



The Biobased Economy: Measuring Growth and Impacts

- **Industrial biotechnology empowers the biobased economy, enhances a broad variety of industries and creates potential for new products.**
- **The biobased economy is poised for accelerated growth, with an abundance of cost-competitive feedstocks, commercial success of pioneer products, and ongoing investment in innovative research.**
- **The United States could capture a fair share of projected worldwide growth of the biobased economy with effective state and federal policy support.**

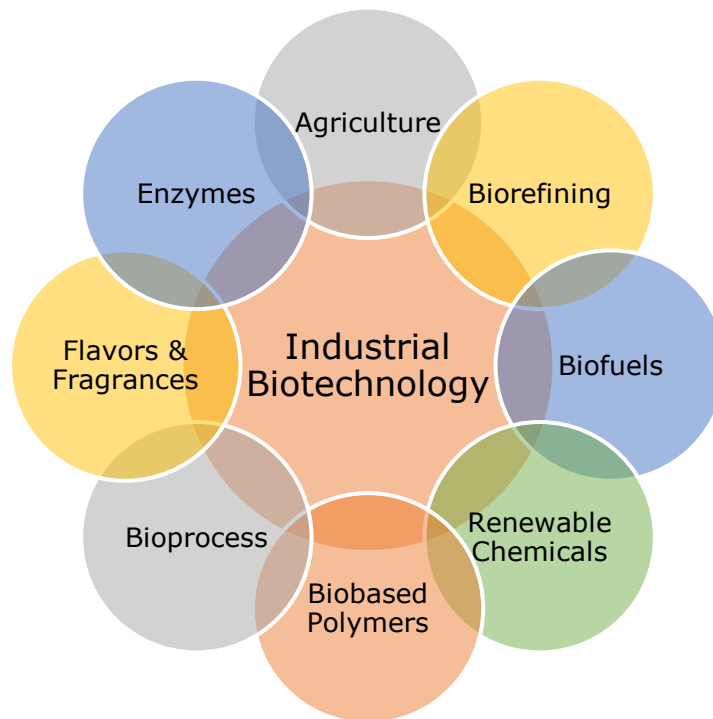
By utilizing the power of industrial biotechnology companies around the globe are creating a robust biobased economy. In the biobased economy, companies use microbial systems, fermentation and other clean tech methods to manufacture sustainable products from agricultural biomass, municipal waste and other low-carbon feedstocks. Biobased production encompasses a value chain from agriculture through the manufacture of consumer goods that provides an alternative to petroleum's value chain and brings environmental, economic and other benefits. The biobased economy can generate new markets for agricultural producers, boost innovation in domestic manufacturing, and stimulate sustainable economic growth. The biobased economy and industrial biotechnology are poised for accelerated growth in the 21st century; federal and state policies can unleash this growth by identifying and supporting all segments of the value chain.

Industrial biotechnology – which is at the center of the biobased economy, as shown in Figure 1 below – generates economic opportunity, investment and employment in:

- agriculture, especially through the development of new crops and new uses for crop residues and waste;

- biorefining of food and feed ingredients for the grocery manufacturing industry;
- biofuel production;
- renewable chemical and biobased polymer production, which impacts cosmetics, textiles, personal care and other consumer product sectors;
- bioprocesses used in pharmaceutical and other manufacturing;
- nutritional ingredients as well as flavors and fragrances; and
- enzymes, which are used in household cleaners, laundry detergents, and food processing.

Figure 1: The Biobased Economy



Industrial biotechnology is sometimes viewed as a subset of the petrochemical industry, since industrial biotech processes are more sustainable and can be paired with or replace traditional chemical processes in the production of a final product. But industrial biotechnology impacts many different industries and creates potential for new products and materials that are not possible or cost-efficient with traditional chemistry.



An increasing number of studies and market analyses measure the economic impact of the industrial biotechnology sector and the biobased economy. Rob Carlson of Biodesic, Inc., estimates that the industrial biotechnology sector generated more than \$105 billion in direct revenue in 2012.¹ Carlson draws his estimate from a review of the total revenue for the biofuels, renewable chemicals, enzymes and biobased polymers industries, controlling for the costs of the non-biotech sectors. He also notes that the overall economic impact from this direct revenue is likely to be 10 to 15 percent larger.

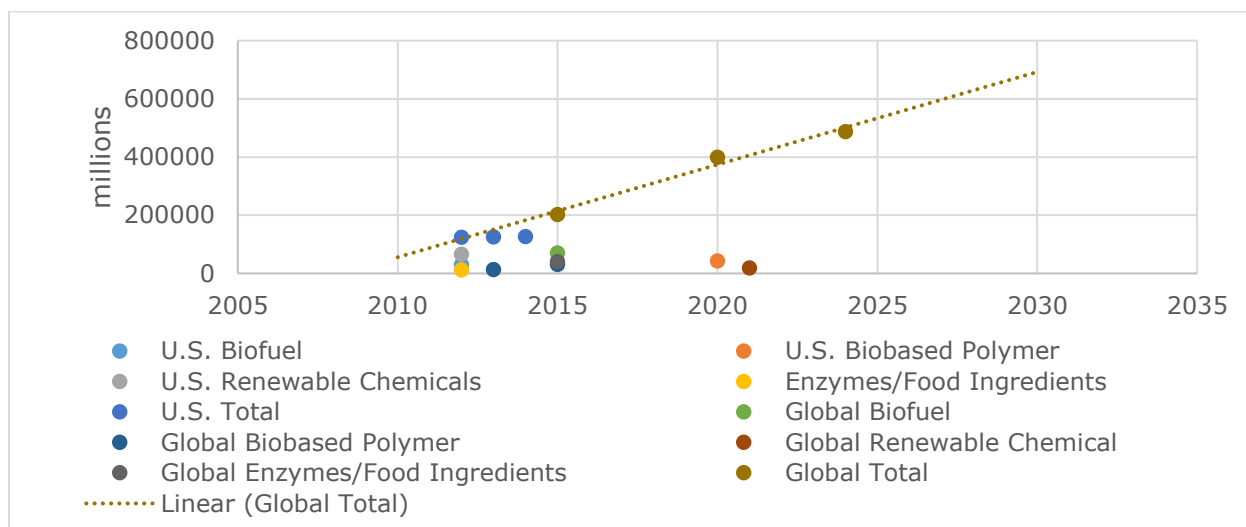
USDA's BioPreferred® Program commissioned a report to Congress and a follow up study of the economic impact associated with the roughly 20,000 biobased products recognized by the program. The analyses include agriculture and forest products that are not directly impacted by industrial biotechnology, but exclude biofuels, food ingredients and bioprocess applications that are not part of the program. The resulting studies found that between 2013 and 2014, the industry's direct revenue grew from \$125.75 billion to \$127 billion. The total economic impact of U.S. biobased production grew from \$369 billion to \$393 billion.² Because biofuels and food ingredients are excluded, the economic impact of the entire industrial biotechnology sector is significantly larger.

Figure 2 below maps a selection of projections and estimates of the economic impact of industrial biotechnology from industry analysts and market watchers. While each study may include or exclude different parts of the biobased economy, all analysts agree that the overall global industry and the various subsectors – biofuels, renewable chemicals, enzymes and biobased polymers – are poised for accelerated growth during the first half of the 21st century.

¹ Carlson, R. Estimating the biotech sector's contribution to the US economy. *Nature Biotechnology*, 34, 247–255, (2016). doi:10.1038/nbt.3491.

² Golden, J.S., Handfield, R.B., Daystar, J., and McConnell, T.E. *An Economic Impact Analysis of the U.S. Biobased Products Industry*. Washington, DC: USDA BioPreferred Program, 2016.

Figure 2: Biobased Economy and Sector Projections



Worldwide production of biobased products – including biofuels, renewable chemicals, and biobased polymers – is projected to grow from approximately \$203.3 billion in 2015 to \$400 billion by 2020 and \$487 billion by 2024.³ The United States is well-positioned to capture a large share of that projected growth, due to investments made today in first-of-a-kind production capacity, innovative research and development, as well as employment and training of U.S. workers.

Similar to assessments of the chemical industry, projections of future growth in industrial biotechnology and biobased manufacturing are built on the abundance and favorable costs of renewable feedstocks, the successful commercialization of pioneer products, and new investments in production capacity. In contrast to traditional industries, though, expectations for industrial biotechnology’s future potential are heightened by the exponential growth in discovery of biological processes. The intensifying pace of research and development in biotechnology, new developments in synthetic biology and gene editing, and recent experience in

³ Grand View Research. “White Biotechnology Market Analysis By Product (Biofuels, Biomaterials, Biochemicals, Industrial Enzymes), By Application (Bioenergy, Food & Feed Additives, Pharmaceutical ingredients, Personal Care & Household Products) And Segment Forecasts To 2024.” San Francisco: October, 2016. McKinsey & Co. “Bio-based chemicals are gradually gaining their share of the global chemicals market.” Boston: Feb. 2016.



engineering commercial scale industrial biotech processes augment projections for accelerated economic growth in the field.

Between 2010 and 2015, investors pumped nearly \$9.2 billion into the industrial

biotechnology sector, primarily in renewable chemicals and biobased polymers. The funding came from a variety of sources, including private equity and some public investment. But the majority of the investment and financing – \$5.3 billion (57 percent) – came from venture capital.⁴ Venture capital investments primarily target research and development of new technologies, and synthetic biology startups have garnered the largest share in recent years.

Another significant source of investment came from partnerships and private equity investments to launch new commercial-scale industrial biotech processes. BioAmber is operating a commercial scale facility in Sarnia, Ontario, Canada to produce biobased succinic acid, which is a building block for polyesters used in fabrics. Myriant is operating a similar facility in Louisiana. Green Biologics has started production in Minnesota of n-butanol, which is a solvent used in many consumer product. Novamont is producing biodegradable plastics at scale in Italy. New partnerships include Genomatica's with BASF to produce butanediol, which can be used in polyesters and cosmetics; Avantium's with Coca-Cola to produce polyethylene furoanate for plastic drink bottles; and Novvi's with Chevron to produce biobased lubricants for automotive applications.⁵ The commercial success of pioneer renewable chemical producers encouraged these additional equity investments.

Continued growth of the biobased economy will benefit rural America by creating new markets for biomass. The U.S. farm sector continues to increase crop productivity – achieving higher yields with relatively fewer inputs – even as crop

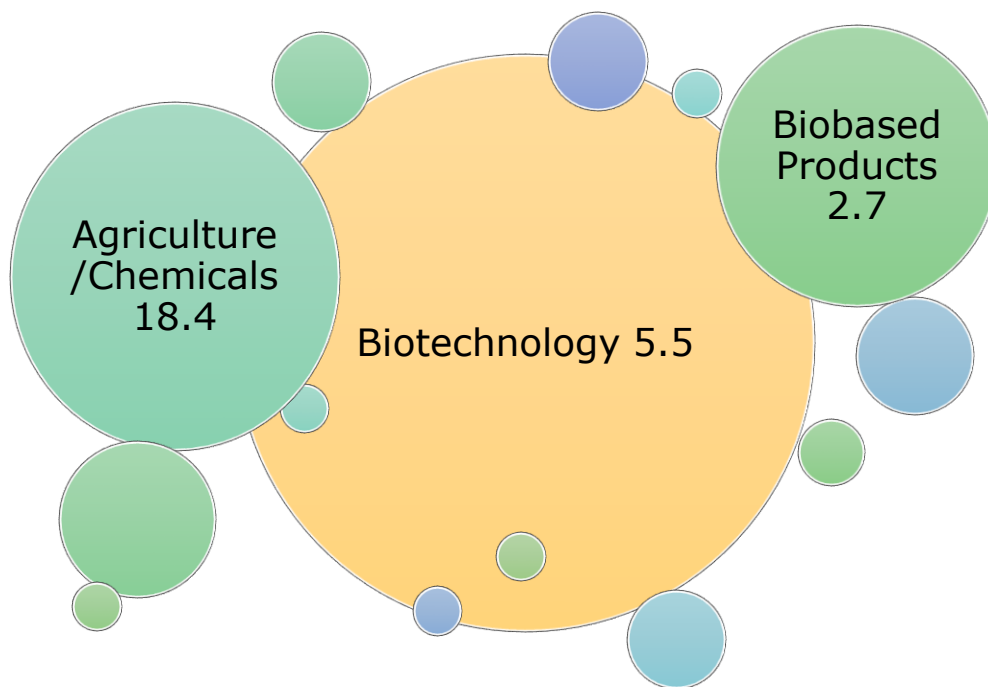
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⁴ Oh, V. "Show Me the Money: Where is Venture Capital Placing Bets in Bio-based?" Boston: Lux Research, Dec. 5, 2016.

⁵ Molchanov, P. "Clean Tech Primer 2017." St. Petersburg, FL: Raymond James & Assc. January 2017.

prices decline. The U.S. Department of Energy has conducted regular analyses of agricultural, forestry, waste, and algal biomass, determining that there is a cost-competitive supply sufficient to displace 30 percent of U.S. petroleum consumption.⁶ The abundance of price advantaged feedstocks makes the biobased product sector an attractive investment opportunity. It can also help to support farm sector earnings, which have been falling with lower commodity prices.⁷

Figure 3: Job Multipliers for Various Sectors of Industrial Biotechnology



In addition to added value for farm production, the biobased economy can generate spillover employment opportunities in engineering, construction and transportation. According to the USDA BioPreferred[®] Program report mentioned above, there are

⁶ U.S. Department of Energy. 2016. 2016 Billion-Ton Report: Advancing Domestic Resources for a Thriving Bioeconomy, Volume 1: Economic Availability of Feedstocks. M. H. Langholtz, B. J. Stokes, and L. M. Eaton (Leads), ORNL/TM-2016/160. Oak Ridge National Laboratory, Oak Ridge, TN. 448p. doi: 10.2172/1271651.

⁷ USDA Economic Research Service. 2017 Farm Sector Income Forecast. Feb. 9, 2017. <https://www.ers.usda.gov/topics/farm-economy/farm-sector-income-finances/farm-sector-income-forecast/>.



1.53 million U.S. workers directly employed in the biobased product industry as of 2014. The industry also creates employment in other industries, such as transportation and feedstock supply, as illustrated in Figure 3. Every direct job in the biobased product industry creates 1.76 jobs in other industries. In a separate study specifically of the biotech industry, TEconomy calculates that every direct bioscience industry job creates 5.5 additional jobs elsewhere in the economy. For workers in the agricultural feedstock and chemicals sector of the biotech industry, which includes biofuel producers, the multiplier is as high as 18.4 additional jobs for every direct job.⁸

The biobased economy is poised for ongoing growth, building on the success of pioneering commercial-scale industrial biotech projects. The potential for growth has attracted billions in venture capital, strategic investments and partnerships. The United States is well-positioned – with abundant biomass resources and innovative research and development in industrial biotechnology – to capture a favorable share of future biobased economy growth and employment. Effective state and federal policy is needed to unleash continued investment and growth.

Among the most important federal policies supporting the biobased economy are those in the Farm Bill's Energy Title. Since 2002, the quinquennial Farm Bill has included energy programs that have effectively supported development of new markets for agriculture and capital formation for rural communities. As Congress members begin work on the next Farm Bill, they should strengthen these effective programs and provide mandatory funding. The BioPreferred® program, as mentioned, has helped the U.S. agriculture sector generate \$393 billion in economic activity and 4.22 million jobs. The Biorefinery, Renewable Chemical, and Biobased Product Manufacturing Assistance Program ensures that institutional lenders serving rural communities have sufficient capital to back large-scale biorefineries. This program will enable banks to join the venture capital and equity investments in industrial biotechnology and renewable chemical production, which will revitalize

⁸ TEconomy/BIO. The Value of Bioscience Innovation in Growing Jobs and Improving Quality of Life. Washington, DC: Biotechnology Innovation Organization, 2016.



U.S. manufacturing, create jobs and improve U.S. economic competitiveness. Congress should create a clear path forward for Farm Bill energy programs to enable U.S. technology producers to unleash innovation and ensure rural communities share in economic growth.