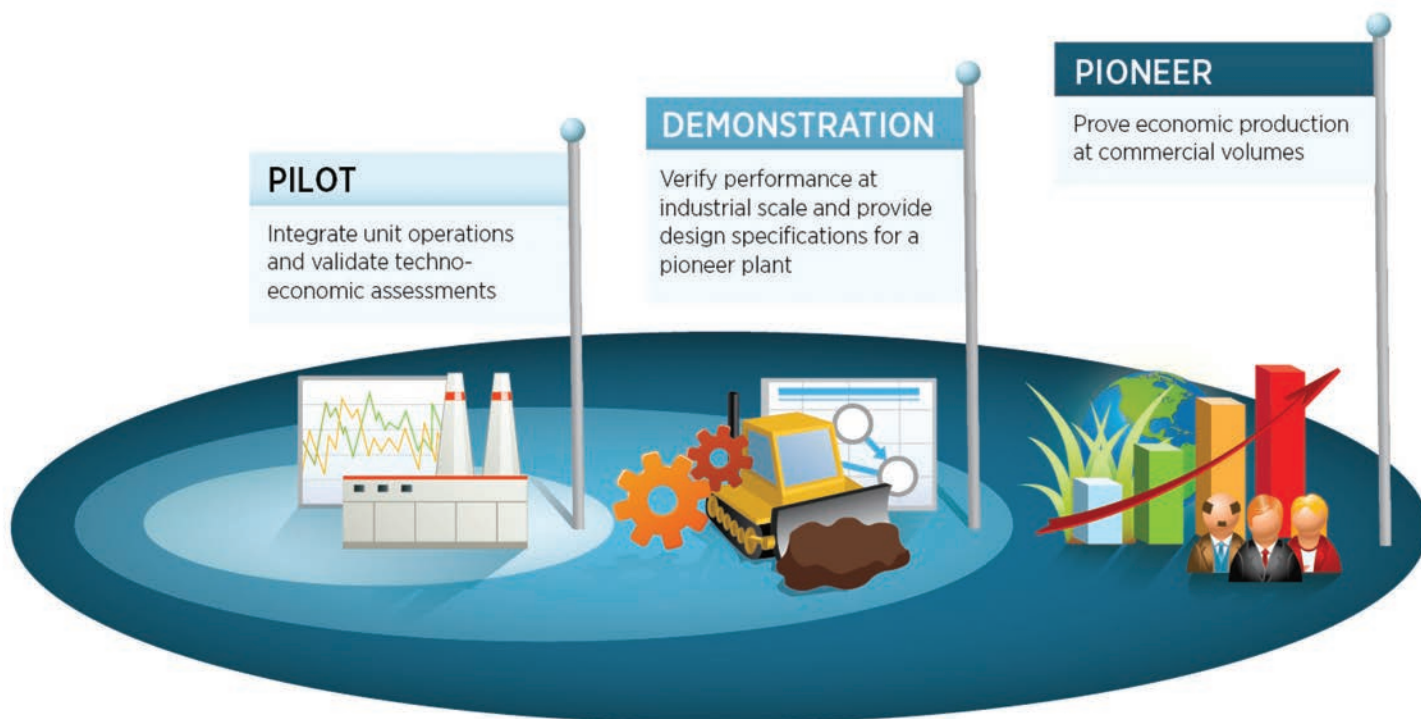
financial risk and may discourage decision makers in financial institutions from providing financing for biorefineries.

- **Codes, Standards, and Approval for Use:** New biofuels and biofuel blends must comply with federal, state, and regional regulations before introduction to the market.
- **Lack of Acceptance and Awareness of Biofuels:** Industry partners and consumers must believe in the quality, value, sustainability, and safety of biomass-derived products and their benefits relative to the risks and uncertainties that widespread changes will likely bring.



The Energy Department provides cost sharing for pioneer biorefinery projects to help validate novel conversion processes and reduce the technical and financial risks to future investors. *Photo: Abengoa*

Progressive Scales of Deployment Projects



The Bioenergy Technologies Office provides cost-shared funding to industry partners to demonstrate promising conversion technologies and systems at progressive scales. Each scale builds upon the results of the prior stage.

Integrated Biorefinery Deployment Activities:

The Bioenergy Technologies Office works through cost-shared public-private partnerships to address critical challenges in the deployment of integrated biorefineries. These biorefinery projects prove the viability of various feedstock and conversion pathways, typically following a progression from pilot through pioneer scale. Each step in this progression helps validate production performance, paving the way for commercial readiness.

- **Design Scale:** These projects perform R&D to demonstrate integrated processes at bench scale which reduces risk in scaling technologies to pilot scale.
- **Pilot Projects:** These facilities verify the integrated technical performance of the given suite of technologies from feedstock in through product out at production capacities equal to

or greater than one dry ton of feedstock per day.

- **Demonstration Projects:** Demonstration-scale facilities verify performance at a scale sufficient to provide data and equipment specifications required to design a pioneer-scale facility. Demonstration facilities, typically between one-fiftieth and one-tenth of the pioneer scale, prove all recycle streams and heat integration for more than 1,000 hours of operations.
- **Pioneer Projects:** These “first-of-a-kind” facilities prove economical production at commercial volumes on a continuous basis with a reliable feedstock supply and production distribution system, and verify environmental and social sustainability performance.



Pioneer-scale biorefineries face many challenges in scaling up and integrating innovative technologies into profitable production systems.
Photo: POET

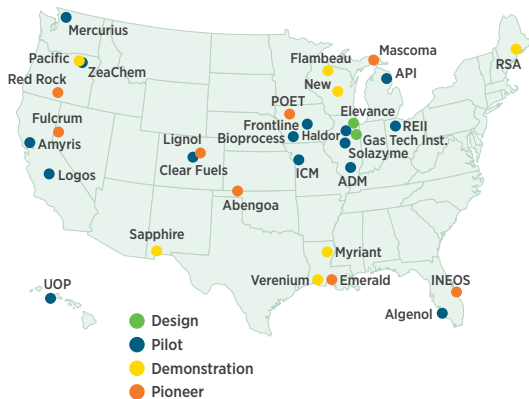


Novel technologies to increase the efficiency and lower the cost of biomass conversion are validated at the pilot and demonstration scale.
Photo: INEOS

Geographic Diversity

Strategically locating biorefinery projects in different areas of the country promotes local and regional economic development and leads to conversion technologies optimized for the biomass feedstocks in each region. Geographic diversity will also provide many areas of the nation with access to a domestic renewable energy supply as the private sector gains confidence in the technologies and scales up investment in new integrated biorefineries.

Integrated Biorefinery Project Locations



For the latest project information and details, please visit our website at <http://energy.gov/eere/bioenergy/integrated-biorefineries>.

Project	Location	Scale	Conversion Technology
Abengoa Bioenergy	Hugoton, KS	Pioneer	Biochemical
Emerald Biofuels	Plaquemine, LA	Pioneer	Thermo-HEFA
Fulcrum Bioenergy	McCarran, NV	Pioneer	Thermo - Gasification
INEOS Bio/New Planet Bioenergy	Vero Beach, FL	Pioneer	Hybrid
Mascoma	Kinross, MI	Pioneer	Biochemical
POET Project LIBERTY, LLC	Emmetsburg, IA	Pioneer	Biochemical
Red Rock Biofuels	Lakeview, OR	Pioneer	Thermo - Gasification
Flambeau River Biofuels, LLC	Park Falls, WI	Demo	Thermo - Gasification
Lignol Innovations, Inc.	Commerce City, CO	Demo	Biochemical
Myriant	Lake Providence, LA	Demo	Biochemical
NewPage	Wisconsin Rapids, WI	Demo	Thermo - Gasification
Pacific Biogasol	Boardman, OR	Demo	Biochemical
Red Shield Acquisition, LLC (RSA)	Old Town, ME	Demo	Biochemical
Sapphire Energy, Inc.	Columbus, NM	Demo	Algae
Verenium	Jennings, LA	Demo	Biochemical
Algenol	Fort Myers, FL	Pilot	Algae
American Process, Inc. (API)	Alpena, MI	Pilot	Biochemical
Amyris, Inc.	Emeryville, CA	Pilot	Biochemical
Archer Daniels Midland (ADM)	Decatur, IL	Pilot	Biochemical
BioProcess Algae	Shenandoah, IA	Pilot	Algae
Frontline	Ames, IA	Pilot	Thermo - Gasification
Haldor Topsoe	Des Plaines, IL	Pilot	Thermo - Gasification
ICM	St. Joseph, MO	Pilot	Biochemical
Logos/EdenIQ Technologies	Visalia, CA	Pilot	Biochemical
Mercurius	Ferndale, WA	Pilot	Hybrid
Renewable Energy Institute International (REII)	Toledo, OH	Pilot	Thermo - Gasification
Rentech ClearFuels	Commerce City, CO	Pilot	Thermo - Gasification
Solazyme	Peoria, IL	Pilot	Algae
UOP, LLC	Kapolei, HI	Pilot	Thermo - Pyrolysis
Zechem, Inc.	Boardman, OR	Pilot	Thermo - Pyrolysis
Elevance	Bolingbrook, IL	Design	Hybrid
Gas Technology Inst.	Des Plaines, IL	Design	Thermo - Pyrolysis