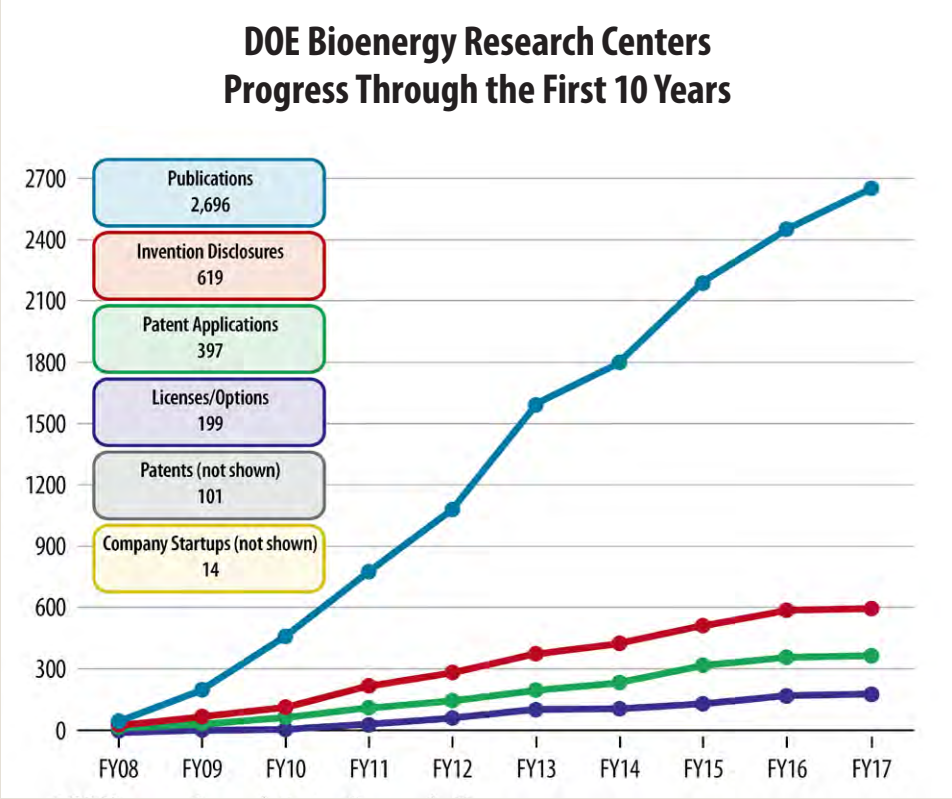
U.S. Department of Energy Bioenergy Research Centers

Developing the science, technology, and knowledgebase necessary to enable sustainable, cost-effective production of advanced biofuels and bioproducts from nonfood plant biomass in support of a new biobased economy

Multiple societal benefits underlie U.S. Department of Energy (DOE) research efforts to support a viable and sustainable domestic nonfood lignocellulosic plant biomass biofuel and bioproducts industry. These benefits include ensuring future energy security, lowering greenhouse gases to mitigate climate impacts, diversifying the range of available biobased products, producing fewer toxic chemicals and byproducts, creating jobs in rural areas, and improving the trade balance.



The resistance of lignocellulose to degradation (called recalcitrance) and lack of efficient methods to convert it to useful products are major impediments to the cost-effective production of fuels and chemicals from plant biomass. Innovation stemming from advanced biotechnology-based research is key to accelerating needed improvements in the sustainable production of lignocellulosic biomass, its deconstruction into sugars and lignin coproducts, and conversion to biofuels beyond ethanol (i.e., advanced biofuels) and bioproducts.

Over 10 years (2007–2017), three Bioenergy Research Centers (BRCs), supported by the Genomic Science program within DOE's Office of Science Office of Biological and Environmental Research (BER), made significant advances toward this new biobased economy. They produced multiple breakthroughs in the form of deepened understanding of sustainable biomass production practices, targeted reengineering of biomass feedstocks, development of new methods for deconstructing feedstocks, and engineering of microbes for more effective production of a diverse range of biofuels.

In all, the BRCs produced 2,696 peer-reviewed publications, 619 invention disclosures, 397 patent applications, 199 licenses or options, 101 patents, and 14 company startups (see figure above, DOE BRCs, Progress Through the First 10 Years). Through this work, they transferred substantial insight and expertise to industry through cooperation with both large and small companies.

From Cellulosic Ethanol to Advanced Biofuels and Bioproducts

These successes are being leveraged in the next phase of DOE bioenergy research and expanded from a focus on ethanol and advanced biofuels to include the development

DOE Bioenergy Research Centers Address Key Science Themes

	Sustainability	Feedstock Development	Deconstruction and Separation	Conversion
CABBI Center for Advanced Bioenergy and Bioproducts Innovation	Integrate economic and environmental analyses for biomass supply.	Develop "plants as factories" concept for biofuels and bioproducts.	Develop product separation technologies for *in planta* production.	Establish automated biofoundry concept for fuels and bioproducts.
cbi The Center for Bioenergy Innovation	Optimize water and nutrient use in dedicated bioenergy crops.	Create multiomics tools for developing high-yield bioenergy crops.	Advance integrated and consolidated thermophilic bioprocessing.	Generate drop-in biofuels and bioproducts from biomass and lignin residues.
Great Lakes Bioenergy Research Center	Conduct long-term studies of producing bioenergy crops on marginal land.	Design improved dedicated bioenergy crops.	Develop renewable biomass deconstruction and separation strategies.	Develop novel biomass conversion microbes.
JBEI Joint BioEnergy Institute	Study environmental resilience of engineered bioenergy crops.	Engineer plants for atom-economical conversion into biofuels and bioproducts.	Develop feedstock agnostic biomass deconstruction processes using renewable ionic liquids.	Develop high-throughput synthetic biology tools and hosts for scalable, atom-economical biofuels and bioproducts.

of bioproducts. These bioproducts are nonpharmaceutical chemicals that directly replace or substitute for chemicals currently derived from petroleum or natural gas. They also may be novel chemicals that cannot be efficiently produced from petroleum.

In this research endeavor, there are four BRCs based in the geographically diverse East, Midwest, Southeast, and West Coast regions. BRC partners include universities, private companies, nonprofit organizations, and DOE national laboratories. The four BRCs take distinctive approaches toward the common goal of accelerating the pathway to improving and scaling up advanced biofuel and bioproduct production processes.

- **Center for Advanced Bioenergy and Bioproducts Innovation** (CABBI; University of Illinois at Urbana-Champaign; cabbi.bio) seeks to enable the production of fuels and chemicals directly in plants as sustainable biofactories for a range of bioproducts.
- **Center for Bioenergy Innovation** (CBI; Oak Ridge National Laboratory; cbi.ornl.gov) is accelerating the domestication of sustainable bioenergy crops and targeted consolidated bioprocessing innovations to improve cost efficiencies within the bioenergy supply chain.
- **Great Lakes Bioenergy Research Center** (GLBRC; University of Wisconsin-Madison; glbrc.org) aims to develop the science and technological advances to ensure sustainability at each step in the process of creating biofuels and bioproducts from lignocellulose.
- **Joint BioEnergy Institute** (JBEI; Lawrence Berkeley National Laboratory; jbei.org) is broadening and maximizing production of economically viable fuels and chemicals from plant biomass to enable biorefinery development.

Remaining basic science challenges that continue to limit the cost-effective conversion of plant biomass to advanced biofuels and bioproducts fall into four scientific focus areas: (1) sustainability, (2) feedstock development, (3) lignocellulosic deconstruction and separation, and (4) conversion to advanced biofuels and bioproducts (see figure above, DOE BRCs Address Key Science Themes).

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