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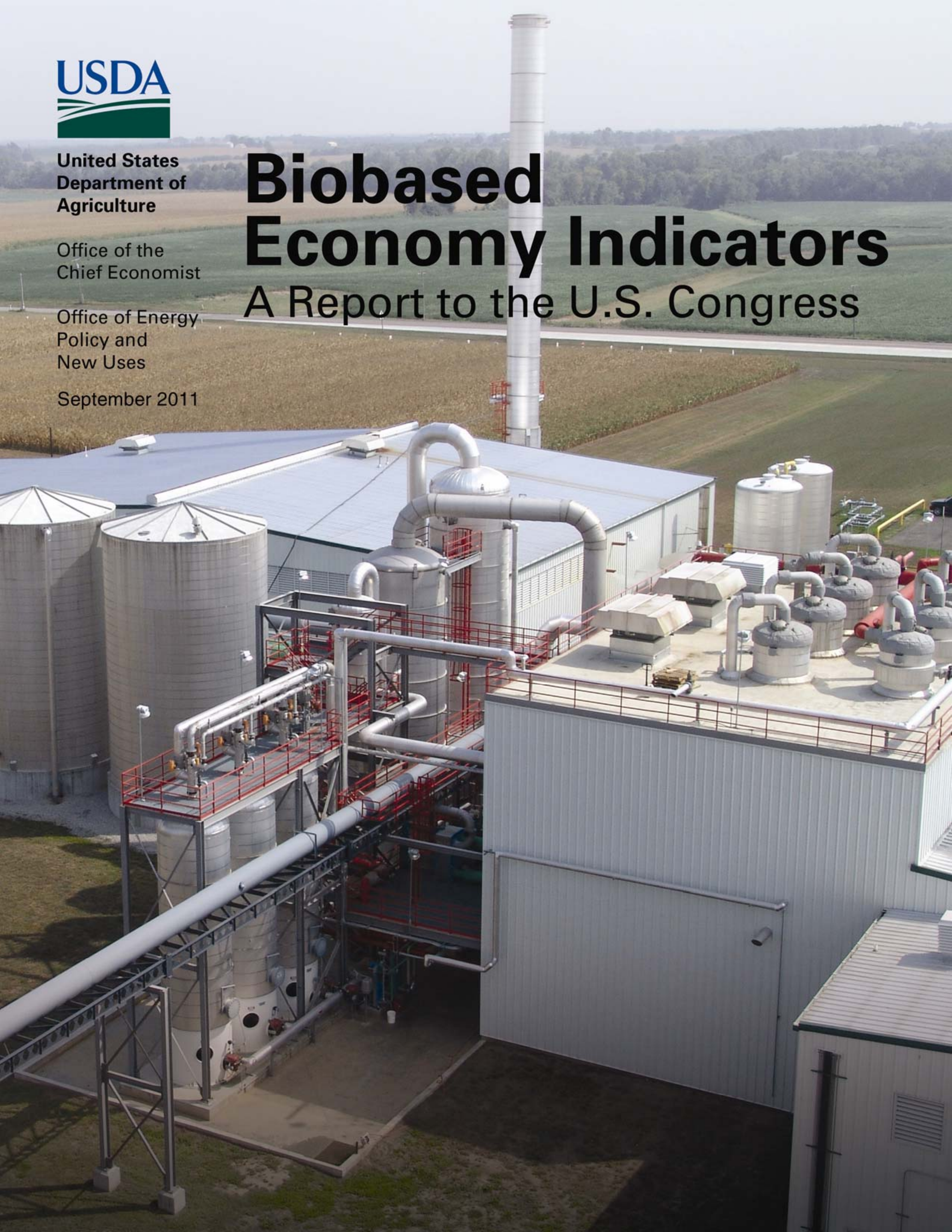
Biobased Economy Indicators

A Report to the U.S. Congress



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Abstract

Section 948 of the Energy Policy Act of 2005 requires the U.S. Secretary of Agriculture to submit to Congress an analysis of economic indicators of the biobased economy. This report outlines the process taken and the results of an analysis of indicators by the United States Department of Agriculture in collaboration with Iowa State University. The data used in the analysis are not meant to represent the current state of the industry, but rather to show what types of information give the best measures of the condition of the biobased economy. This report contains data gathered in 2008 and reflects the most current information available on biobased economy indicators.

Public forums were held for input on potential indicators. After a thorough investigation, four input indicators, four investment indicators, and eight output indicators were selected for in-depth analysis. Each of these indicators was studied to understand where data gathering methods are inadequate, the relevance of each indicator to the growth of the bioeconomy, and how it is or might be measured. Further analysis was conducted to explore how indicators can be combined to assess growth, profitability, and uncertainty in the bioeconomy.

To gain a good understanding of the status of the bioeconomy, it will be necessary to consistently track a comprehensive set of bioeconomy indicators. Unfortunately, many of the indicators that surfaced as key measures of the bioeconomy are not currently known. The following recommendations, if addressed, would support the development of a variety of accurate indicators so better informed business and policy decisions can be made.

- An advisory and policy planning committee with membership from the Federal Government could be established to regularly communicate on the topic of bioeconomy indicators.
- Formalizing biobased industry measurement standards between government agencies and the private sector should lead to more consistent estimates of data.
- Development of a biobased industry and commodity usage survey could be undertaken to expand the amount of information available on non-fuel segments of the industry.
- A revision of the North American Industry Classification System may be necessary to more effectively gather biobased industry data.
- Policy makers and planners should concentrate on measuring a few key indicators that give a sense of the scope and depth of biobased product usage and change.
- Lastly, industry could lead the development of standardized and regular industry measures designed to provide planning and guidance information for the industry.

As new indicators become available, industry, investors, and policy makers will be able to make more informed decisions and the sustainability of the industry can improve.

Keywords: biobased products, ethanol, biodiesel, fuels, chemicals, economic indicators.

Preface

The Energy Policy Act of 2005 (EPAct) (Public Law 109-58) required the U.S. Secretary of Agriculture to issue reports on the economic potential in the United States for the widespread production and use of commercial biobased products through calendar year 2025 and on the analysis of economic indicators of the biobased economy. This report addresses the latter requirement.

This study was prepared under the direction of the Office of Energy Policy and New Uses of the Office of the Chief Economist, U.S. Department of Agriculture, in cooperation with the Center for Industrial Research and Service of Iowa State University. Principal authors are Marvin Duncan of the Office of Energy Policy and New Uses and Ronald Cox, Liesl Eathington, Dave Swenson, and John Miranowski of Iowa State University.

The majority of the analyses in this report was based on data current in 2008. Though indicators may have changed since the referenced material was originally published or during the preparation of this report, there has been little change in the relevance of the indicators or in the issues associated with measurement and data availability.

Harry Baumes, Acting Director, Office of Energy Policy and New Uses

For updates on Biobased Products, please visit:
http://www.usda.gov/oce/reports/energy/index.htm

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1. Executive Summary

The Energy Policy Act of 2005 (EPAct) was signed into law on August 8, 2005. The overarching goal of EPAct is to ensure future jobs through secure, affordable, and reliable energy. Section 948 of the legislation requires the U.S. Secretary of Agriculture to submit to Congress an analysis of economic indicators of the biobased economy. This report outlines the process taken and the results of an analysis of indicators by the United States Department of Agriculture (USDA) in collaboration with Iowa State University. The data used in the analysis are not meant to represent the current state of the industry, but rather to show what types of information give the best measures of the condition of the biobased economy.

The main reasons given in support of the development and growth of a biobased economy are widely known: decrease U.S. dependency on foreign petroleum (and thus improve security), decrease the trade deficit, help rural economic development, reduce carbon emissions, and improve the environment.

The bioindustry must be competitive to grow. Investors, policy makers, and businesses all want to understand the business viability of biobased product companies. Knowledge of the status of the bioeconomy will help with:

- development of policies that aid growth and do not have unintended consequences;
- determination of areas where government research funds should be invested; and
- analysis of the industry so companies can effectively invest their own resources.

There are many kinds of data that could be gathered to help develop the knowledge to accomplish these objectives. Unfortunately, measuring the bioeconomy is not straightforward. The biobased products industry, despite its relatively young state, is multidimensional. There are many different product sectors, including fuels, end-use consumer products, commodity chemicals, and biopower. Bioeconomy activities include employee training programs; government policy-making activities at the local, state, and federal levels; a wide array of research and development activities; and so on.

The problem is exacerbated by the lack of clear definitions of what the bioeconomy includes. For instance, it may not make sense to include all industrial biotechnology products in bioeconomy analyses since not all biotech processes use agricultural feedstocks. Obviously, the geographic extent of analyses affects the magnitude of results. As well, there is debate on whether mature products should be included in the scope of analyses. Even if there is consensus on what is considered a part of the bioeconomy, a framework does not exist for classifying biobased products in a way in which accurate data can be collected within existing Federal Government data systems.

A number of definitions, however, can be offered. In this report, a biobased economy is defined as “U.S. activities related to the production and distribution of biobased products.” The definition is further constrained to new-use products—biobased products that have developed a market presence since 1972. The industry can be segmented a variety of ways. This report describes it as composed of four sectors: fuels, end-use products, chemicals, and power.

Biofuels are defined as any transportation fuel that is produced from plant-based renewable resources. The primary focus in this report is on ethanol and biodiesel since data are more readily available for these than for most other biobased products.

End-use biobased products are defined as items sold directly to end-use consumers (point of purchase) or business-to-business sales. Business-to-business sales might include transactions where only minor modifications to the product are made (e.g., repackaging) or wholesale distribution of end-use products. End-use biobased products include all products that are not categorized as biofuels or biochemicals.

The term “biochemical” is typically used to define chemical products that are manufactured using enzymes, microorganisms, or renewable resources. The focus of this report is on commodity chemicals or intermediates that use a biomass feedstock as opposed to a petrochemical feedstock.

Biopower includes both the generation of electricity and the production of heat in combined heat and power plants. The fuel for biopower plants can come from biogenic municipal solid waste, landfill gas, wood, or agriculture feedstocks or by-products.

This work to develop relevant measures of the bioeconomy started with the development of an extensive list of potential indicators. Two public forums were then held to garner advice from attendees. After further study, 16 different indicators were selected for in-depth analysis.

Four input indicators were investigated, including prices of energy inputs for biobased production, amount of cropland in energy-dedicated crops, quantity of grain and oilseed inputs used in biobased production, and the quantity of chemical and other inputs used in biobased production.

Four investment indicators made the final list. They were tax and trade policies, government spending on bioeconomy research and development (R&D), private capital investment in plant and equipment, and company-funded research and development.

There were eight output indicators analyzed—carbon offsets from biobased production, industrial absorption and/or consumer acceptance of biobased products, production levels of chemical-based products, emissions from biobased production, biofuels price levels, direct value added from biobased production, production levels of biofuels, and quantity of by-products from biofuel production.

Numerous indicators did not make the final list but could be studied in separate efforts. These include items like total nonfarm payroll employment in bioeconomy activities, private firm formation, public attitudes toward and understanding of biobased products, and life-cycle analysis. The latter is important because there is widespread belief that biobased products are friendlier to the environment than petroleum-based products. Since many biobased products are more costly than the alternative, a life-cycle analysis has become one tool to show that a more expensive biobased product will cost less over the life of the product (either monetarily or by some environmental measure).

Each indicator in the reduced list was studied in more depth to gain a better understanding of where data gathering methods are adequate and where additional work is needed. The relevance of each indicator to the growth of the bioeconomy is addressed in this report, together with a discussion of how the indicator is currently or might be measured. An example of one or more suggested measures is given, if data were available. The limitations of the data and assumptions made in any analyses are highlighted.

In general, the indicators validate a widespread belief: There has been a recent rapid growth of the biofuels industry. A variety of currently available indicators illustrate what is happening in this sector. Examples include production levels of biofuels and estimates of commodity feedstock inputs. Aggregating policy-related information is more difficult because of the plethora of state and federal programs. Unfortunately, there is significantly less information available on the other sectors of the bioeconomy.

Further economic analysis was conducted to explore how indicators might be combined to assess various aspects of growth, profitability, and uncertainty in the bioeconomy. For instance, a composite diffusion index might serve as a means to gauge the near-term condition of the biobased products industry, providing a measure of how widespread a business cycle movement has become. It is relatively straightforward to begin the development of a bioeconomy diffusion index. Companies could be recruited to participate from each of the principal sectors of the bioeconomy—fuels, chemicals, end-use products, and power.

Composite indicators can also be generated to reflect changes in the overall state of the bioeconomy. A composite index summarizing information contained in an array of individual indicators would help the public, industry, media, and policy makers see an overall picture that is not so obvious from the component indicators themselves. Data for a component biofuel index may be straightforward to collect, but a composite indicator must take into account changes in all bioeconomy sectors to gauge the overall condition of the bioeconomy. For this to occur, additional data need to be gathered and reported in a more timely manner from within the chemicals, end-use products, and power sectors of the industry.

More complex indicators can also be constructed from baseline indicator data. Gross margins of biofuel plants are highlighted in this report. These indicators display the considerable variability that this sector has experienced over the past few years. This sector has had periods of high volatility, followed by generally robust margins, followed by a sharp erosion of margins.

To gain a good understanding of the status of the bioeconomy, it will be necessary to consistently track a comprehensive set of bioeconomy indicators. Unfortunately, many of the indicators that surfaced as key measures of the bioeconomy are not currently known because data are not collected, the data are confidential or are suppressed because they might disclose the identity of the firm, or the indicators are not easily measurable. A number of recommendations, if addressed, would support the development of a variety of accurate indicators that are released in a more timely fashion so better informed business and policy decisions can be made.

- First, an advisory and policy planning committee with membership from officials of the USDA, the U.S. Department of Energy, the U.S. Bureau of Economic Analysis, the U.S. Bureau of Labor Statistics, the National Institute of Standards and Technology, and possibly the National Science Foundation could be established to regularly communicate on the topic of bioeconomy indicators. Individuals could come together on a regular basis, legislatively mandated if necessary, to communicate plans for future data gathering, establish protocols for sharing data, and support international dialog on the measurement and analysis of the biobased products industry.

- The next step would be to formalize biobased industry measurement standards. There are widely varying views of what is and is not part of the burgeoning bioeconomy. Clear and consistent definitions must be developed between government agencies and the private sector to allow consistent estimates of data. Some issues that need more work include defining the portion of the biobased products supply chain to be included in economic analyses; deciding the degree of inclusion of by-products from conventional industrial sources, landfill gas, and municipal solid waste; and deciding if indicators will only focus on new uses.

- The development of a biobased industry and commodity-usage survey could also be undertaken. An assortment of information is available on the biofuels sector, but data on other segments of the biobased products industry are scarce. Additional data need to be collected to create additional bioeconomy indicators and to improve awareness of the entire industry. Information that might be appropriate to gather includes the contribution of biobased products to gross domestic product, the sales of biobased chemicals, the sales of biobased intermediates and end-use products, private capital investment in plants and equipment, biofuel subsidies, and percentage of employees involved in biobased production.

- To more effectively gather biobased industry data, a revision of the North American Industry Classification System (NAICS) may be necessary. Since the NAICS system was developed based on the idea that producing units should be grouped based on similarity of production processes, and since there is such diversity among the variety of biobased products, this could be problematic.

- There are a wide variety of indicators that could be generated and tracked, but it is recommended that policy makers and planners concentrate on measuring a few key indicators that give a sense of the scope and depth of biobased product usage and change in recent years. It is recommended that reliable summary compilations be made of (1) annual government support of biobased industrial activity by type of support and amount and (2) biofuels and biobased chemical sales. As government agencies develop better and more reliable measurement and reporting protocols, additional items or subcategories can be explored.

- Lastly, industry must also play a role in helping gather relevant data if the condition of the broad bioeconomy is to be fully understood. Industry could lead the development of standardized and regular industry measures designed to provide planning and guidance information for the industry itself.

A variety of indicators have been proposed to describe the current and expected future state of the U.S. bioeconomy. Some indicator data are readily available, but primarily for the biofuels sector. A number of steps will need to be taken to develop additional bioeconomy indicators. As new indicators become available, industry, investors, and policy makers will be able to make more informed decisions, and the sustainability of the industry can improve. A robust industry can help improve national security and expand economic development opportunities.

2. Introduction

The Energy Policy Act of 2005 was signed into law on August 8, 2005 (Public Law 109-58) [1].[1] The overarching goal of EPAct is to ensure future jobs through secure, affordable, and reliable energy. Section 948 of the legislation requires the U.S. Secretary of Agriculture to submit to Congress an analysis of economic indicators of the biobased economy. This report outlines the process taken and the results of an analysis of indicators by USDA in collaboration with Iowa State University. The data used in the analysis are not meant to represent the current state of the industry, but rather to show what types of information give the best measures of the condition of the biobased economy.

To accomplish this task, it is first necessary to determine the root intent of the legislation so that appropriate indicators can be developed. The main reasons given in support of the development and growth of a biobased economy are widely known: decrease U.S. dependency on foreign petroleum (and thus improve security), decrease the trade deficit, help rural economic development, reduce carbon emissions, and improve the environment. These improvements to the U.S. economy might occur from substitutions of petroleum-based products, fuels, chemicals, and power by biobased equivalents; by improvements over petroleum-based products; or by the development of entirely new products or processes.

Investors, policy makers, and businesses all want to understand the business viability of biobased product companies. Knowledge of the condition of the bioeconomy will help with:

- development of policies that aid growth and do not have unintended consequences;
- determination of areas where government research funds should be invested; and
- analysis of the industry so companies can effectively invest their own resources.

The industry is being examined more closely as of late because there have been recent bankruptcies and consolidations, there are a number of systemic constraints that may slow the growth of the ethanol industry (distribution costs, development of cellulosic-based processes, and number of flex-fuel vehicles on the market), the profitability of the biodiesel industry has suffered, and there are few indications that there has been any significant increase in the procurement of biobased products by the Federal Government. Additional technical and economic research within some sectors of the industry must be completed to better understand limitations to growth. Further analysis of the net energy gain of biofuels development, the net carbon balance of ethanol production, and the long-term need for subsidies to maintain a viable industry are just a few issues that need further study.

Regardless of the current state of the biobased products industry, it is important to understand the change in the industry and the economic impact of the industry on the U.S. economy. The problem statement might succinctly be stated as, “How is the country doing shifting from a petroleum-based economy to a biobased economy?” If this is occurring, one might expect to see a larger fraction of the energy and products consumed in the United States being produced with renewable biobased feedstocks. The total cost of the products for the consumers and society (product price, industry subsidies, disposal costs, etc.) might also decline. That is, not only is the industry growing and becoming a viable substitute for petroleum-based products based on

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[1] A list of references is included in Chapter 9, beginning on page 127.

performance, but also that the cost to the consumer and society of biobased products is comparable to or better than petroleum-based alternatives.

Measuring the bioeconomy is not straightforward. The biobased sector of the U.S. economy, despite its relatively young state, is multidimensional. For example, there are many different biobased product groups such as fuels, commodity chemicals, and end-use consumer products (see Appendix A). Within each of these product groups there are wide varieties of distinct product types and production locales, each of which employs a variety of feedstocks, labor, machinery, and technology. In addition to the production of biobased products, activities in the biobased economy include a wide array of research and development activities; government policy-making activities at the local, state, and federal levels; employee training programs; and so on. In light of the very dynamic, diverse, and complex set of economic activities associated with the biobased economy, it is natural and useful to consider the development of efficient methods to quantitatively summarize these activities in ways that would be informative and easily digestible with regard to the overall magnitudes of, and trends in, major components of the bioeconomy.

Combining or aggregating information from distinct economic activities to provide succinct summaries of these activities is standard practice in economics, particularly in macroeconomics. For example, the economy's production of the many different final goods and services produced is summarized by the well-known gross domestic product (GDP) measure. GDP summarizes the economy's current production of goods and services by measuring the market value of this output. The economy is producing so many dollars' worth of goods and services per year. While the dollar value in and of itself is not particularly informative, changes in (real) GDP from one year to the next provide useful information on the rate at which economic production is increasing (or decreasing).

One can imagine a bioproduct analog to GDP in which the market value of current biobased output could be constructed and used to measure changes over time in biobased output. Similarly, measures of, for example, total labor employment in biobased activities, research and development expenditure, capital investment, and patent applications could be constructed to produce a manageable and digestible set of indicators of key components of the biobased economy.

In addition to indicators that summarize various dimensions of biobased economic activities, it would be helpful to have a more highly aggregated composite indicator to summarize the overall state of the bioeconomy. Composite indicators, such as the composite leading economic indicator, combine related but distinct indicators to provide barometers of the overall levels of activity in the manufacturing sector of the economy or the economy itself.

There have been a number of efforts to develop indicators for sectors of the economy related to the biobased products industry. The biotech industry is currently being analyzed by many others, such as the Organisation for Economic Co-operation and Development [2, 3].

The Biomass Research and Development Board was created to coordinate programs within the Federal Government to promote the use of biobased fuels and products [4,1]. The board's Interagency Working Group on Sustainable Development Indicators (SDI Group) is looking at a number of indicators related to sustainability [5]. Proposed indicators fall into the general categories of greenhouse gases, soil quality, water use, air quality, biological diversity, land use change impacts, resource use, cost competitiveness of feedstock production, value of products and employment, food/feed/fiber supply, public health and safety, legal compliance, imported oil displacement, net energy balance, and biofuels access.

The SDI Group is focusing on biofuels whereas this report addresses fuels, chemicals, and end-use biobased products. Their work is specifically focused on sustainability, which is very important for long-term industry growth. This report is directed more toward the short-term economic condition of the industry. The bioeconomy industry could grow in the short term, despite a decline in some sustainability indicators. Several of the indicators the Sustainability Interagency Work Group proposes will be of interest to the biobased products industry to help make business decisions but are not direct measures of the condition of the industry or a measure of how well biomass is replacing petroleum.

This report includes a few indicators that are similar, including measures of greenhouse gases, land productivity, resource use (fraction of total fuel use), value of products, food/feed/fiber supply, and imported oil displacement. These few duplicate indices are basic metrics that help address the sustainability issue and are also important measures of the economic condition of the biobased products industry.

It is hoped the results from this report will be used by the Federal Government and state governments to assist in the development of policies and legislation and by industry to assist in formulating business strategies. To that end, it is crucial that the economic indicators of the biobased economy be selected based on sound economic criteria, accurately reflect biobased economic activity, and be well understood by stakeholders.

Five tasks were completed as part of this effort:

1. Develop a list of economic indicators of the biobased economy.
2. Gather input from stakeholders to help prioritize the list.
3. Gather data on key economic indicators.
4. Explore relationships between key indicators and determine if a composite biobased products index can be derived.
5. Propose future data requirements based on limitations of existing data.

Background information regarding the industry and economic indicators is provided in Chapter 3. A summary of the process undertaken to develop a short list of indicators is discussed in Chapter 4. This is followed by an analyses of key indicators in Chapter 5. Chapter 6 highlights some detailed analyses of a few indicators. Finally, Chapter 7 includes several recommendations to help improve the collection of accurate bioeconomy data.

3. Background

Many different characterizations of a biobased economy are commonplace. Terms are defined here so it is clear what is and is not included. The basic state of the bioeconomy is then covered to set the stage for later discussions. This is followed by an introduction to economic indicators and a discussion of the complexities associated with developing indicators for this sector of the economy.

3.1. Definitions

The authors define a U.S. biobased economy as "U.S. activities related to the production and distribution of biobased products." A definition of biobased products was provided by Congress in the Farm Security and Rural Investment Act of 2002 [6]. Congress later modified the definition in the Food, Conservation, and Energy Act of 2008, stating "The term 'biobased product' means a product determined by the Secretary to be a commercial or industrial product (other than food or feed) that is— (A) composed, in whole or in significant part, of biological products, including renewable domestic agricultural materials and forestry materials; or (B) an intermediate ingredient or feedstock." [7].

For the purposes of this study, the definition of a biobased product is further constrained to new-use products. Mature market products (e.g., cotton shirts) are not included in the current analysis since many do not consider these types of products as part of a new bioeconomy. Items like cotton shirts were developed in the marketplace because of a basic consumer request for the product instead of as a mechanism to decrease U.S. dependency on foreign oil, to help rural economic development, or to improve the environment. In addition, the economic analysis of these markets can be extremely complex because of how they have been "woven" into the global economy over decades. For instance, there has been a widespread loss of jobs in textile production and apparel manufacturing in the United States due to a labor-cost driven shift to Southeast Asia.

The biobased products industry can be segmented a variety of ways. This report describes it as composed of four sectors: fuels, end-use products, chemicals, and power. Discussions here are primarily focused on biofuels and newly developed end-use products that have developed a market presence since 1972.

Biofuels are defined as any transportation fuel that is produced from plant-based renewable resources. Some classify the manufacture of certain fuels as industrial biotechnology because they involve the use of enzymes (ethanol), while other fuels may not fit this definition (biodiesel). In this report, biofuels are defined as all transportation-focused fuels using renewable feedstocks, whether or not they involve biotechnology as part of the industrial process. The primary focus here is on ethanol and biodiesel since these data are more readily available than are data for most other biobased products.

End-use biobased products are defined as items sold directly to end-use consumers (point of purchase) or business-to-business sales. Business-to-business sales might include transactions where only minor modifications to the product are made (e.g., repackaging) or wholesale distribution of end-use products. End-use biobased products include all products that are not categorized as biofuels or biochemicals.

The chemical industry is an advanced industry that produces a wide range of products, including fuels, commodity chemicals, fine chemicals, specialty chemicals, polymers, food ingredients, flavors, fragrances, and pharmaceuticals.

The term biochemicals is typically used to define chemical products that are manufactured using enzymes, microorganisms, or renewable resources. This processing is referred to as white biotechnology. This differs from red biotechnology, which refers to the use of biotechnology in healthcare, and green biotechnology for the agricultural sector [8].

In this report, the definition of biochemicals is further restricted. First, transportation fuels are grouped separately, as discussed above. Second, since this work predominantly focuses on new uses, products like high-fructose corn syrup are not included in the definition.

Many industrial biotechnology products do not use agricultural feedstocks, so the manufacture of these products may have limited impact on the reduced consumption of petroleum.[2] As such, products like biobased pharmaceuticals and others that do not use agricultural feedstocks are not included in the definition. Other processes, chemicals, etc. (e.g., enzymes), may be constraining the growth of the industry and may warrant further study.

What remains within the definition of biochemicals used here are commodity chemicals or intermediates that use a biomass feedstock as opposed to a petrochemical feedstock. Some of these biochemicals could also be classified as end-use products (e.g., biobased 1,3-propanediol). The Food, Conservation, and Energy Act of 2008 specifically includes intermediate ingredients in the definition of “biobased products” for purposes of the Federal BioPreferred program [7]. A brief description of the BioPreferred program is included in Appendix A.

Biobased chemicals receive secondary focus in this report since many of the biobased chemical intermediates are produced by companies that also produce petroleum-based chemicals, which makes data gathering more difficult. A recently released report by the U.S. International Trade Commission details some very recent findings on the chemical industry [8]. A discussion of biobased chemicals is also included in a recent report to Congress [9].

Biopower generally includes both the generation of electricity and the production of heat in combined heat and power plants. The fuel for biopower plants can come from biogenic municipal solid waste, landfill gas, wood, or agriculture feedstocks or by-products.

Most electricity that is currently generated with biomass is produced through direct combustion using conventional boilers. Coal-fired plants can use biomass to supplement the coal stream, which is referred to as co-firing. Methane generated from the decay of biomass in a landfill or from an anaerobic digester can also be burned to produce steam and then electricity (see [10,11]).

[2] The development of enzymes for chemicals produced from nonagricultural feedstocks may have a secondary positive effect on the development of enzymes and microorganisms for the production of other chemicals from biobased feedstocks.

The generation of power through the use of wood and agricultural by-products is seen as one way to assist with the growth of the bioeconomy. However, the growth of this subsector has been slow. There has been a general decline in the consumption of energy from wood over the past two decades. Also, only a very small fraction of the total electricity produced in the United States is from agricultural by-products. This is due in part to higher capital and operating costs compared with conventional power plants; the costs associated with harvesting, storing, and transporting plant residue; and the additional costs associated with transmission lines to move the energy from remote areas where the power is generated to population centers where there is the greatest need for electricity.

Since the industry is small and since growth in the industry has been slow, the biopower sector is not analyzed in any detail in this report. Currently, the U.S. Department of Energy (DOE) releases data on wood and waste energy consumption [12].

3.2. Current State

Biofuels

As of October 2008, BBI International reported there were 178 operational ethanol plants in the United States, 31 under construction, and 8 idle (see Figure 1). Combined capacity in operation and under construction was 13.8 billion gallons per year. Seventy percent of this projected capacity is in six states: Iowa, Nebraska, Illinois, Minnesota, Indiana, and South Dakota.

As of October 2008, BBI International reported there were 113 operational biodiesel plants in the United States, 12 under construction, 31 idle, and 21 unconfirmed (see Figure 2). Combined capacity in operation and under construction was 2.2 billion gallons per year. About one-third of this projected capacity is in three states: Texas, Iowa, and Missouri.

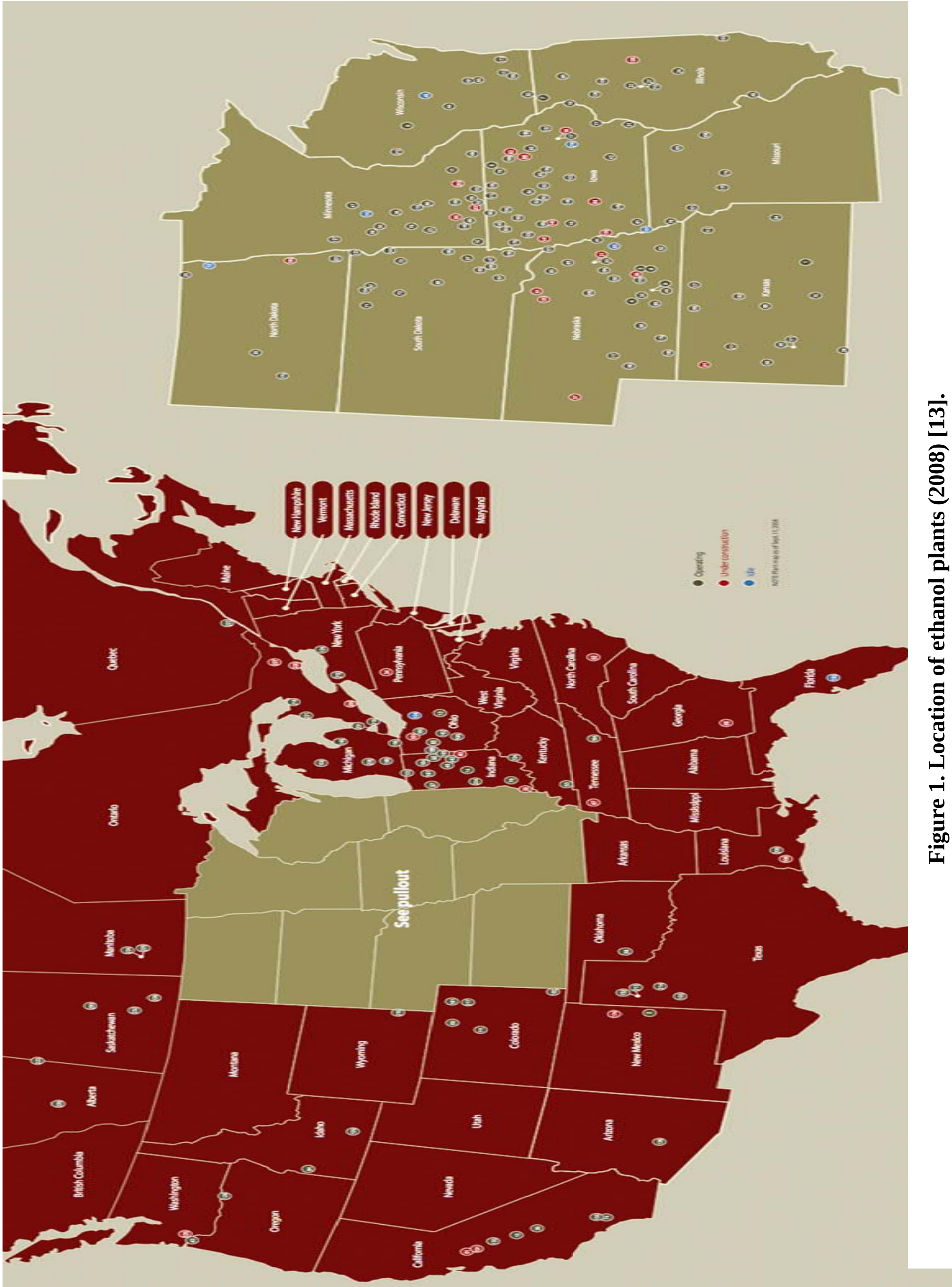

Figure 1. Location of ethanol plants (2008) [13].

Figure 1. Location of ethanol plants (2008) [13].

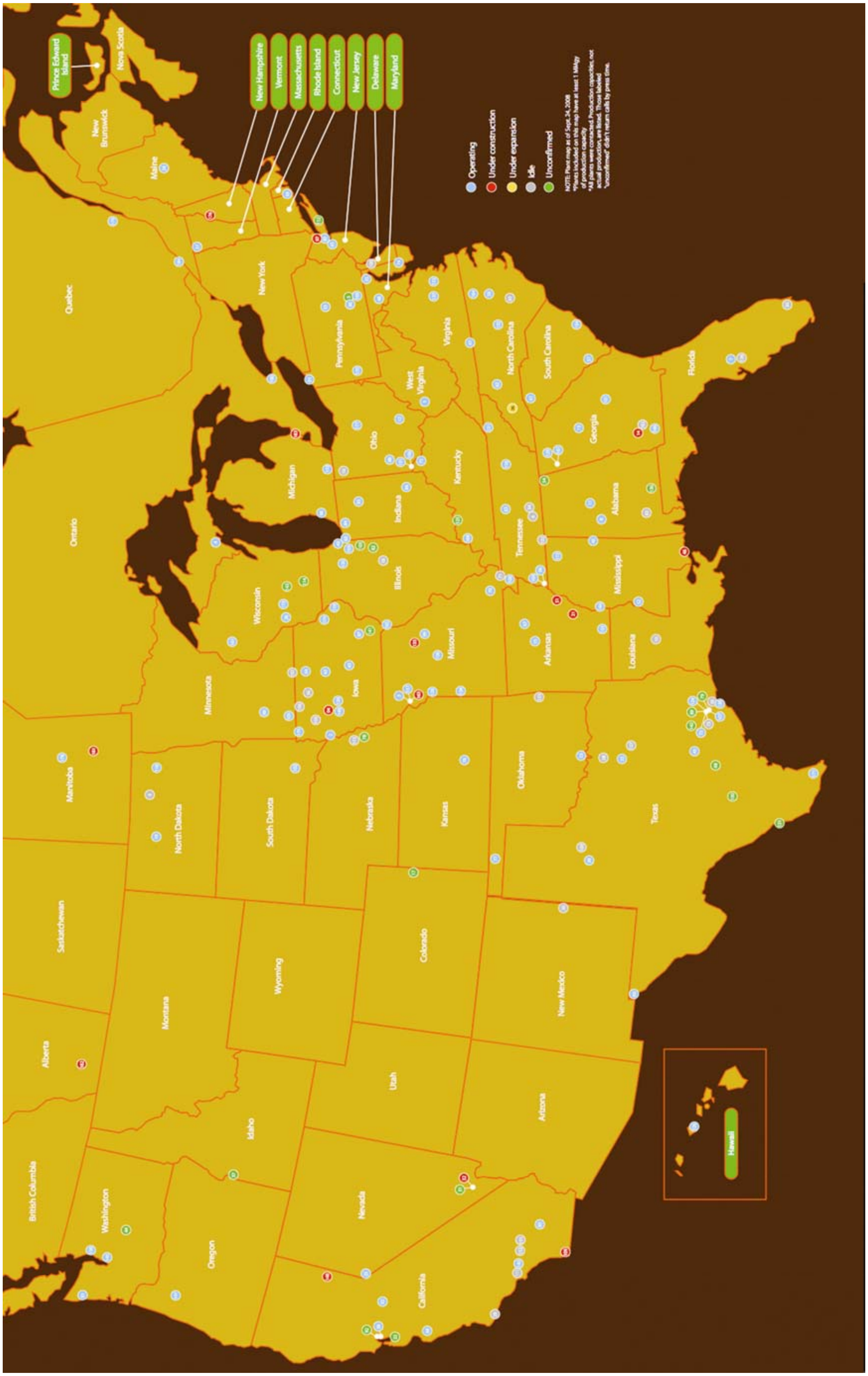

Figure 2. Location of commercial biodiesel plants (2008) [13].

End-Use Biobased Products

The biofuels industry has been widely studied. The end-use biobased products sector has been studied to a much smaller extent, largely because of the diversified nature of the industry.

Iowa State University has located over 2,100 companies that produce end-use biobased products in the United States as part of their support of the USDA Office of Energy Policy and New Uses and their work on the BioPreferred program. These companies produce or distribute over 15,000 different products. Appendix A contains a list of the products these companies sell. Additional information can be found at www.biopreferred.gov.

The locations of the biobased product companies that are being explored as part of the BioPreferred program are displayed in Figure 3. Iowa State University recently completed a survey of these companies [14]. The locations of the 925 U.S. respondents to the survey are displayed in Figure 4. The region definitions in the figure are the same as the four census regions used by the U.S. Bureau of Census.

Figure 3. Location of biobased product companies (2008).

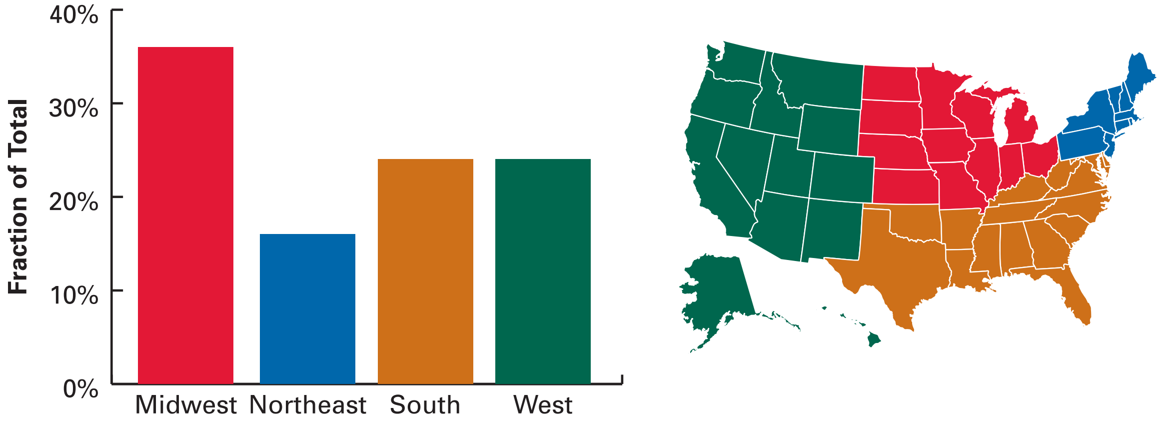

Figure 4. Location of U.S. biobased products survey respondents [14].

Of the total number of companies responding to the survey, 73 percent primarily considered themselves a manufacturer, 25 percent were primarily a wholesaler or retailer, and 2 percent classified themselves as something different. Of all respondents, 81 percent stated they manufactured a biobased product. Fifty percent of the companies also manufactured or distributed a nonbiobased product.

The respondents' biobased products were categorized into one of three broad types—end use, intermediates, and fuels. The median size of the companies that stated they produce end-use products was 10 employees. The median size of the companies that produced intermediates was 20 employees. The median size of the companies that produced fuels was 41.5 employees. In total, one-third of the companies had five employees or less. Nearly two-thirds had 20 employees or less.

In the survey, the companies were asked what the primary product was that they sell. Seventy-one percent of the total companies were categorized as being in the chemical industry (see Figure 5). The top seven North American Industry Classification System (NAICS) categories of the respondents are displayed in the figure.

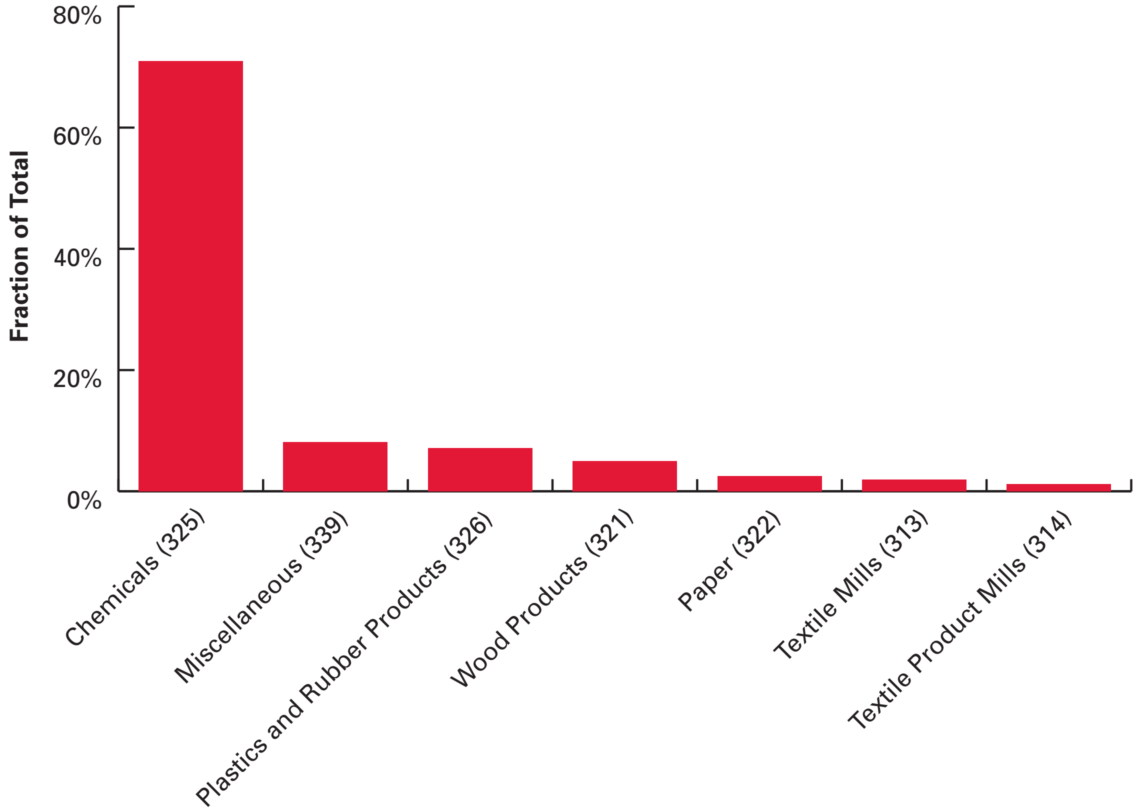

Figure 5. Top NAICS categories of the biobased products survey respondents [14].

Approximately one-half of the companies provided additional information that allowed the survey authors to further classify the products to a four-digit NAICS code. The primary four-digit NAICS categories of the companies that produced chemicals are displayed in Figure 6. The product descriptions associated with these four-digit NAICS codes are listed in Table 1.

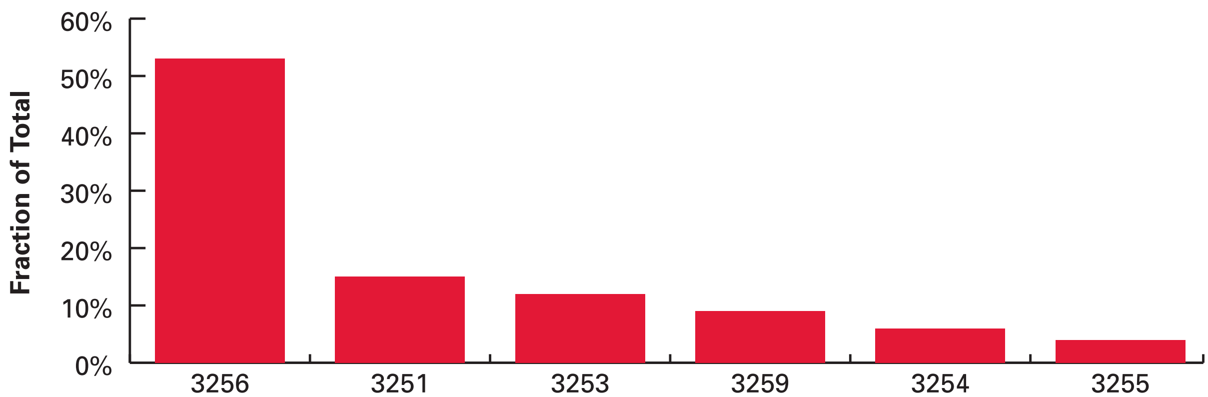

Figure 6. Products sold by the companies that provided four-digit NAICS information [14].

Table 1. Four-digit NAICS code descriptions.

4-Digit NAICS	Description
3256	Soap, cleaning compound, and toilet preparation
3251	Basic chemicals
3253	Pesticide, fertilizer, and other agricultural chemicals
3259	Other chemical products and preparation
3254	Pharmaceuticals and medicines
3255	Paints, coatings, and adhesives

The companies were also asked how long they had been selling biobased products. Nearly two-thirds of the companies have been selling biobased products for less than 10 years, and over 86 percent for less than 20 years. While over 13 percent of the companies have been in business for over 50 years, only 4 percent have been selling a biobased product for that length of time.

It is not unexpected to find such a small number of companies selling biobased products for over 50 years. The BioPreferred database was developed with a focus on new-use biobased products, defined as products developed since 1972 (see [6]). As such, no attempt was made to include mature markets (e.g., cotton shirts) in the survey.

Biochemicals

The U.S. International Trade Commission recently released a survey of the chemical and biofuels industries [8]. A variety of results are reported from survey respondents from the ethanol, biodiesel, biobased-pharmaceuticals, and biobased-chemicals (except pharmaceuticals) industries.

Figure 7 displays the change of the biochemical (non-pharmaceuticals) respondents, scaled to an index of 100 for the year 2004. Non-pharmaceutical biochemicals were defined in this reference as including enzymes and microorganisms, commodity chemicals, specialty chemicals, intermediates, polymers, food additives, flavors, and fragrances.

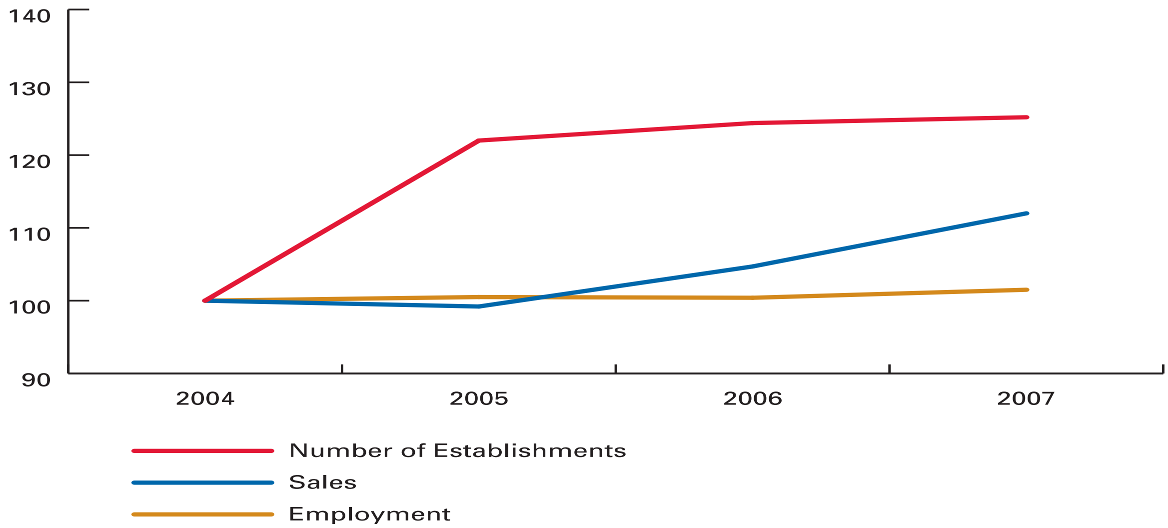

Figure 7. Changes in biochemical companies (indexed to 2004).

Biopower

Biomass accounted for over 5 percent of the primary energy produced in the United States in 2008. This includes biofuels, wood, and waste energy [15]. A consumption breakdown of all renewable energy, including biomass, is included in Figure 8. There has been a general decline in the consumption of energy from wood over the past two decades, while there has been a recent steep increase in the consumption of energy from biofuels. Energy from waste, landfill gas, and biogenic municipal solid waste (MSW) has been fairly flat since 2001.

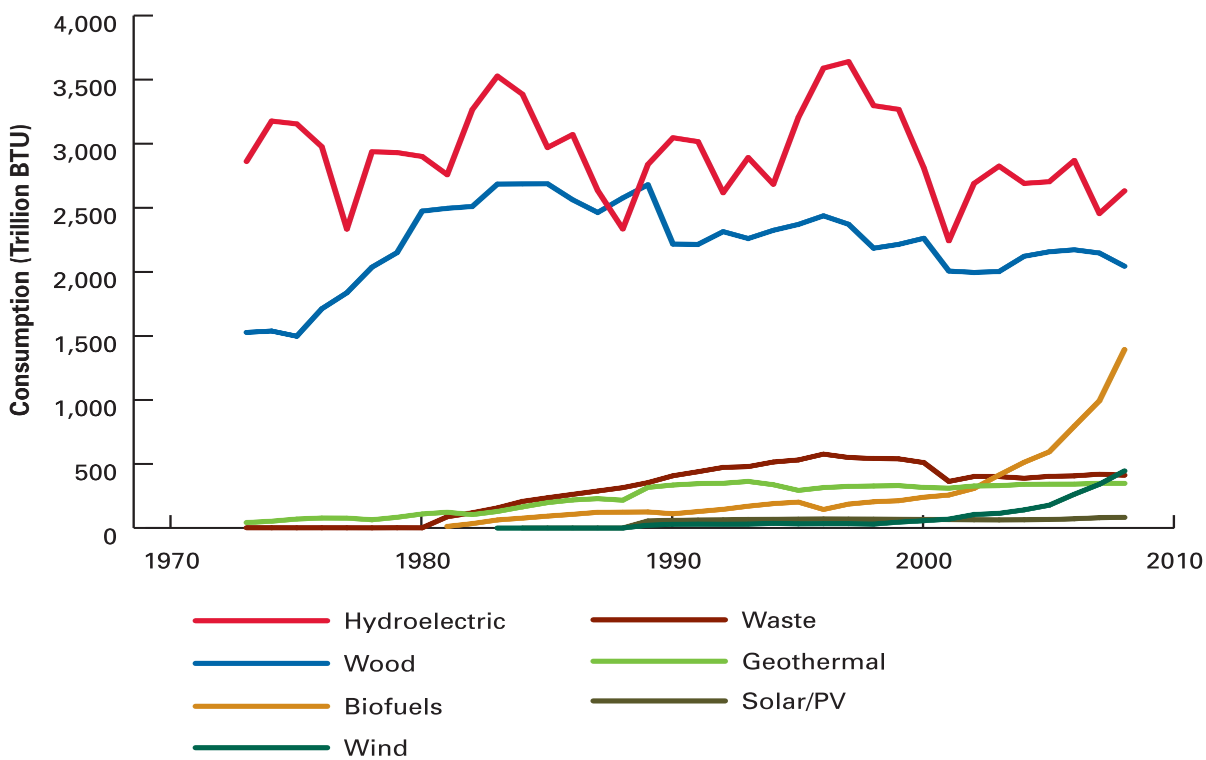

Figure 8. U.S. renewable energy consumption by source [12].

Figure 9 displays the change over the past few years in the energy (including electricity and combined heat and power) produced from biomass in the industrial, electric power, and commercial sectors as a fraction of the total energy produced (from coal, nuclear, petroleum liquids, natural gas, renewables, etc.). In 2007, these combined to 1.3 percent of the energy generation in the United States.

It is evident that the industrial sector is playing a slowly declining role in the production of energy. With the continued erosion of manufacturing in the United States and the high start-up costs associated with production, especially for small operations, it does not seem likely there will be any near-term growth in this sector.

The electric power sector includes plants selling only electricity and combined heat and power plants whose primary business is selling electricity, or electricity and heat, to the public. This sector has been growing in total output, but when viewed as a fraction of the total energy consumed in the United States, the industry has been flat.

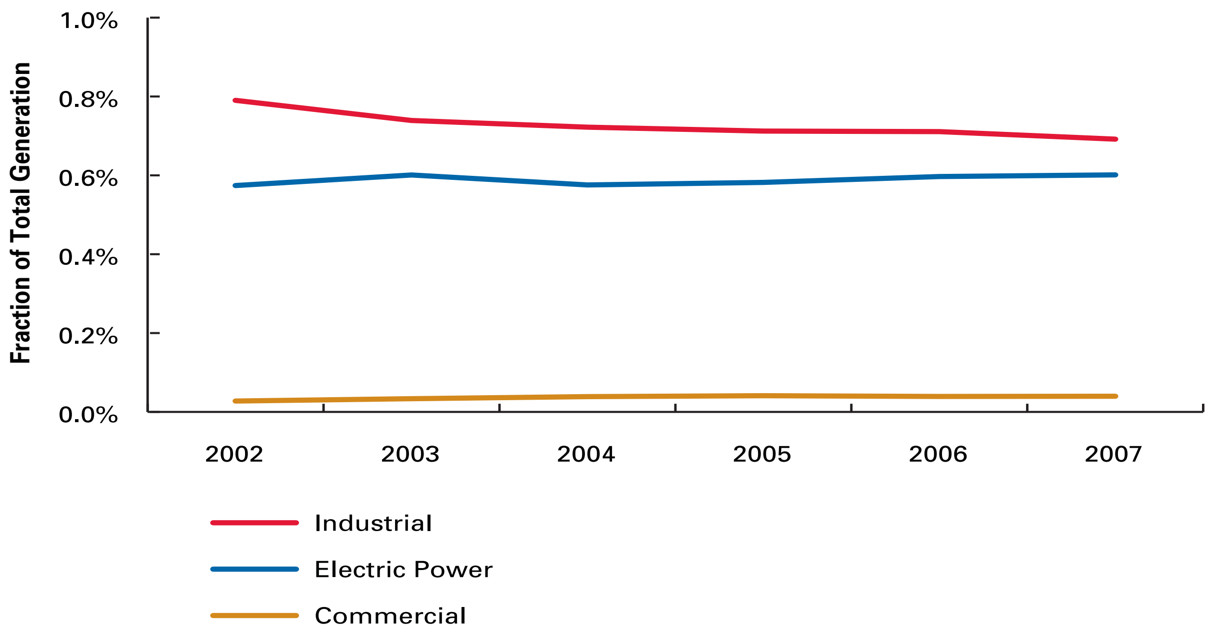

Figure 9. U.S. power generation from biomass by sector [16, 17, 18].

Figure 10 includes a breakdown of the electric power sector in terms of landfill gas and biogenic MSW, wood and derived fuels, and other biomass. Biogenic MSW includes energy generated from paper, paperboard, wood, food, leather, textiles, and yard waste. Wood and derived fuels includes energy from black liquor and wood/woodwaste solids and liquids. Other biomass includes agricultural by-products, crops, sludge waste, and other biomass solids, liquids, and gases [16].

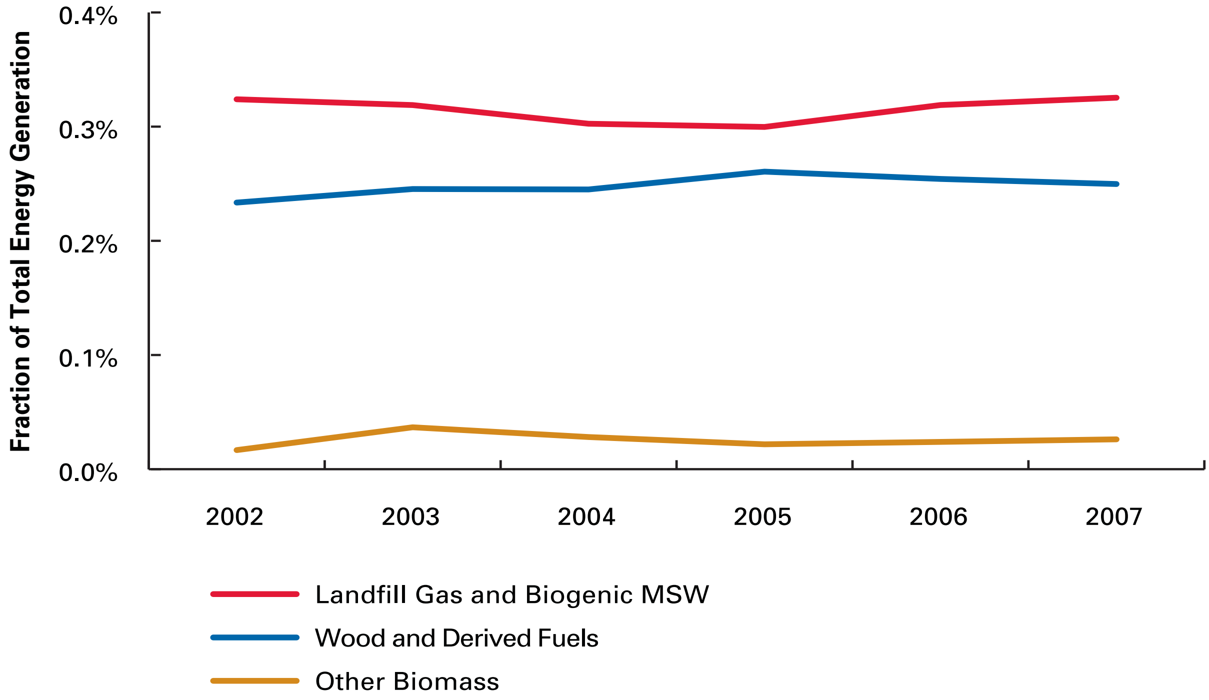

Figure 10. U.S. electric power sector generation by biomass type [16, 17, 18].

3.3. Introduction to Economic Indicators

Economic indicators can be grouped in a number of ways. For instance, activity indicators can be used for descriptive analyses and linkage indicators can be used to illustrate how the economy and society are interconnected [19, 20, 21]. Three general designations for types of indicators are used in this report—inputs, investments, and outputs.

Inputs are the overall production recipe for different commodities. They include items like commodity feedstock use, biomass feedstock costs and use, biobased workforce and employment, natural gas costs, etc. These tend to be measures of current consumption of resources.

Investments are public and private support of economic activity. These are a type of input indicator as well, but more directed to indicators that are monetary based. By definition, they are measures of activities that are tacitly assumed to drive a future change in outputs. Investment economic indicators include items like the following:

- Capital—new and planned investment in biobased product plants, number of biobased product manufacturers
- Technology—R&D expenditures, patent activity
- Human—biobased training and degree programs
- Infrastructure—transportation systems, pipelines

It is important to track economic inputs and investments in the bioeconomy, but economic outputs, in particular, need to be measured before you can fully determine the impact of biobased product firms on the U.S. economy. Outputs are the flow of commodities into production and final demand. Indicators include items like ethanol value and volume, by-products value and volume, etc.

Well-defined output indicators should scale in a systematic way, starting from the establishment to the firm. They should then scale geographically (state, United States, international) or by industry (industry subsector, industry total).

Of most interest are indicators that measure direct impact—that is, the initial change in final demand within the biobased products industry. Of secondary importance are indirect impacts—changes in businesses supplying to the biobased products industry. Of lesser importance are the induced impacts associated with increased spending by households that benefit from additional income earned from the direct and indirect activity.

Individuals tracking the bioeconomy are interested in leading, coincident, and lagging indicators. Businesses are often interested in leading indicators to predict future changes in the industry. These indicators should change before the economy changes. The Institute for Supply Management's composite manufacturing index, the Purchasing Manager's Index (PMI), is an example of a leading indicator.

Coincident indicators are expected to change in conjunction with a change in the economy. As such, these indicators tend to give a picture of what the economy is doing right now. Biodiesel capacity utilization is an example of a coincident indicator.

Lagging indicators are used to understand past activity, patterns, and trends. They tend to change after the economy has changed. Gross domestic product generated by the ethanol industry is an example of a lagging indicator.

The tacit assumption is that outputs will lead to impacts—job creation, income growth, etc. These then help to achieve the long-term goals previously discussed—decreased U.S. dependency on foreign oil, improved rural economic development, and an enhanced environment.

3.4. Problem Complexity

It is important to understand the complexities associated with measuring bioeconomy indicators to help in determining which indicators should receive the most attention at this stage of industry development. More detailed discussion of these problems and recommendations for change are covered in Chapter 7.

A paraphrase of a statement made by Anthony Arundel. co-author of *The Bioeconomy to 2030*, succinctly describes the complexities associated with biobased products [22].

> *The generic feature of biobased products is both the cause of its high socio-economic potential and a major challenge for biobased products metrics.*

Biobased products can include a diverse cross-section of items like enzymes; biobased end-use products (e.g., glass cleaners); commodity, fine, and specialty chemicals; intermediates and polymers; food additives; fuels; flavors and fragrances; pharmaceuticals; and biobased energy. These products are woven into the economy in complex ways, making it difficult to compute the impact on the U.S. economy.

There are many potential economic indicators that could be used by companies, policy makers, economists, and others to better understand how the bioeconomy has changed and how it might change going forward. Some of the difficulties associated with gathering data for economic indicators and analyzing the indicators are highlighted categorically below.

Terminology

Mature industries typically develop standard terminology over the course of decades of interaction at conferences, reviews of journal articles, and development of standards. The biorenewables industry is a relatively new industry, so terminology is not as clearly defined. This becomes problematic in regard to defining the scope of problems and in developing metrics for analysis. For example, there is a wide variety of terms used to define products with positive environmental or biological characteristics. Terms like green, biobased, environmentally friendly, earth-friendly, biotech, nontoxic, recyclable, re-useable, and biodegradable are commonplace.

The nonstandard use of terms like these is problematic in defining the biobased products industry. For example, inconsistently defined terms such as these make it difficult to survey the general public to determine consumer acceptance of biobased products.

Problem Boundaries

As discussed previously, defining what will and will not be considered part of the core bioeconomy is important and has a great impact on the magnitude of various indicators.

For the bioeconomy to grow, many different segments of the economy must effectively interact. The connectedness of the bioeconomy can most easily be discussed in a supply chain framework. Supply chains are often defined as all of the players involved in the movement of a product or service to the end customer. These companies transform natural resources into an end-use product, often via many different companies that add incremental value along the way.

Many economic analyses are very inclusive when considering the various players in a supply chain that have been impacted by a specific activity. Defining the extent of this supply chain has an impact on the magnitude of a variety of indicators. For instance, some economic analyses include farmers in the number of jobs created by the ethanol industry. This would be similar to including a job in an iron ore mine in an analysis of the number of jobs created by the automobile industry. Defining the components of the supply chain used in an analysis, and whether the link in the chain pre-existed or not, is important to note. Otherwise, comparisons of different analyses may lead to erroneous conclusions.

Once the supply chain extent has been bounded, it is then necessary to define the lateral extent of the economic analysis. Of most interest are indicators that measure direct impact, that is, the initial change in final demand within the biobased products industry. Of secondary importance are indirect impacts, changes in businesses linked to the biobased products industry. These can be thought of as peripheral industries supporting, but not essential to, the growth of the bioeconomy. This would include, for example, the manufacture of motors that are sold to an ethanol plant. Of lesser importance are the induced impacts that result from the increased spending by households that supply labor in the bioeconomy.

Economic analyses can look at a sector of the economy and how it expands or contracts in isolation, neglecting unintended consequences. The analyses can also be expanded to include competing sectors or peripheral industries that could be affected by changes within the sector. For instance, a loss of business in companies that use petroleum feedstocks might offset any economic gains associated with a growth in the biobased products industry.

Even though the extent of an analysis may be defined well, the impact of the changes in the economy may not be easy to quantify. Increased corn acreage could lead to a reduction of buffer strips, which then leads to increased erosion. The financial impact of a social or environmental change such as reduced water quality may not be easily quantifiable.

The scope of any economic analysis can also be bounded by a geographic boundary that will affect the magnitude of the results. For instance, the United States could see a reduction in greenhouse gas emissions as a result of direct reductions in the use of petroleum feedstocks in U.S. manufacturing plants. However, the global output of greenhouse gases could increase due to (1) a higher consumption of imported goods due to lower product prices; (2) less efficient production processes in other countries; (3) less environmentally friendly processes in other countries; (4) increases in transportation to the United States; and (5) increased transportation within the United States.

Temporal boundaries also might affect results. The guidelines associated with the BioPreferred program state that “USDA additionally will not designate items for preferred procurement that are determined to have mature markets. USDA will determine mature market status by whether the item had significant national market penetration in 1972” [23]. In its response to public comments on the mature markets exclusion, USDA stated the intent “is to stimulate the production of new biobased products and to energize emerging markets for those products.” Given this intent, they found that “it is entirely appropriate for the guidelines to exclude products having mature markets from the program” [24]. Temporal restrictions of this nature will obviously alter the magnitude of any economic analysis.

North American Industry Classification System

The North American Industry Classification System (NAICS) is used as a way to classify different types of economic activity [25]. The classification system is based on a production-oriented framework. The NAICS is broken into 20 industry sectors—5 goods-producing sectors and 15 service-producing sectors. There are 1,170 industries identifiable by the 6-digit NAICS code. The NAICS system is the primary classification system used by the U.S. Government’s Bureau of Economic Analysis, Bureau of Labor Statistics, Census Bureau, and others as their base categories for economic analyses and labor counts, etc.

The business establishments that fall into the various NAICS classifications often use similar raw materials, capital equipment, and labor resources. For instance, business establishments in the *fabricated metal product manufacturing* sector (NAICS 332XXX) manufacture products made of iron or steel using processes like forging, roll forming, and stamping to produce a variety of end-use products. More detail on the wide variety of end-use products in the category can be found by looking at the full six digits; for instance, *cutlery and flatware manufacturing* (332211), *sawblade and handsaw manufactur*ing (332213), *prefabricated metal building and component manufacturing* (332311), *power boiler and heat exchanger manufacturing* (332410), *metal can manufacturing* (332431), and *spring (heavy gauge) manufacturing* (332611), etc.

A variety of NAICS categories are more focused on general classes of end-use products; for instance, *apparel manufacturing* (315), *chemical manufacturing* (325), and *furniture and related product manufacturing* (337). These products may be made from a variety of feedstocks; for instance, *nonupholstered wood household furniture manufacturing* (337122), *metal household furniture manufacturing* (337124), and *household furniture (except wood and metal) manufacturing* (337125). In the latter case, this furniture is made of materials such as plastics, reed, rattan, wicker, and fiberglass.

As the NAICS system now stands, there is no simple way to gather data on biobased products since there is not a NAICS three-digit code for products manufactured out of biobased feedstocks, as has been defined for the metal fabrication product manufacturing sector. Also, for the various three-digit NAICS categories more aligned with end-use products, there are no six-digit numbers set aside for biorenewable feedstocks, with few exceptions. For example, some information on the use of wood in biobased products could be captured in some of the subsectors like *nonupholstered wood household furniture manufacturing*, which was previously mentioned. However, a chair made out of a recently developed biorenewable feedstock, like polylactide acid (PLA), could not be easily captured. A chair that is predominantly made out of PLA would currently be captured in the *household furniture (except wood and metal) manufacturing* (337125) subsector.

Similar difficulties occur with other NAICS sectors. The ability to capture trade information is limited since many of the subsectors within the wholesale trade and retail trade sectors are similar to manufacturing subsectors. For instance, the sale of biobased furniture could be captured in both of the generic subsectors *furniture merchant wholesalers* (423210) and *furniture stores* (442110). Within the utilities sector, electricity generated completely from biorenewable feedstocks would be included in the generic category *other electric power generation* (221119), which includes solar, wind, and tidal power.

Availability of Data

Some data are simply not knowable or are so limited that one might question the return on investment of gathering the data. For instance, information on many indicators can be gathered only through surveys of industry. Since there are a wide variety of biobased products available, the kinds of data that can be gathered and aggregated to study the change in the overall industry are limited (e.g. jobs, etc.). Also, industry tends to report only data that is available in public reports, so the amount of technical information that can be gathered is minimal.

Data Accuracy

Underreporting of data can occur due to the methods used to capture data. Often company information is captured based on its primary product line. Since biobased product lines developed by traditional petroleum-based companies are likely to be a small fraction of total sales, the economic impact of the biobased product lines could be missed, resulting in an underestimation of the size of the biobased products industry.

The output volume of an intermediate product may be known, but the end-use consumption may not be as easily captured. For instance, a company producing enzymes could be selling its products into the biofuels sector or could be selling enzymes into the food industry.

Other indicators may not provide an accurate view of the industry as a whole. A bioeconomy index made up of the performance of major biobased companies has been suggested as a possible measure of the financial condition of the bioeconomy. This index might provide a good aggregate measure of U.S. bioeconomy companies, but global changes may be missed. Also, privately held companies would not be represented. As well, the indicator may be weighted toward the economic behavior of the large companies represented in the index. This becomes more problematic if only a small fraction of the large companies' outputs are biobased.

Economic Linkages

Economic activity is linked in complex ways. Inputs may be weakly connected to outputs or the outputs may significantly lag the inputs. This makes it difficult to accurately understand the cause-and-effect relationships of various activities.

Figure 11 displays the variation in the fraction of U.S. patents issued since 1976 that include the word ethanol in the patent title, together with the amount of fuel ethanol produced in the United States. The ramp-up of annual ethanol production occurs 20 years after the peak in patent activity. The patent peak "event" may have preceded and contributed to a ramp-up in company-developed trade secrets that then led to the growth of the industry. Alternatively, the rapid growth in the early 2000s may have little dependence on earlier patent activity. The patents may not be associated with fuel ethanol. The ramp-up in annual production may have more to do with the increase in the price of petroleum, the establishment of the volumetric ethanol excise tax credit, the phase-out of Methyl Tertiary Butyl Ether (MTBE), and consumer perception that ethanol was "green" energy.

There appears to be a recent increase in ethanol-related patent activity, which is lagging the ethanol production increase. This lag may be a result of backlogs in the U.S. Patent and Trademark Office.

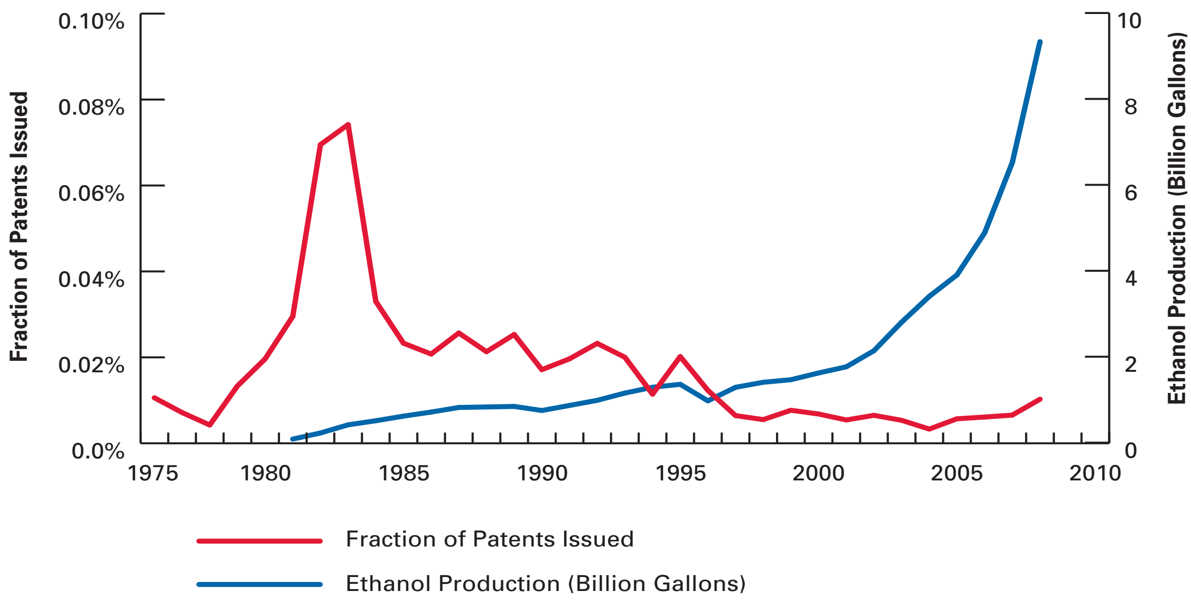

Figure 11. Lag in indicators—patents versus production.

Attainment of Legislative Intent

An often-cited reason for the need for a bioeconomy is the revitalization of rural America. Development of a metric that indicates progress toward a hard-to-measure goal such as this is not straightforward because of many of the aforementioned issues. Also, even if the Bureau of Economic Analysis and the Bureau of Labor Statistics begin gathering bioeconomy-related data, it is likely that detailed data for rural communities will be suppressed until the industry grows significantly larger.

The recent Iowa State University survey of biobased product companies suggests that a significant amount of the benefits from the manufacture and distribution of end-use biobased products may be more likely to occur in urban areas than in rural areas. In the study, the locations of the survey respondents were classified in two separate ways—by rural-urban commuting area (RUCA) classification and by the size of the town or city where the company was located [14].

Figure 12 displays the locations of the U.S. survey respondents by grouped RUCA classifications. The RUCA is a designation mechanism that uses the U.S. Bureau of Census urbanized area and urban cluster definitions and commuting information to classify census tracts [26].

As evident in the figure, the vast majority of the biobased product companies that responded to the survey are classified as metropolitan. This means the companies are located in a county with a city with 50,000 or more inhabitants or are located in a county where 10 percent or more of the inhabitants commute to an urbanized area.

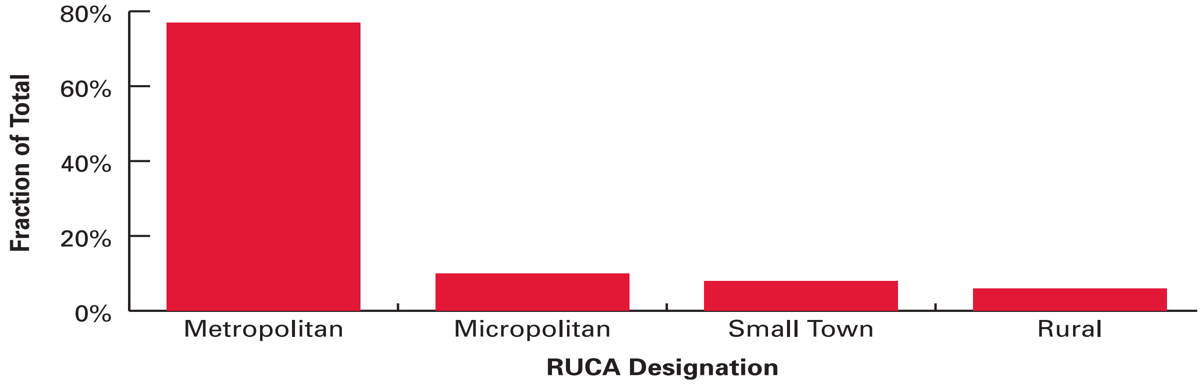

Figure 12. Location designation of U.S. biobased products survey respondents — rural-urban commuting area (RUCA) classification [14].

There are strengths and weaknesses of any definition. For example, a company located in Nevada, Iowa (population 7,000), is considered a metropolitan company because of the proximity to Ames, Iowa (population 51,000). Since so much of the U.S. population is classified as living within metropolitan areas, a different definition of rural and urban was investigated.

A second analysis of the respondents was conducted based on the size of the town or city where the company was located. Three broad classifications were used: cities with 50,000 or more inhabitants, cities with 20,000–49,999 inhabitants, and cities with fewer than 20,000 inhabitants. Figure 13 shows the locations of the respondents by city size.

A city-size approach has weaknesses as well. For example, a company located in Clive, Iowa (population 13,000), is designated to be within a small population city even though it is located 7 miles, center-to-center, from Des Moines, Iowa (population 199,000). Clearly, a more in-depth analysis is required to fully understand the extent to which nonfarm businesses are directly impacting the economies of rural America.

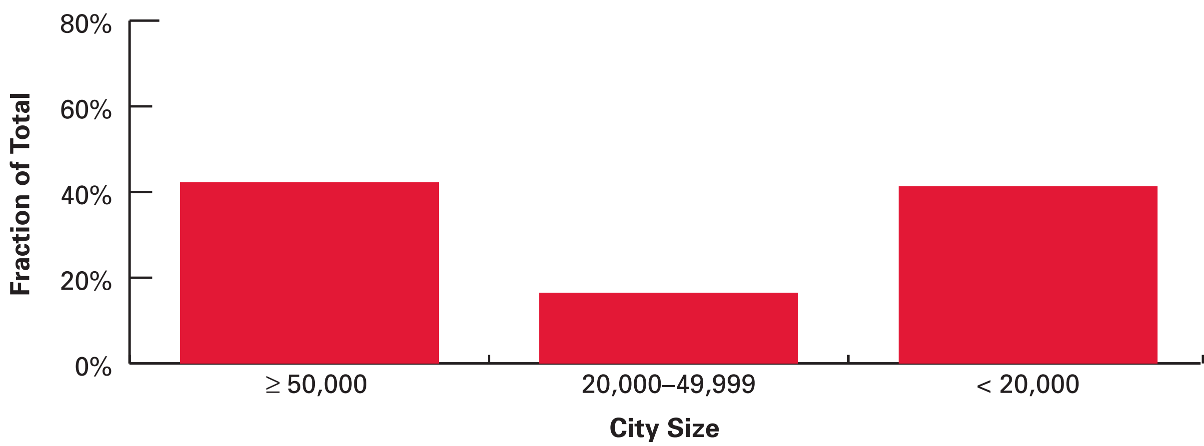

Figure 13. Location designation of U.S. biobased products survey respondents —city size [14].

4. Selection of Biobased Product Economic Indicators

The process of developing a short list of economic indicators of the bioeconomy began with the generation of an extensive list of potential indicators. A preliminary list of indicators was obtained from USDA, and this list was expanded through work at Iowa State University. Sixty-nine indicators were delineated and broadly grouped as either input, investment, or output indicators.

A public forum was convened in Washington, D.C., in November 2007 to garner additional recommendations, to further scrutinize the list of indicators, to group like indicators, and to reduce the set to a shorter list for further analysis. Invitees included individuals from large and small manufacturers, industry associations, academia, and Federal agencies that were reliant on economic data or were responsible for data generation.

A second public forum was held in Chicago, Illinois, in April 2008 at the Biotechnology Industry Organization's World Congress on Industrial Biotechnology and Bioprocessing. Participants numerically scored the refined list of indicators, and discussions were then held to try to understand why indicators were rated differently between the D.C. forum and the Chicago forum.

The combined results from the two forums were used to reduce the original list of indicators to 31, which were explored in more depth. The group was further reduced to a final list of 16 key indicators.

4.1. Potential Economic Indicators

An extensive list of economic indicators was developed through the process highlighted above. The various indicators were grouped in the broad categories of inputs, investments, and outputs. The complete list of potential indicators is included in Tables 2–4 below.

There are many more economic indicators that can be developed beyond what is listed below. Some indicators are very narrowly defined. They may provide a lot of detailed information about a niche, but a more robust, industry-wide analysis is preferred. Also, items like life-cycle analysis and issues like food versus fuel, while very important, are not included because they are not economic indicators in the classic sense.

Inputs

Inputs are the basic resources for the production recipe of a business. Outputs from one industry may serve as inputs for another. Inputs may include physical goods or nonindustrial inputs like labor.

Table 2. Potential input measures of the bioeconomy.

Inputs	Indicators and Examples
Agricultural Commodities Used for Biobased Products	Grain (corn, sorghum, wheat)
	Oilseeds (soybeans, canola, rapeseed)
	Nonforage grasses (switchgrass, miscanthus)
	Woody crops
	Other crops
Processed Agricultural Products and By-Products Used for Biobased Products	Wet and dry corn milling by-products
	Fats and oils
	Woodwaste
	Other vegetative pulps and fibers
	Other by-products (cotton hulls, bagasse)
Other (Variable) Manufactured Inputs	Chemical and other inputs (enzymes, yeasts)
Natural Resources and Energy	Land in energy-dedicated crops
	Water
	Coal
	Natural gas
	Petroleum
	Other energy inputs
Labor Requirements	Agricultural commodity production jobs related to biobased products
	Biofuels manufacturing jobs
	Other biobased manufacturing labor (fibers, construction materials, plastics, lubricants, adhesives, solvents)
Input Markets (Prices)	Agricultural commodity prices (corn, soybeans)
	Processed agricultural products prices
	Other (variable) input prices
	Agricultural land rents
	Energy prices (coal, natural gas, petroleum)
	Agricultural commodity production wages (see crops above)
	Biofuels manufacturing wages (ethanol, biodiesel)
	Other biobased manufacturing wages (fibers, construction materials, plastics, lubricants, adhesives, solvents)

Investments

Investments are sometimes referred to as readiness indicators. They put in place mechanisms and equipment to allow the industry to grow. This includes tax policies, public and private R&D, education initiatives, number of degrees, etc.

Table 3. Potential investment measures of the bioeconomy.

Investments	Indicators and Examples
Direct Public Spending	Direct payments to individuals (USDA Bioenergy Program)
	Grants (DOE Regional Biomass Energy Program, DOE Alternative Fuel Transportation Program)
	Loans and loan guarantees
	Infrastructure to new plants (roads, pipeines, other)
	Other incentives (federal, state, local)
	Other direct spending
Indirect Public Spending	Bioeconomy promotion
	Bioproduct procurement (FB4P)
	Research and development
	Workforce development/education systems (agricultural and science degree programs)
	Transportation infrastructure (highways, locks and dams, multimodal transportation)
Tax Policy	Production tax credits, tax rebates, depreciation allowances
Trade Policy	Tariffs and quotas
Private Firm Formation	Number of firms
Private Capital Investment	Plant and equipment
	Storage and distribution infrastructure (rail capacity, rail cars, grain elevators)
	Other investment
Private Research and Development	Company-funded research and development
Other Private Investment	Stock market indicators (bioindustry stock index, initial public offerings)
Private/Public Ventures	University program sponsorship

Outputs

Output measures are important because they are the most connected measure to the end goal of reduced energy dependence, etc. The industry can never be robust if there are not outputs that generate income and profits.

Table 4. Potential output measures of the bioeconomy.

Outputs	Indicators and Examples
Direct Output: Commodity Flow	Biofuels production (ethanol, biodiesel)
	By-products of biofuels production (distillers' grains)
	Fibers production
	Construction materials production
	Plastics production
	Adhesives production
	Lubricants production
	Solvents production
	Other biobased products
Direct Output: Prices	Biofuels sales (ethanol, biodiesel)
	By-products of biofuels sales (distillers' grains)
	Other biobased products
Direct Value Added	Biofuels value added (gross domestic product)
	Other biobased products' value added (gross domestic product)
Indirect Economic Outcomes	Estimated multiplier effects from biobased production (intermediate requirements)
External Outcomes	Emissions (CO_2, other air emissions, water emissions, solid waste)
Industrial Absorption	Consumer acceptance (E85 stations, flex-fuel vehicles sold)
Intellectual Property	Patents
Offsets, Adjustments, and Disruptions	Petroleum industry and distribution
	Agricultural support industries and systems (reduction in acreage for food and livestock feed)
	Environment (land removed from conservation programs)

4.2. Selection Process

A public forum was convened in Washington, D.C., in November 2007 to garner public input on the importance of various economic indicators. Individuals were invited to participate from a number of Federal agencies, including the DOE, U.S. Department of the Interior, Environmental Protection Agency (EPA), General Services Administration, International Trade Commission, National Institute of Standards and Technology (NIST), National Renewable Energy Laboratory, National Science Foundation, Oakridge National Laboratory, Office of the Federal Environmental Executive, Office of Management and Budget, Sandia National Laboratory, and the USDA.

Individuals associated with Federal agencies responsible for gathering data were also invited. These agencies included the Bureau of Economic Analyses, Bureau of Labor and Statistics, Bureau of Transportation Statistics, Census Bureau, Energy Information Administration, International Trade Administration, USDA National Agricultural Statistics Service, National Science Foundation, and Research and Innovative Technology Administration.

Several associations with interest in the bioeconomy were invited, including the Agricultural Utilization Research Institute, American Agriculture Economics Association, American Council for an Energy Efficient Economy, American Farm Bureau, American Forest and Paper Association, Biotechnology Industry Organization, BIOWA, Farm Foundation, MBI International, Midwest Plains Institute, National Biodiesel Board, National Corn Growers Association, National Resources Defense Council, Renewable Fuels Association, Union of Concerned Scientists, and United Soybean Board.

Invitations also went out to a short list of individuals from large private companies that either produce biobased products or are in the biobased products supply chain. A number of small biobased product companies were also invited. Individuals from a number of universities engaged in research associated with the bioeconomy were invited as well.

Approximately 30 individuals attended the forum. Two primary questions were posed to the attendees to narrow the boundaries of the conversation.

- What measures of the bioeconomy should the U.S. Government collect and make available to help you run your biobased product company more effectively and to help your company grow?
- What measures of the bioeconomy need to be collected and made available to help policy makers gauge the health of the industry, develop new legislation, and assess the impact of past legislation?

The first question drives the discussion toward leading indicators to better understand future trends. The second question tends to drive the discussion toward lagging indicators that measure how the industry has changed as a result of new policies, investments, etc.

The attendees first reviewed the proposed list of indicators and then brainstormed additional possibilities. Six additional indicators and topics were discussed, including:

- Private firm formation—small versus large companies
- Percent utilization of plants and equipment
- Private capital investment in harvest, storage, and transportation
- Carbon offsets
- Food versus fuel
- Life-cycle analysis

Since the food-versus-fuel issue is not an economic indicator, this topic was restated as “food production offsets.” Also, life-cycle analysis is not considered an economic indicator. This issue might possibly be rephrased in the form of an indicator. For instance, a life-cycle analysis credit might be employed. This was not considered further due to lack of support by attendees.

The attendees then debated the importance of the various indicators and publicly indicated their top choices. The selections made by participants representing industry were tallied separately from participants from government. Figure 14 displays the top selections, sorted by indicator category, for all votes. The category "indirect public spending" includes items like government-funded research and development. Direct public spending includes items like grants to individual companies.

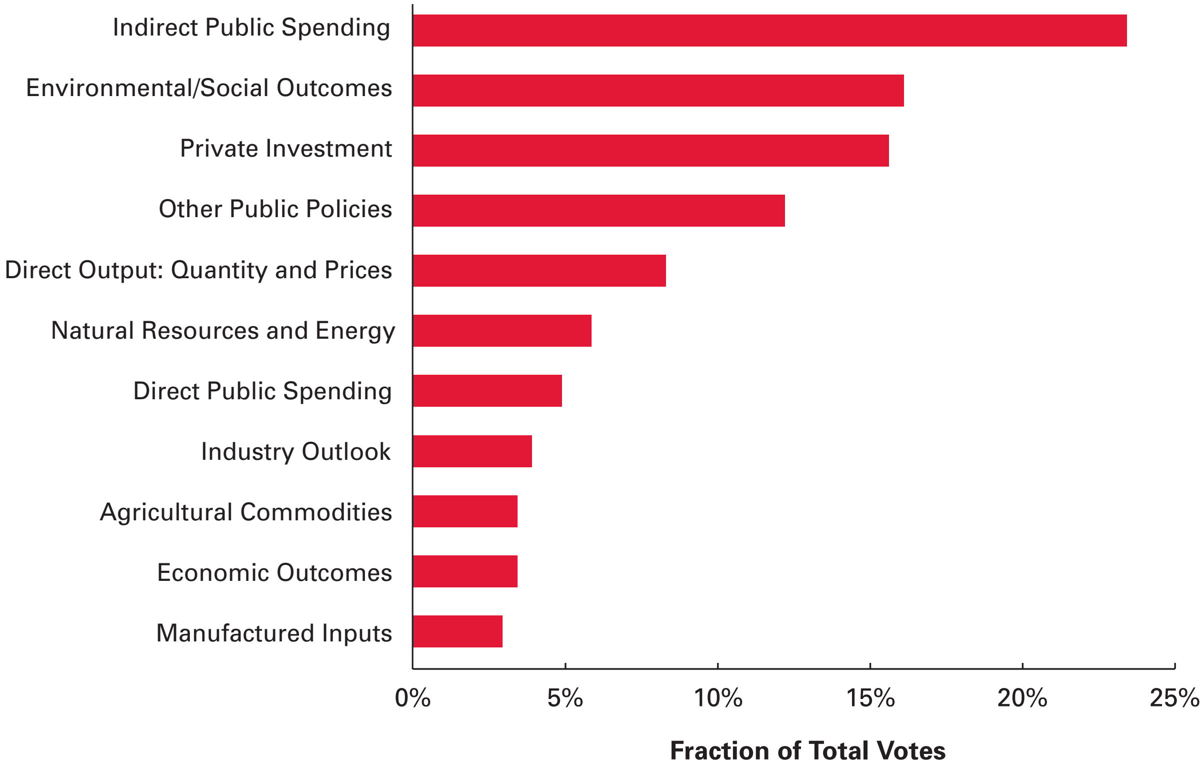

Figure 14. D.C. Economic Indicators and attendee votes by category.

The top-scoring indicators (each capturing 3 percent or more of the total votes) are listed by primary type below.

- The top-rated input indicator was the price of energy inputs.
- The six top-rated investment indicators were
  - government tax and trade policies;
  - private capital investment in harvest-storage-transportation infrastructure;
  - public bioeconomy research and development spending;
  - preferred procurement programs;
  - workforce development systems;
  - public spending on bioeconomy promotion.
- The four top-rated output indicators were
  - carbon offsets from biobased production;
  - food production offsets;
  - chemical-based production sales;
  - industrial absorption and consumer acceptance.

Four of the top six indicators at the D.C. forum related to government. This may be because many of the attendees at the forum were either government employees or representatives from the large manufacturers and industry associations.

Government employees drove support for three of the top six investment indicators in attendance. Attendees from the business sector cast 50 percent or less of the votes for public bioeconomy research and development spending, preferred procurement programs, and workforce development systems.

Harvest, storage, and transportation infrastructure was rated high by attendees because there was a perception that insufficient infrastructure was constraining industry growth.

Output indicators of end-use biobased products did not rate high, in part because votes were split between various indicators. For example, attendees could choose between construction materials, plastics production, adhesives production, lubricants production, solvents production, other biobased products production, other biobased products' prices, and other biobased products' value added.

A few industry representatives voiced support for some type of composite leading indicator of the condition of the industry after the ranking exercise was conducted. As such, it did not appear in the final D.C. rankings.

A second public forum was held in Chicago, Illinois, in April 2008 in partnership with the Organisation for Economic Co-operation and Development (OECD). It was held in conjunction with the Biotechnology Industry Organization's World Congress on Industrial Biotechnology and Bioprocessing. The forum was open to all conference attendees. The same two questions were posed to the roughly 60 participants.

- What measures of the bioeconomy should the U.S. government collect and make available to help you run your biobased product company more effectively and to help your company grow?
- What measures of the bioeconomy need to be collected and made available to help policy makers gauge the health of the industry, develop new legislation, and assess the impact of past legislation?

Attendees were asked to privately score a reduced list of 30 indicators on a one-to-five scale. A rating of 1 equated to *very little policy and business relevance*. A rating of 5 equated to *very high policy and business relevance*. Figure 15 displays the top selections of the participants, sorted by indicator category.

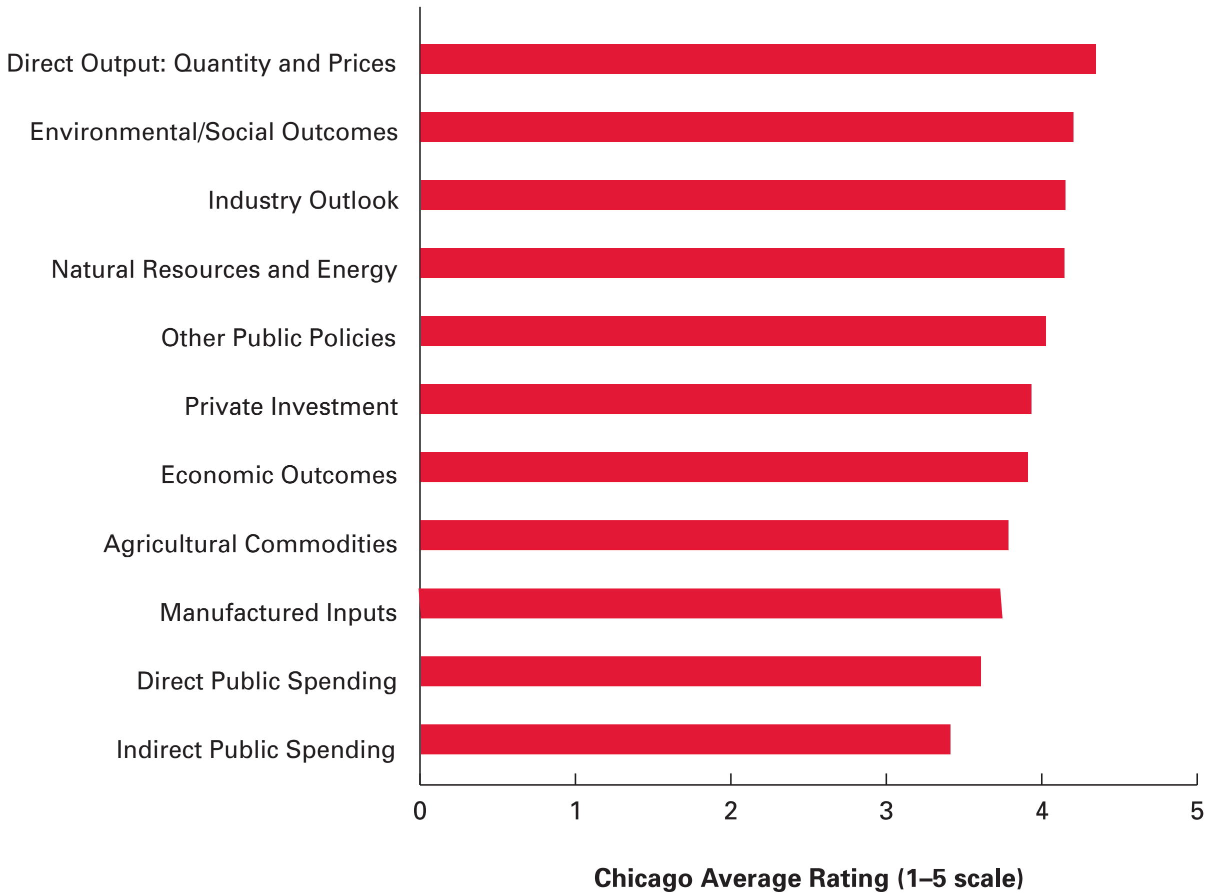

Figure 15. Economic indicators and Chicago attendee rating by category.

The top-scoring indicators (all scoring 4.2 or higher on a 5-point scale) are listed by primary type below.

- The top-rated input indicator was cropland in energy-dedicated crops.
- The two top-rated investment indicators were
  - company-funded research and development;
  - private investment in plant and equipment.
- The eight top-rated output indicators were
  - biofuel production levels;
  - industrial absorption and consumer acceptance;
  - emissions from biobased production;
  - carbon offsets from biobased production;
  - chemical-based production sales;
  - by-products production levels;
  - biofuels price levels;
  - value-added (GDP) from biobased production.

Information was gathered on whether the respondents were a manufacturer and whether they were from the United States. The differences between the ratings between manufacturers and nonmanufacturers and between U.S. attendees and non-U.S. attendees were small for most of the indicators. Manufacturers were much more interested in a composite index of industry expectations than nonmanufacturers. U.S. respondents were also much more interested in a composite index than non-U.S. respondents. Prices of energy inputs for biobased production were of less interest to manufacturers than to nonmanufacturers.

Direct comparisons between the D.C. and Chicago forums are not valid because of the different approaches taken at each location and because of the different number of indicators addressed. That said, some broad differences of opinion were observed.

- D.C. attendees preferred investment indices. Attendees at the Chicago forum preferred output indicators.
- While four of the top six indicators in D.C. were government related, none of the top six indicators at the Chicago forum were related to government.
- *Manufactured inputs* ranked last at both forums.
- *Indirect public spending* ranked significantly higher at the D.C. forum, while *agricultural commodities* and *direct public spending* ranked significantly higher at the Chicago forum.
- There was general consensus on where *other public policies* and *natural resources and energy* should be ranked.

Several indicators are currently widely tracked because they are key indicators of the condition of the industry, but they were not rated high in either forum. For example, the volume of ethanol production was ranked in the middle overall. There was a sense that indicators like ethanol production were not ranked high by some participants because they were more interested in indicators that were not currently available.

The results from the two forums were combined to produce an overall ranking. The list of indicators is included as Tables 5–7 below, together with brief commentary regarding positive and negative attributes.

Table 5. Top-ranked input indicators.

Indicator	Comments
Prices of energy inputs for biobased production	Affects industry profitability.
Amount of cropland in energy-dedicated crops	Affects food vs. fuel debate, conservation, and petroleum replacement. Track both acreage and yield increase. Land in CRP can be considered.
Quantity of grain inputs used in biobased production	Affects food vs. fuel debate and petroleum replacement. Survey needed for nonfuel products.
Quantity of chemical and other inputs used in biobased production	Cost of enzymes important to the success of the industry. Difficult to measure. Survey needed.
Quantity of processed agricultural products used in biobased production	Probably a small fraction of total product inputs.
Quantity of oilseed inputs used in biobased production	Can be picked up in feedstock production (acreage and yield).

Table 6. Top-ranked investment indicators.

Indicator	Comments
Tax and trade policies	Includes rebates, production tax credits, etc. Affects many aspects of the industry, including profitability.
Government spending on bioeconomy R&D	Indicates government commitment. Distributes the R&D burden.
Private capital investment in plant and equipment	Indicates productive capacity and industry's commitment and expectations. Difficult to get data. Includes HST. Survey needed.
Company-funded research and development	Indicates industry's commitment and expectations. Survey needed.
Private capital investment in HST infrastructure	Cannot know this in detail without a company survey. Subset of all private capital investment.
Government spending on transportation infrastructure	This is not an indicator of the health of the industry.
Government spending on bioproduct procurement programs	A better measure might be the dollar value of goods purchased (see GDP).
Private firm formation	Production of new plants higher than old. Mergers reduce the indicator.
Percentage utilization of private plant capital	Investment in capital a better measure.
Government grants and direct payments to firms and individuals	Not a good measure of the health of the industry.
Government spending on loans and loan guarantees	Private sector investment a better measure of industry health. Not as important once industry is growing.
Government spending on workforce development/education systems	Impact on industry can lag investment. Difficult to measure impact.
Government spending on bioeconomy promotion	D.C. ranking weighted by government employee input. Difficult to measure impact.

Table 7. Top-ranked output indicators.

Indicator	Comments
Carbon offsets from biobased production	Environmental benefits.
Industrial absorption and/or consumer acceptance of biobased products	Market potential and success. Survey needed.
Production levels (sales) of chemical-based (and fiber-based) products	Market success, like fuel sales. Difficult to measure. Survey needed.
Emissions from biobased production	Environmental benefits.
Biofuels price levels	Industry profitability.
Direct value added (GDP) from biobased production	Industry size and contribution. Industry detail needed.
Production levels (gallons) of biofuels	Market success.
Quantity (tons/gallons) of by-products from biofuels production	Helps stabilize the industry. Need quantity and price. Survey needed.
Composite index	Aggregate measure of industry health to facilitate dialog. Measure of past activity. Might consider crush margin as an alternative.
Food production offsets (food vs. fuel)	This is an issue, not an indicator. Correlation difficult.
Estimated multiplier effects from biobased production	Provides little additional information. Depends on context.
PMI-type composite index	Development of a leading indicator of business activity should be industry led.

From the indicators listed in Tables 5–7, a subset was selected for detailed analysis. Forum ranking alone did not drive the selection process. Additional selection criteria were developed based on three considerations: (1) the indicator's potential value to end-use biobased product companies since there was little representation from this sector at the open forums; (2) the indicator's utility in economic analysis; and (3) various data quality and data availability issues.

The results from the Iowa State University survey of end-use biobased product companies were examined to learn what is limiting the growth of companies and to address which indicators might be more valuable to this sector of the bioeconomy [14]. Figure 16 displays the level of importance given to various items. The top three limitations to growth are comparable to several of the economic indicators that surfaced in the present work: transportation costs, which are highly dependent on the price of energy; raw material costs; and capital.

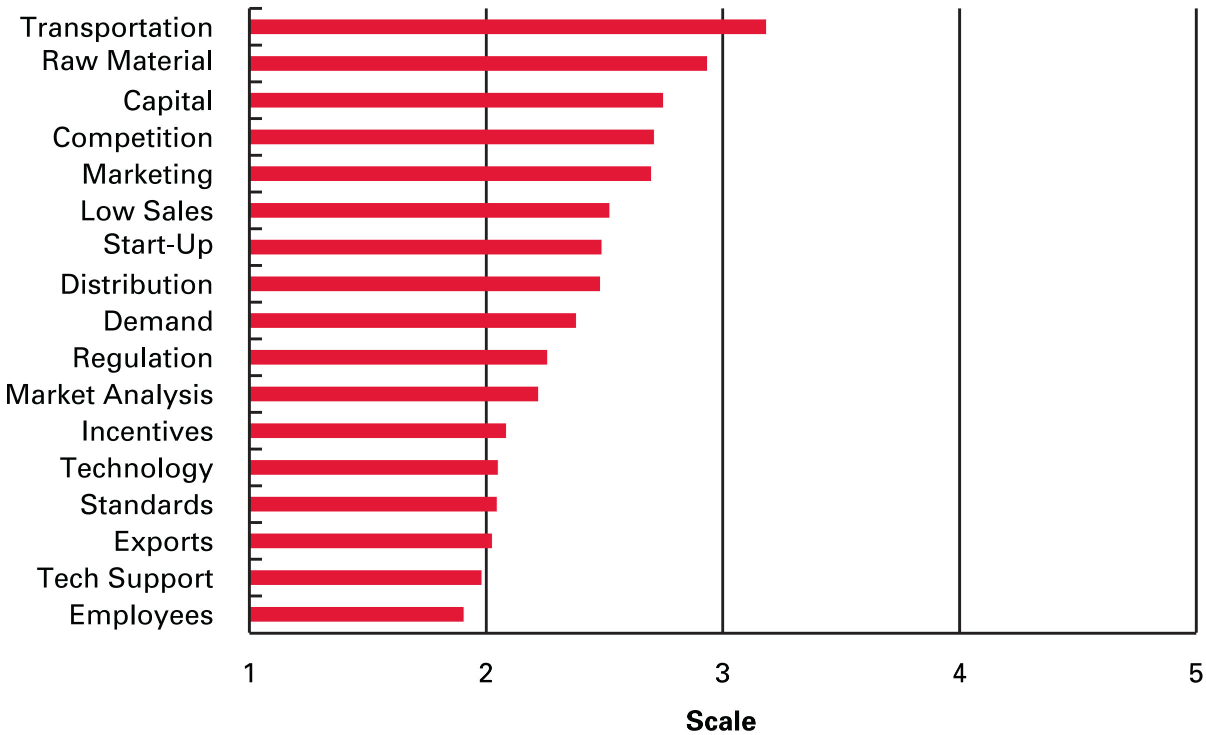

Figure 16. Relative importance of factors on a scale of 1-5 limiting the growth of biobased product companies [14].

The indicators were also rated based on their utility in conducting various types of economic analysis. This rating was combined with the ratings obtained in the D.C. and Chicago forums to construct a measure of overall indicator importance.

Several issues relating to the availability and quality of data for research and analysis were also considered. Eight different data quality measures were constructed to address the following issues:

- Government sources of data are preferred over nongovernment sources because they are more likely to maintain continuity, consistency, and objectivity in their data collection methods.
- Indicators that can be measured using currently available data series are preferable to those that require new data collection initiatives. In some cases, existing data collection programs might be adapted with relatively minor changes to survey instruments and classification systems in order to address questions relating to the bioeconomy.
- Data that are collected on a weekly, monthly, or quarterly basis are superior for economic modeling and forecasting purposes. Data collected on an annual basis are also useful for monitoring trends in the bioeconomy. Highly detailed data, such as that collected in the Census of Agriculture, may be collected only every 5 years. Data for still other indicators might only be obtained from one-time scientific studies.
- Indicators that require detailed information about the operations of firms may be subject to high levels of data suppression, even when they are collected by

government sources. Data are frequently suppressed for small industries in order to protect the confidentiality of individual firms.

- Detailed data about specific crops and industries are preferable to less detailed data at the aggregated industry or sector level. For some indicators, changes to NAICS would substantially improve the level of detail available for analysis. For other indicators, detailed data collection might prove to be so onerous that analysis never moves beyond broad sector or economy-wide levels.
- The reliability of a particular indicator depends on the methods that were used for data collection. In general, it is assumed that government program data, fiscal data, and census data are highly reliable. Data that are collected through surveys, whether publicly or privately administered,may be less reliable depending on the sample size and quality of the survey. For indicators based on data that are estimated rather than directly observed or collected, the reliability of the data depends upon the assumptions and research methods employed.
- For some indicators, uniform standards of measurement and commonly accepted definitions have yet to be developed. This is particularly the case with indicators relating to environmental or societal trade-offs. For other indicators, changes in definitions over time make the analysis of trends more difficult.

Table 8 summarizes how each indicator was evaluated using the eight data quality measures. These data quality measures were combined with the overall importance measures to obtain a final score for each indicator. The actual scoring for each indicator is illustrated in Table 9.

Table 8. Selection criteria weightings.

Criteria	Value	Weight
Source of data	Government	2
	Nongovernment	1
Availability of data	Currently collected	3
	Existing collection framework could be adapted	2
	New collection effort or framework required	1
Frequency of current or likely data collection	Weekly, monthly, or quarterly	3
	Annually	2
	Less frequently than annual	1
Access to data	Publicly available	2
	Proprietary data	1
Detail currently available	Detailed crop or industry	3
	Aggregated industry or sector	2
	Economy-wide	1
NAICS change would improve detail	Yes	2
	No	1
Reliability of data	Census, fiscal, or regulatory data	3
	Survey	2
	Other	1
Other measurement issues/ problems	Yes	-3
	No	-1
D.C. forum rating	Top third	3
	Middle third	2
	Bottom third	1
Chicago forum rating	Top third	3
	Middle third	2
	Bottom third	1
Rating by Iowa State University authors	High importance	3
	Moderate importance	2
	Lower importance	1
Total score	The total score was calculated as the product of the importance ratings (first three) plus the sum of weights for the data ratings (last eight).	

Table 9. Ranking of top 30 indicators.

Description	Source	Availability	Frequency	Access	Level of Detail	NAICS Change Would Improve Detail	Reliability	Other Measurement Problems	Importance—D.C. Forum	Importance—Chicago	Importance—ISU	Overall Score
Biofuels price levels												34
Production levels (sales) of chemical and fiber-based products												29
Prices of energy inputs for biobased production												28
Tax and trade policies												28
Direct value added (GDP) from biobased production												26
Private capital investment in plant and equipment												25
Production levels (gallons) of biofuels												25
Industrial absorption and/or consumer acceptance												24
Emissions from biobased production												24
Government spending on bioeconomy R & D												23
Quantity of by-products from biobased production (distillers' grains)												23
Amount of cropland in energy-dedicated crops												21
Quantity of grain inputs used in biobased production												19
Company-funded R & D												19
Carbon offsets from biobased production												19
Quantity of chemical and other inputs used in biobased production												16
Private capital investment in HST												16
Government spending on transportation infrastructure												16
Quantity of oilseed inputs used in biobased production												16
Government grants and direct payments to firms/individuals												15
Private firm formation												15
Percentage utilization of private plant capital												14
Quantity of processed agricultural products used in biobased production												14
Government spending on bioproduct procurement programs												14
Estimated multiplier effects from biobased production												13
Government spending on loans and loan guarantees												13
Government spending on workforce development/education systems												13
Government spending on bioeconomy promotion												13
Composite index of industry expectations (PMI)												13
Food production offsets (food vs. fuel)												12

Figure 17 depicts an example of a relatively high-scoring indicator—the monthly production level of biofuels, measured here by the volume of ethanol production. This indicator scored among the top half in both forums and was rated highly for its usefulness in economic analysis. The indicator also scored well in several data quality measures. Ethanol production volume is publicly available on a monthly basis and not subject to suppression because it is a measure of the total production of a commodity. The level of detail is high, as ethanol is one of the few biobased products with its own NAICS code. The reliability is also high because these data are directly measured.

Figure 17. U.S. fuel ethanol oxygenate production (thousands of barrels)—Example of a high-scoring indicator. [27].

Figure 18 depicts an indicator that scored lower in this analysis, private firm formation, which is a measure of the number of new bioeconomy-related firms created. This indicator received an overall average rating at the forums but scored lower in the additional analysis for a number of reasons, including data availability, frequency, level of detail, and other measurement problems.

- Data availability—Most of the readily available data on changes in the number of firms by industry measures the *net* change in firms, which is influenced both by the rate of new firm formations as well as firm deaths or dissolutions. Data series that describe the actual number of firm births in a given year are not available at high levels of industrial detail.

- Data frequency—Data for smaller firms without paid employees are released on an annual basis with a 2-year lag. These firms accounted for 48 percent of U.S. manufacturing firms in 2006 and would likely represent many of the newer, start-up firms. Data for firms with employees on payroll are available on a quarterly basis with a lag time of approximately 6 months.
- Level of detail—The current industrial classification system is not detailed enough to cleanly define sets of firms that are engaged in biobased manufacturing. With the exception of firms in the biofuels industries, most firms engaged in most other types of biobased production are grouped with other firms producing similar, but nonbiobased, products.
- Measurement issues—Data on the number of firms by industry are available on a Standard Industrial Classification (SIC) basis prior to 1997 and on an NAICS basis from 1998 onward. Data anomalies related to the conversion from SIC to NAICS confound attempts to document changes over time.

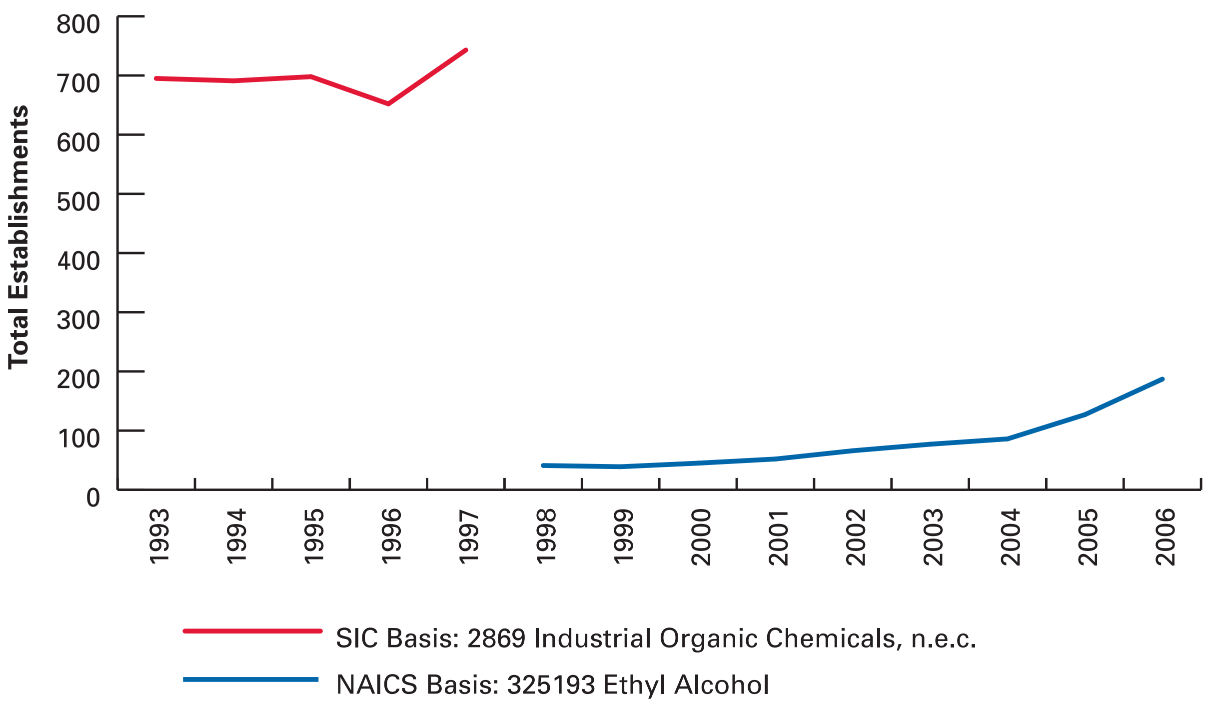

Figure 18. Private firm formation—Example of a low-scoring indicator.

Based on the thorough review of all of the indicators illustrated in Table 9, a short list of indicators emerged. In all, 16 of the original set of indicators were selected for a more detailed examination. Studies of the remaining indicators are beyond the scope of this report. The final list of indicators is displayed in Table 10. This list is not meant to be all-inclusive, but should be viewed as a starting point for future discussions and studies.

Table 10. Key economic indicators of a biobased economy.

	Type	Indicator
1	Input	Prices of energy inputs for biobased production
2	Input	Amount of cropland in energy-dedicated crops
3	Input	Quantity of grain and oilseed inputs used in biobased production
4	Input	Quantity of chemical and other inputs used in biobased production
5	Investment	Tax and trade policies
6	Investment	Government spending on bioeconomy R&D
7	Investment	Private capital investment in plant and equipment
8	Investment	Company-funded research and development
9	Output	Carbon offsets from biobased production
10	Output	Industrial absorption and/or consumer acceptance of biobased products
11	Output	Production levels (sales) of chemical-based (and fiber-based) products
12	Output	Emissions from biobased production
13	Output	Biofuels price levels
14	Output	Direct value added (GDP) from biobased production
15	Output	Production levels (gallons) of biofuels
16	Output	Quantity (tons/gallons) of by-products from biofuels production

The next section provides brief commentary on several indicators that did not make this short list and the reasons why they did not. Studies of these indicators are beyond the scope of this report.

Following this, in Chapter 5, is a summary of each of indicators 1 through 16 above. This includes a discussion on the relevance of the indicator, how it is or could be measured, and the availability of the data.

Chapter 6 explores how various individual indicators could be combined to form a composite index. Discussions are also included on how individual indicators might be analyzed together to monitor industry operating margins and other measures of the condition of the industry.

4.3. Potential Future Studies

There are a number of proposed indicators that did not make the short list of key indicators but that might warrant further study in the future.

Employment

Total nonfarm payroll employment is often included in most analysts’ short list of economic indicators. Labor employment in bioeconomy activities might be tracked over time, and biobased labor employment to total labor employment in the economy could be used as measures of the growth of and transformation to a biobased economy.

The most straightforward way to measure labor employment over a given period of time is to simply measure the number of workers employed over that period of time. The U.S. Department of Labor's Bureau of Labor Statistics (BLS) uses business survey data and payroll data to construct economy-wide monthly measures of labor employment, expressed as thousands of workers employed. These data are also available at the industry and sector levels and are broken down into job types (service employment, manufacturing employment, etc.). The survey methods used by the BLS might be directly applied to measure total employment in the biobased sector of the economy, and employment in the biobased sector could be broken down by industry, location, type of job, etc.

Though an employment indicator could be developed, the value of this indicator, at this time, is deemed low in comparison to many of the other indicators that can be computed. For instance, indicators like gross domestic product are driven by a number of changes in industry, including the number of employees and the wages per employee. An industry can grow, as defined by GDP, but employment can grow at a slower rate, or even decrease, if the productivity of the industry grows fast enough. Finally, mechanisms are not currently set up at the federal level to collect much of this information.

Until better methods are developed to define biobased products and to systematically collect GDP data, other estimates of employment can be relied upon. For example, there are various studies on employment within the biofuels industry (e.g., Miranowski [28]). Some employment numbers have also been released as part of the Iowa State University study of the companies in the BioPreferred database [14].

Public Attitudes and Understanding

Public attitudes toward and understanding of biobased products are important for the growth of the bioeconomy for at least two reasons. First, the government's commitment and ability to financially support the growth of the bioeconomy relies on a willing public. Second, public attitudes toward and understanding of biobased products will influence the demand for these products, which ultimately will determine the future of the bioeconomy. Measuring public attitude could be used as a leading indicator.

Typically, attitudes and understanding are measured by surveys. The National Science Board's biennial *Science and Engineering Indicators*, for example, reports the results from the National Science Board's (NSB's) survey of domestic and international public attitudes toward and understanding of science and technology (S&T). The survey includes questions designed to measure S&T literacy, primary sources of information about S&T, understanding of the nature of science inquiry, and attitudes toward S&T, to name a few.

The Conference Board's Consumer Confidence Index (CCI) provides a model that could be used to furnish an indicator of public attitudes and understanding regarding the bioeconomy [29]. The Conference Board oversees a monthly survey of 5,000 representative U.S. households to measure consumer attitudes toward a number of dimensions of the economy. The survey includes questions about consumer attitudes toward current and expected future business conditions, current and expected future labor market conditions, current and expected future income, future buying plans, future vacation plans, perceptions of the stock market, expectations about inflation, and so on. The survey results are aggregated into a single number, the CCI. Increases (decreases) in the CCI are interpreted to mean that consumers are more optimistic (pessimistic) about the current and expected direction in which the economy is heading.

An indicator of public attitudes toward the bioeconomy could be developed by applying the Conference Board's index number methodology to the results of a survey similar to the attitude/understanding survey used by the NSB.

Though a public attitudes indicator could be developed, the value of this indicator at this time is considered low. Various alternative output measures are proposed that assess the willingness of the industry to produce products. These products will not be produced over time if the industry does not project customer demand and if the companies do not remain profitable. Also, as long as the biobased products meet similar performance standards as traditionally produced products, it is likely that cost and availability are more important indicators of consumer intentions.

Plant Enzyme Patents

Current biofuel production requires enzymes to enhance production efficiency. Future biofuel development will require additional enzymes to successfully transition into efficient and profitable biomass-based energy systems. Since lack of new enzymes enzymes could constrain the growth of the industry, an indicator that focuses on innovation in this area might be of value.

Figure 19 displays the sharp increase in plant enzyme patents that occurred during the late 1990s, as a percentage of all enzyme patents, and the overall leveling off of that growth during the first decade of 2000 (see [30]). It remains to be seen how closely the level of plant enzyme patent activity will align with the rapid increase in biofuel production and the incentives for the development of new enzymes.

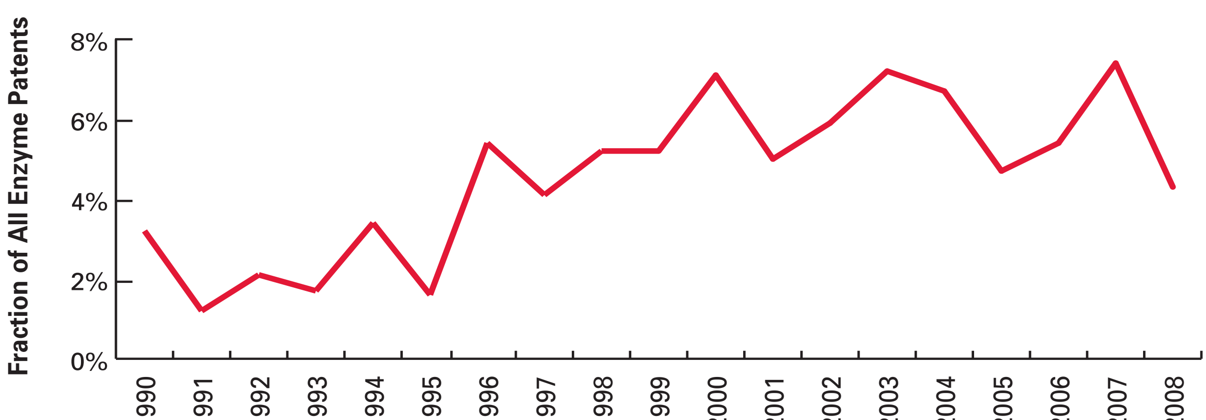

Figure 19. Plant enzyme patents.

Though an enzyme-related indicator could be developed, it is not proposed that it be developed at this time. Various proposed output measures are dependent on the successful development of cost-competitive enzymes. Also, as discussed previously, patents may only be a small fraction of the technical advances made in an industry, with the remaining developments held as trade secrets. Also, many patents that are awarded never lead to a commercial product. Lastly, it will be difficult to ascertain the fraction of enzyme sales that are supporting new markets versus existing markets.

Life-Cycle Analysis

There is widespread belief that biobased products are friendlier to the environment than petroleum-based products. In fact, biobased product companies recently reported that the environment is the number one reason their customers buy their products [14]. Life cycle analyses (LCA) are often an integral part of environmental discussions because they are a formalized process for evaluating whether the creation of the product, from raw material extraction through final disposal, is sustainable or whether the impact on the environment is less than the competition.

Since many biobased products are more costly than the alternative [14], an LCA has become one tool to show that a more expensive biobased product will cost less over the life of the product (either monetarily or by some environmental measure). While this analysis may be important in comparing the relative cost of two products, the analysis, per se, is not an economic indicator.

An alternative approach could be taken by creating a credit that is based on an LCA score. The credit could then be used as an indicator. Taking this kind of an approach might warrant further analysis.

Food versus Fuel

The food-versus fuel-debate has received considerable attention recently because of rising food costs that are being attributed to increased cost of commodities, in part due to an increased demand for biofuel feedstocks. Even though the food-versus-fuel debate has received considerable attention, it does not qualify as an economic indicator. Certain dimensions of the debate, such as food production offsets, may be a candidate indicator, but the debate itself is not.

Further, short-run market fluctuations or aberrations do not constitute useful indicators. For example, the price of crude oil reached $147/barrel (bbl) in July 2008 and corn followed suit, increasing to nearly $8/bushel (bu). By November 2008, oil went below $60/bbl and corn significantly below $4/bu.

The influence of biofuels policies on the prices of food in the United States and globally is a subject of intense debate and academic scrutiny. Over the next few years, the USDA as well as other responsible agencies should be able to better determine the parameters of the relationships between biofuels policies and food prices in order to better inform future policy.

Multiplier Effects

Biofuel and biobased product investments may play an important role in the economic future of rural communities. Yet, much controversy surrounds the impacts of these investments on local and regional employment, value added, and income. Most of the existing local multiplier analyses consider one plant size (e.g., 50 million gallons) and ignore economies of plant size, only consider rural communities that lack the industry-supporting services available in more urban settings, and miscalculate or ignore the impacts of construction activity.

Direct and multiplier impacts are important indicators of industry impacts but are beyond the scope of this report. Future studies could include an analysis and measurement of the multiplier effects of the biobased industry for different sized plants, rural versus urban environments, different biobased product production, and local leakages in returns to capital under different financing strategies. Such an analysis would give a better perspective on the impacts of expanding biobased product production into new product lines, into diverse locations, and into new plant scales or sizes.

5. Analysis of Key Indicators

This chapter contains an overview of key economic indicators that were selected by industry and government stakeholders as being particularly relevant to public policy and business decision making. Beginning with a preliminary list of indicators from USDA, researchers at Iowa State University identified 69 economic indicators that described various dimensions of the bioeconomy. These indicators were broadly categorized into one of the following three groups: inputs to biobased production processes, investments in bioeconomy development, and outputs or outcomes of biobased activities. After applying various criteria described in the previous section, the original list of indicators was reduced to the 16 key indicators presented here.

The discussion for each indicator addresses several issues, including (1) its relevance to the condition of the bioeconomy; (2) how the indicator is currently measured or might be measured; (3) identification of currently available data sources; and (4) illustration of one or more of the suggested measures, if data are available.

The limitations of the data and assumptions made in any analyses are highlighted for each measure illustrated. The example measures are not intended to provide a comprehensive analysis of any particular indicator, nor do they address many questions central or tangential to the particular issue. This section is intended, primarily, to illustrate the current state of information about the bioeconomy and the challenges associated with its measurement. The next chapter provides examples of more complex analyses of economic indicators that may be used for operations analysis and assessment of broad industry trends.

A number of sources were used to gather data, including the U.S. Department of Commerce's Bureau of Economic Analysis, the U.S. Department of Labor's Bureau of Labor Statistics, the USDA National Agricultural Statistics Service, the USDA Economics Research Service, the DOE Energy Information Administration, tax records, industry associations (e.g., Renewable Fuels Association), and data from a survey of biobased product manufacturers completed by Iowa State University.

5.1. Prices of energy inputs for biobased production

Relevance

Energy is an important input into biobased production. Many biobased industries are energy intensive, so the price levels and the price variabilities over time are very important input considerations affecting industry profitability and viability. Modern biofuel operations depend in large part on natural gas. Some modern facilities utilize coal as a heat source. More modern plants are exploring co-generation opportunities, but those operations are primarily experimental.

Measurement

There are several important considerations when measuring costs over time. These include the overall trend in prices, adjustments for inflation, and the variability and the volatility of prices due to external factors or unforeseen occurrences.

Candidate measures would include the nominal and inflation-adjusted prices of energy inputs on a monthly or weekly basis, inputs indexed to a beginning time period, and energy costs per unit of production or as a fraction of all production inputs.

Data Availability

Information availability is very high. The DOE Energy Information Administration produces weekly, monthly, and annual price data for all primary energy sources in the United States.

Example indices are included on the following pages.

5.1.1. Key Energy Costs as Percentages of 1990 Values

Data Source: U.S. Energy Information Administration

Energy is required to produce biofuels and other biobased industrial products and to distribute them via rail, barge, or truck. During the decade of the 1990s, U.S. energy costs were comparatively stable, but by the late 1990s, diesel and natural gas prices began a sharp increase. By the end of 2007, U.S. diesel prices were 300 percent above 2000 levels. Natural gas closed the year at just over 250 percent higher than the 1999 price. Comparatively, electricity, though trending upward since 2000, as of 2007 was only 34 percent higher than the price in 1990. Consumer prices rose an average of 59 percent over the same period of time.

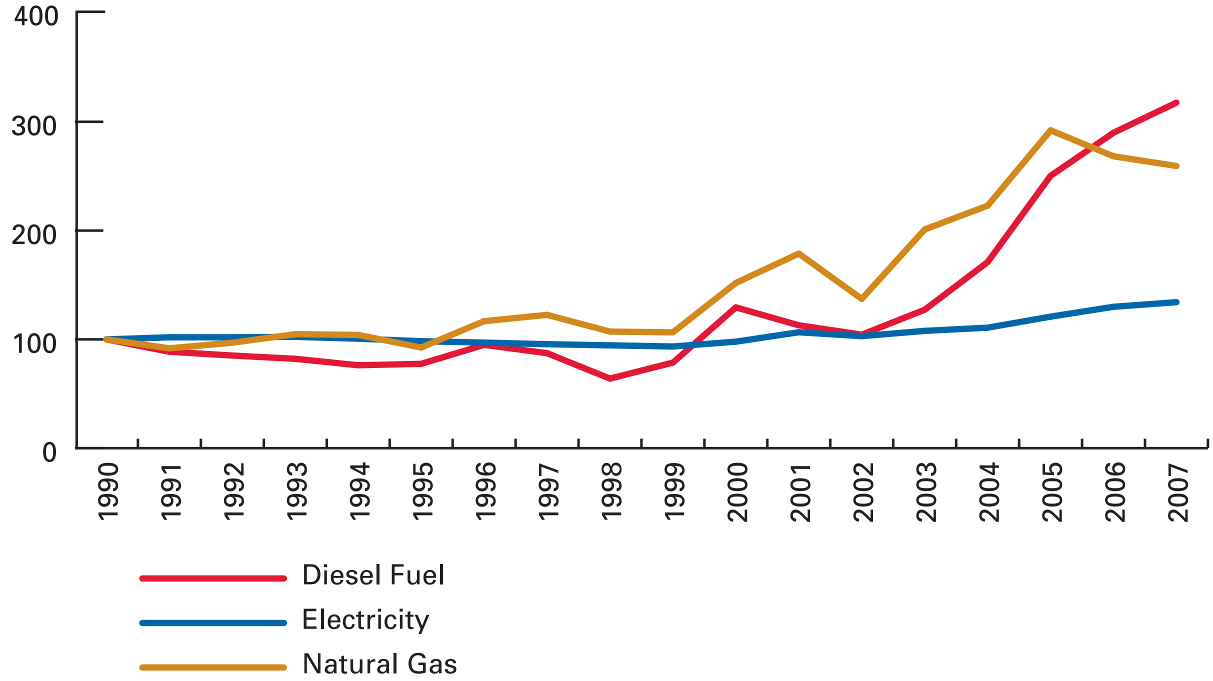

Figure 20. Nominal key energy costs (indexed to 1990) with a base of 100.

5.1.2. Corn and Natural Gas Costs Per Gallon of Ethanol

Data Sources: USDA; U.S. Energy Information Administration

The profitability of the ethanol industry depends on many factors. The sale of the fuel, by-products, etc., creates income. There are a variety of expenses, including manufacturing overhead; direct labor costs; and direct material costs, which include the cost of corn and natural gas, among other things. Recently, added demand for corn by the growing ethanol industry coupled with rising energy prices has driven up the per-gallon cost of producing ethanol in the United States. Considering just the cost of corn and natural gas, combined costs were less than a dollar per gallon for most of the series displayed below with the exception of the interval 1994-1997. From 2004 through 2007, however, the combined cost increased by 85 percent.

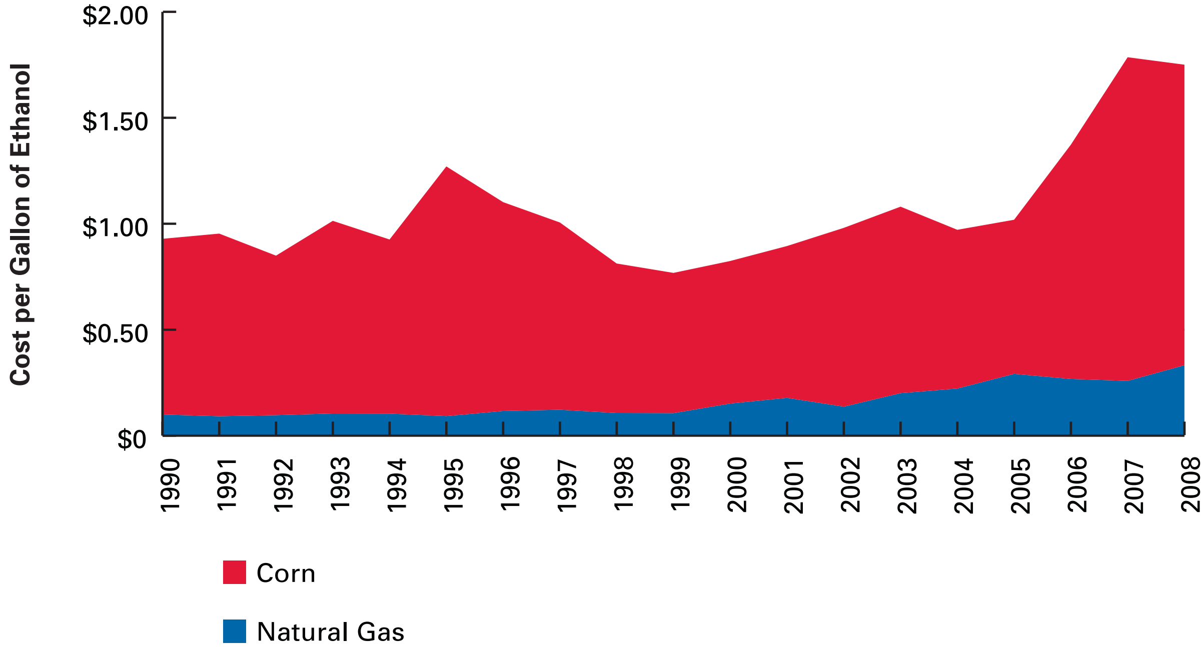

Figure 21. Primary input costs.

5.2. Amount of Cropland in Energy-Dedicated Crops

Relevance

Biobased energy production requires agricultural land. The Nation's most productive and valuable agricultural land is currently being used. Increases in crop-based biofuels will inevitably result in some trade-offs between land used primarily for food production and land used for other nonfood uses, like biofuels. There is also idled, highly erodible, and less productive land in the national Conservation Reserve Program. Some of those acres may be tapped for perennial biomass feedstocks as those technologies emerge and markets develop for cellulosic sources of energy. If that does occur, those acres will not compete as directly with hay or fiber cropland or corn acres as would prime agricultural acres. However, if grazing lands are used to produce dedicated energy crops, that competition for agricultural lands will have indirect land use effects.

Measurement

Given the nature of biomass feedstocks and the state of the technology in biomass fuel production, there are serious constraints in estimating the use of crop and other productive lands for dedicated energy crops. Currently there are several methods of estimating energy-dedicated crop production. The measures depend on the issue being addressed. In the main, the focus has been on the amount of grains or oilseeds diverted toward energy production at the expense of other uses, which are primarily for food production. Analyses become more complicated if a portion of the by-products of fuel production are returned to the food supply chain. The most common example of this is the distillers' grains resulting from the production of ethanol, which are typically returned to the feed market.

There is a definitional issue at stake regarding whether a crop is primarily intended as an energy input, as well as the location of production. Regarding modern corn-based and soy-based biofuel production, the supposition is that higher fractions of production close to processing facilities are dedicated as energy inputs. But that is just a supposition, as the grains and oilseeds are fungible commodities and it is not possible to accurately source the inputs consistently. Actual energy-only crops like switchgrass or miscanthus are not as fungible, as they have more limited alternative markets and they will not transport long distances efficiently. If and when those crops emerge, their designation as energy crops will become much easier to make.

Like corn, many biomass feedstocks have alternative uses such as feed and cover crops. The difference is that to estimate the acres of corn devoted to fuel ethanol production, one essentially works backwards from the amount of ethanol produced in a given year. First, the total gallons of ethanol produced are determined. That value is divided by the gallons of ethanol produced per bushel of corn to estimate the bushels of corn required. Then the estimated bushels are divided by the national average corn yield to arrive at the acres of cropland used to produce corn for fuel ethanol. Accordingly, national summaries over time are more common, such as the amount of the U.S. corn crop used in ethanol production and the estimated fraction of farm acres used to produce biofuels.

As to estimating non-corn acres, while it may be possible to estimate total acreage devoted to particular grass varieties, it is unlikely there would be sufficient information to estimate yields of biomass per acre. More importantly, there is not an established commercialized technology to determine ethanol industry yield per dry ton of biomass. The current estimates range from 60 to 100 gallons per dry ton. So, even if one knows the average gallons per dry ton from a particular technology, one could not calculate the acres of cropland with any degree of precision.

Another area of concern revolves around the potential conversion of environmentally sensitive row cropland to producing fuel. When cellulosic production becomes commercially feasible, both the amount of land required and the location of the production may become less meaningful because these crops are likely to use less commercial nutrients and, being close-grown crops, to reduce the potential for runoff and erosion as well as chemical leaching to tile drainage and groundwater. The trade-off of converting marginal row crop acres to dedicated energy acres might be both environmentally and economically beneficial.

Data Availability

Since the availability of data on perennial grasses is limited, the current focus is on corn production. A similar approach will need to be taken as additional information on other feedstocks becomes available.

The USDA and the many state agriculture statistics agencies collect a rich array of data on state, county, and crop-reporting district agricultural land use. Those statistics are benchmarked during the quinquennial censuses of agriculture, during which time much more detailed analysis of producer behavior and agricultural land use can be obtained.

Example indices are included on the following pages.

5.2.1. Corn Acres Harvested for Ethanol Production

Data Sources: USDA Economic Research Service (ERS) Feed Grains Database; USDA National Agricultural Statistics Service (NASS)

In 1990, the corn grown on an equivalent of just 3 million acres was diverted into ethanol production. By 2007, that amount had increased to nearly 20 million acres. The growth is most pronounced since 2001, where the equivalent of 5 million acres of corn was required to produce the Nation's ethanol output. The compounded annual rate of increase from 2001 through 2007 was 25 percent.

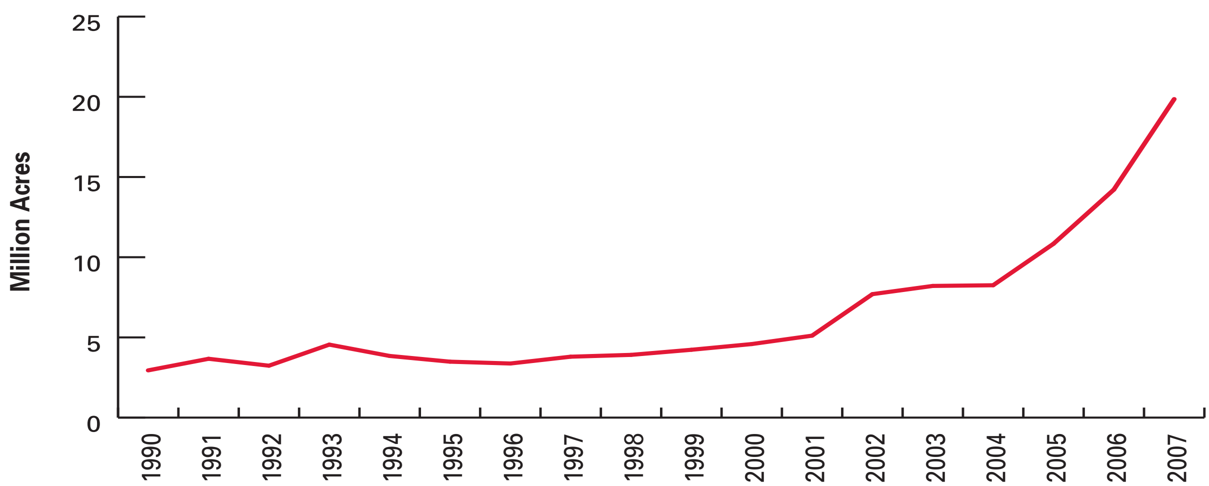

Figure 22. Corn acres harvested for ethanol production.

5.2.2. Corn Acres Harvested for Ethanol Production as a Percentage of U.S. Harvested Cropland

Data Sources: USDA ERS Feed Grains Database; NASS

While the amount of all U.S. cropland that was used to produce ethanol from corn has risen sharply, so too has the fraction of corn used for ethanol production. During the mid-1990s that amount was just above 1 percent. Thereafter the fraction began to rise, with two noticeable jumps in the 2001 to 2002 period and the 2004 to 2006 period.

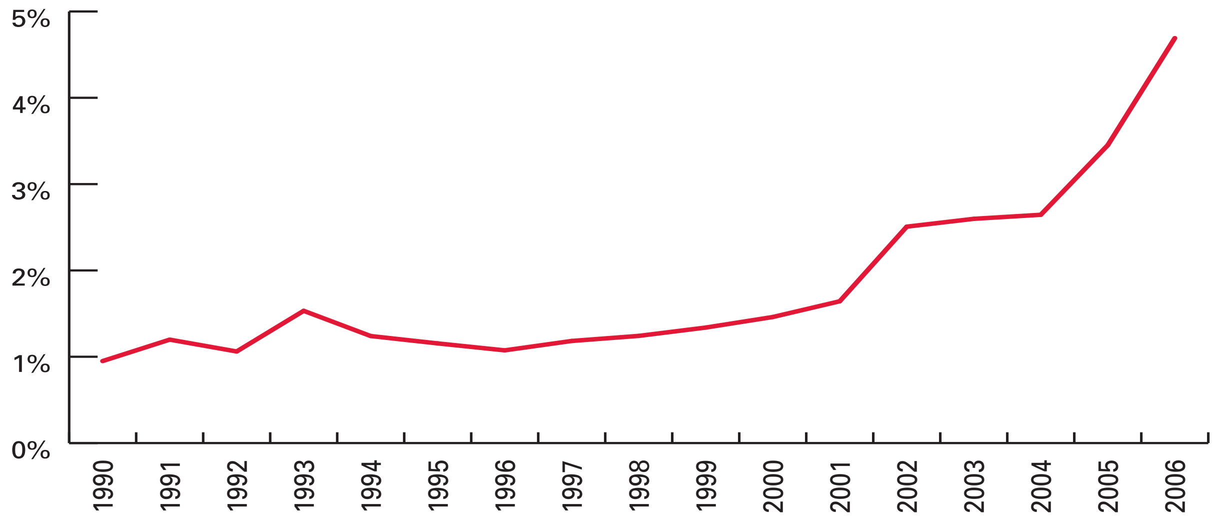

Figure 23. Corn acres harvested for ethanol production as a percentage of U.S. harvested cropland.

5.3. Quantity of Grain and Oilseed Inputs Used in Biobased Production

Relevance

The amounts of corn and soybeans that are diverted into biobased energy and products compete with other important uses, which can have strong implications for the prices paid by competing users of those crops like livestock producers, primary food producers, and importers of U.S. crops. This area requires careful measurement because there are, for example, beneficial by-products from ethanol production that find their way back into animal feeds. This issue has added urgency of late because of food-versus-fuel concerns and because the prices of all grains for a period rose sharply, causing food price increases nationally and globally. There is, therefore, an emerging and strong sensitivity to the issue of converting food grains into energy and other nonfood products.

Measurement

The grain inputs to biofuel production are gauged by backing out the grain requirements based on known biofuel production. These estimates are straightforward, but they are dependent on assumptions about the efficiencies of, for example, ethanol production facilities and livestock feeding rations. In addition, as in the case of biodiesel production from oilseeds, it may not be clear at any point in time which type of oilseed is being used, whether the facility is actually producing an energy product, or whether other fat substitutes are being used. Non-biofuel uses, on the other hand, would require detailed and expensive industry surveys to identify their precise production recipes and the amounts of grains required. Candidate measures include the amounts and percentages of annual crop production over time going to competing uses like energy, animal feeds, food production, and exports.

Data Availability

The USDA and the various state agricultural statistics agencies compile estimates of crop production at the county, crop-reporting district, state, and national levels. The disposition of those crops is based on estimates of livestock on feed, historic primary food demands for grains and oilseeds, output levels of the Nation's biofuel industries, and export sales. Grain supply information is available on a historical basis and is estimated frequently during a crop year, as are other anticipated uses of those crops by the USDA. Biobased energy production is also estimated by the DOE. Currently there are no reliable sources of publicly available data on nonenergy biobased product grains and oilseeds demand by U.S. industries.

Example indices are included on the following pages.

5.3.1. Disposition of the U.S. Corn Supply

Data Source: USDA ERS Feedgrains Database

Four major categories of corn supply usage are assessed. U.S. corn production is used in foods, for seeds, or for other industrial uses; it is fed to animals; it is converted into alcohol fuels; and it is exported. As shown in figure 24, the amounts required for feed purposes fluctuate strongly by quarter indicating a supply-and-demand volatility for that sector and the need, therefore, of adequate seasonal reserves. On an annualized demand basis, however, the overall trend is relatively flat with that sector demanding about 1.5 billion bushels per quarter. There is some cyclical behavior evidenced in the export component as well, while the fuel alcohol fraction has grown from least use in the first quarter of 2001 to the second greatest use by the end of 2007.

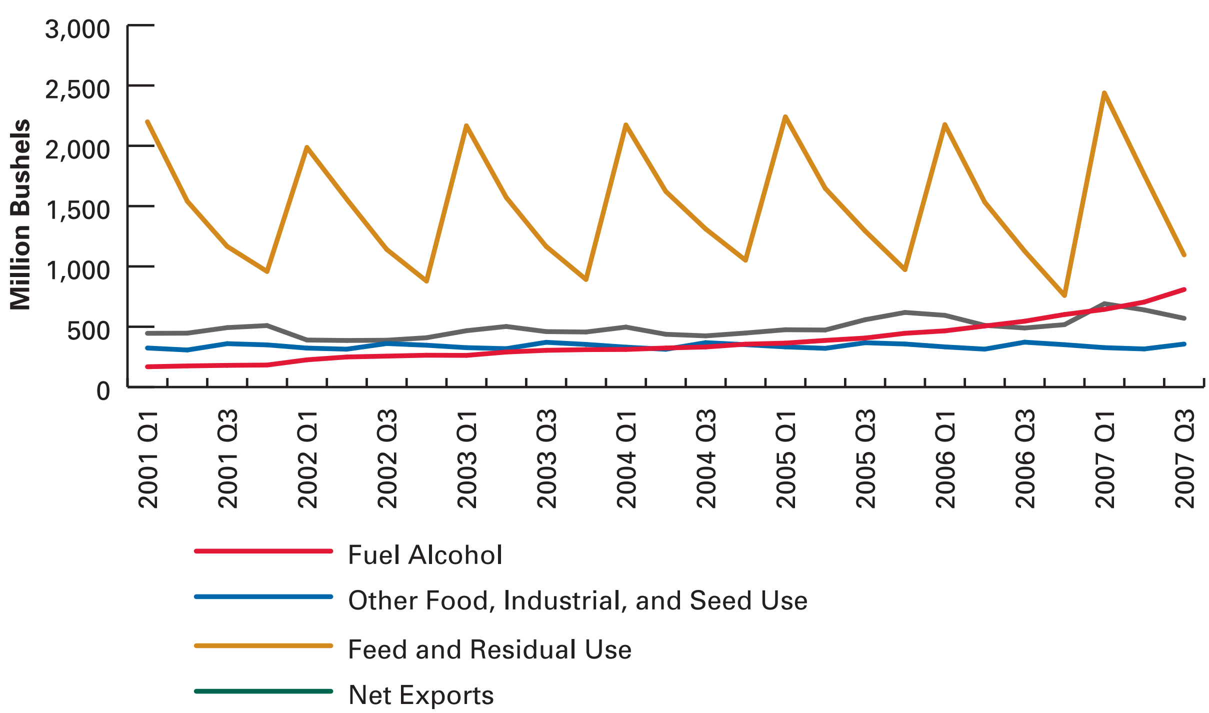

Figure 24. Disposition of the U.S. corn supply.

5.3.2. Corn and Soybean Inputs to Industrial Production

Data Source: USDA ERS Feed Grains Database

Quantity measures for two major field crop inputs into industrial production are displayed. Values are expressed as percentages of the amounts used by industry in 1990. For corn, the values measure the amount used for food, alcohol, and other industrial uses. For soybeans, the values measure the amount of soybeans crushed, from which are derived oils, fuels, foods, feeds, and a host of other industrial products. There has been a sharp increase in corn supplies dedicated to industrial uses since 1995.

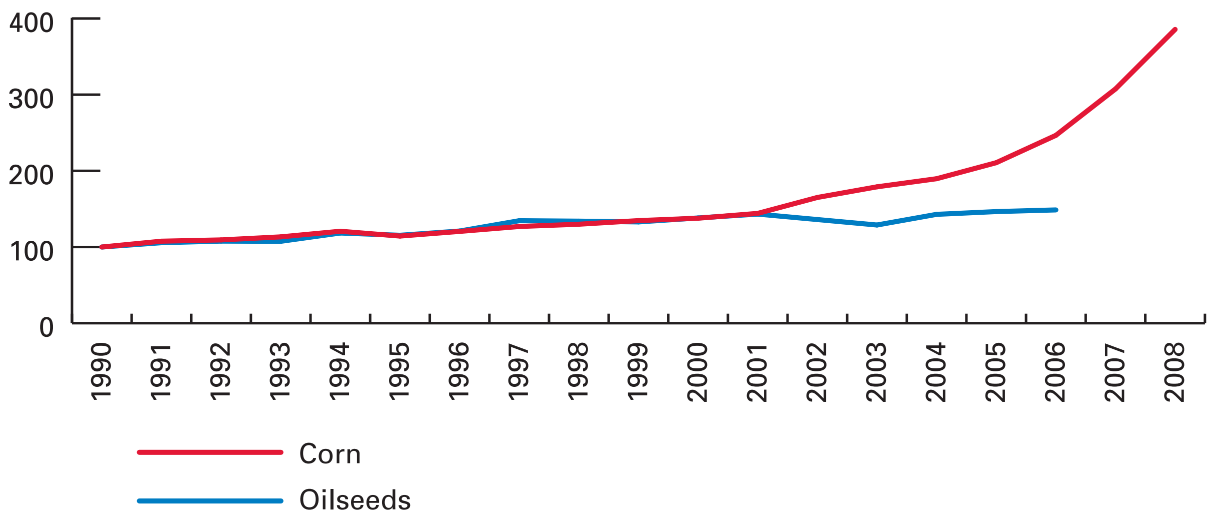

Figure 25. Corn and soybean inputs to industrial production (indexed to 1990).

5.4. Quantity of Chemical and Other Inputs Used in Biobased Production

Relevance

Modern and future biofuel and other biobased product development and profitability depend on the uses of enzymes, yeasts, and other organic and inorganic chemical inputs. This is a key component to the anticipated success of enzymatic-cellulosic production of biofuels. Advances in enzyme research are required for future production efficiencies of cellulosic feedstocks. As those advances become commercially viable, the quantities of chemical inputs will increase, which can eventually serve as an indirect indicator of the size of biobased production in the United States. There are other non-energy inputs into biofuel production as well. For example, natural gasoline is typically used to denature ethanol. Similarly, alcohol, catalysts, and cleaners are all required to finish biodiesel.

Measurement

Currently, the majority of demand for chemical inputs is from corn-based ethanol production. The amounts used can be backed out of actual fuel production based on estimated input quantities. For example, the amount of ethanol denaturant used can vary from 2 to 5 percent, depending on the price of natural gasoline relative to the price of ethanol. Accordingly, the estimated amount of this chemical input used in ethanol production can be imprecise at times. Estimates of chemical use in other biobased production would require information about actual sales of input chemicals by producing firms made to firms making biobased products.

Data Availability

The amount of ethanol produced is obtained by the U.S. Energy Information Administration, from which indirect estimates of chemical inputs can be made. The actual production recipes of ethanol firms can be obtained from university-level research and engineering studies of modern biofuel production requirements.

The ideal source for non-biofuel users would be very detailed input-output accounts such as those produced by the U.S. Bureau of Economic Analysis (Benchmark Input-Output Accounts). Unfortunately, the level of industrial detail currently available does not identify producers or purchasers of these commodities in the kind of detail necessary to estimate quantities produced and used for biobased products. These data can be derived from actual industrial production audits or surveys, but there are no such data currently available to the authors' knowledge.

The Bureau of Economic Analysis maintains annual input-output (I-O) accounts for U.S. industries. These I-O accounting tables detail the flow of goods and services from one industry to another in the production of the Nation's Gross Domestic Product. The accounts may also be used to discern the input requirements, or production "recipes," of particular industries. The annual accounts are benchmarked every 5 years.

An example index is included on the next two pages.

5.4.1. Chemical Inputs as a Percentage of Total Industrial Inputs for Selected Industries

Data Sources: Commodity-By-Industry Direct Requirements; 2002 Benchmark Input-Output Tables; U.S. Bureau of Economic Analysis

Input-output (I-O) tables provide a useful accounting framework for determining the input requirements of particular industries of interest. These tables are generally structured so that specific commodities, or production inputs, are listed in rows. Industries that purchase commodities and other inputs for their production processes are listed in columns. The values at the intersection of each row and column represent the cost of a particular commodity required by the industry, expressed as a percentage of the industry's total production input requirements.

Table 11 shows an input-output table published by the U.S. Bureau of Economic Analysis (BEA). The 22 specific chemical commodity inputs listed in the first two columns illustrate the level of chemical input detail that is currently available from BEA's published I-O tables. The table highlights the use of basic organic chemical inputs (produced within NAICS 325190) by nine different industries. Other basic organic chemical inputs are virtually unused in some of these industries (e.g., reconstituted wood product manufacturing), represent a relatively low fraction of total inputs in others (e.g., wet corn milling), and are a high fraction in others (e.g., plastics material and resin manufacturing).

As is evident from the table, there is currently no way to distinguish between biobased and nonbiobased inputs or purchasing industries. For example, to measure the quantity of enzymes purchases by ethanol producers, it is not possible to distinguish enzymes from all other basic organic chemical inputs (NAICS 325190) or to distinguish ethanol producers from other manufacturers of basic organic chemical products (NAICS 325190).

Table 11. Chemical inputs as a fraction of total industrial inputs for selected industries.

		Industries								
		311221	31122A	311225	321219	322110	325110	325190	325211	325412
IOCode	Commodities	WCM	SOOP	FORB	RWPM	PM	PCM	OBOCM	PMRM	PPM
325110	Petrochemical manufacturing	0	0	0	0	0.0011114	0.2304668	0.1460485	0.1174869	0.0009831
325120	Industrial gas manufacturing	0	0	0	0	0.0010259	0.001455	0.0076055	0.0055332	0.0003157
325130	Synthetic dye and pigment manufacturing	0	0	0	0	0.0018239	0.0000749	0.0013249	0.0005694	0.0000028
325181	Alkalies and chlorine manufacturing	0	0	0	0	0.0153035	0.0018455	0.0098441	0.0013452	0.0001022
325182	Carbon black manufacturing	0	0	0	0	0	0	0.0000109	0.0016396	0
325188	All other basic inorganic chemical manufacturing	0	0	0	0	0.0297236	0.0020221	0.0143921	0.0160539	0.0007613
325190	Other basic organic chemical manufacturing	0.0153807	0.0001945	0.000099	0.0001894	0.0206042	0.2429308	0.1406506	0.2445834	0.0331812
325211	Plastics material and resin manufacturing	0	0	0	0.0702174	0	0.0004654	0.003265	0.0388744	0
325212	Synthetic rubber manufacturing	0	0	0	0	0	0	0.0000564	0.0010873	0
325220	Artificial and synthetic fibers and filaments manufacturing	0	0	0	0	0	0	0.0001292	0.0002879	0
325310	Fertilizer manufacturing	0	0	0	0	0	0.0052798	0.0057073	0.0052152	0.000046
325320	Pesticide and other agricultural chemical manufacturing	0	0	0	0	0	0	0	0	0
325411	Medicinal and botanical manufacturing	0	0	0	0	0	0	0	0	0.0875283
325412	Pharmaceutical preparation manufacturing	0	0	0	0	0	0	0	0	0.0398428
325413	In-vitro diagnostic substance manufacturing	0	0	0	0	0	0	0	0	0.001772
325414	Biological product (except diagnostic) manufacturing	0	0	0	0	0	0	0	0	0.021107
325510	Paint and coating manufacturing	0	0	0	0.0117746	0	0.0003905	0.00095	0.0008746	0
325520	Adhesive manufacturing	0	0	0	0.0067308	0.0020804	0.0002247	0.0027627	0.0036143	0.0002789
325610	Soap and cleaning compound manufacturing	0	0	0.0003818	0	0	0.0000428	0.001263	0.0001375	0.0000055
325620	Toilet preparation manufacturing	0	0	0	0	0	0	0	0	0
325910	Printing ink manufacturing	0	0	0	0	0	0	0	0	0
3259A0	All other chemical product and preparation manufacturing	0	0.0004264	0	0.0009296	0.0020804	0.0005617	0.0095329	0.0122784	0.0029484
Subtotal	All chemicals	0.0153807	0.0006209	0.0004808	0.0898418	0.0737533	0.48576	0.3435431	0.4495812	0.1888752

WCM = Wet corn milling; SOOP = Soybean and other oilseed processing; FORB = Fats and oils refining and blending; RWPM = Reconstituted wood product manufacturing; PM = Pulp mills; PCM = Petrochemical manufacturing; OBOCM = Other basic organic chemical manufacturing; PMRM = Plastics material and resin manufacturing; PPM = Pharmaceutical preparation manufacturing

5.5. Tax and Trade Policies

Relevance

Examples of government tax and trade policies that influence the growth of the biobased economy include production tax credits, tax rebates, depreciation allowances, use mandates, tariffs, and quotas. Some of these policies are implemented at the federal level, while others are implemented by state and local governments. Tax and trade policies are intended to stimulate private investment and production of biobased products. Goals may include helping private firms overcome barriers to entry, nurturing start-up firms, protecting domestic producers, expanding current markets for biobased products, and encouraging private research and development activities. In addition, these policies send signals to markets about the public sector's level of interest and commitment to the growth of the biobased economy.

Measurement

Most tax and trade policy data simply describe the number of programs in place and the parameters of specific policies. Such indicators do not measure the costs to taxpayers, potential benefits, or market distortions that may result from these policies. Finally, the available tax and trade policy data generally do not reflect the efficiency or effectiveness of the policies they describe, nor do they measure the actual growth or competitiveness of biobased industries.

Data Availability

The DOE's Office of Energy Efficiency and Renewable Energy tracks federal and state biofuel-related policies, including ethanol and biodiesel. The information is updated annually after the close of each state's legislative session. Similar data describing state programs encouraging other biobased product development would require an independent, state-by-state investigation, an effort that was not undertaken for this research.

Example indices are included on the following pages.

5.5.1. Federal Biofuel Tax and Trade Policies

Data Sources: DOE, Office of Energy Efficiency and Renewable Energy; U.S. Energy Information Administration

Federal tax and trade policies are frequently revised and refined. As such, any inventory of Federal and state biofuels-related policies quickly becomes obsolete. That issue having been noted, the following policy snapshot from 2009 helps to illustrate the scope of programs that encourage the production and use of biobased alternative fuels in the United States. The information was compiled using data from the DOE's Office of Energy Efficiency and Renewable Energy, which operates an Alternative Fuels and Advanced Vehicles Data Center (AFDC). The AFDC includes a database of state and federal laws and incentives related to alternative fuels and other transportation-related topics. The federal policy information is updated in the database after enacted legislation is signed into law.

As of July 2009, the AFDC database listed seven specific federal tax incentive programs related to ethanol or biodiesel. Four of the programs were targeted toward alternative fuel producers, three were available to alternative fuel dealers, and one was targeted to fuel station builders or operators.

- Small Ethanol Producer Tax Credit. An income tax credit of $0.10 per gallon of ethanol was available to qualified small ethanol producers. The credit applied only to the first 15 million gallons of ethanol produced in a tax year. (Reference 26 U.S. Code 40)
- Small Agri-Biodiesel Producer Tax Credit. An income tax credit of $0.10 per gallon of agri-biodiesel was available to qualified small producers of agri-biodiesel. The credit applied only to the first 15 million gallons of agri-biodiesel produced in a tax year. (Reference 26 U.S. Code 40A)
- Cellulosic Biofuel Producer Tax Credit. An income tax credit was available to qualified cellulosic biofuel producers registered with the Internal Revenue Service (IRS), in the amount of up to $1.01 per gallon of cellulosic biofuel under certain specified conditions of sale or use. Only qualified fuel produced in the U.S. for use in the U.S. was eligible. If the cellulosic biofuel also qualified for alcohol fuel tax credits, the credit amount was reduced to $0.46 per gallon for ethanol and $0.41 per gallon for other biofuels. (Reference 26 U.S. Code 40)
- Volumetric Ethanol Excise Tax Credit (VEETC). Ethanol blenders registered with the IRS were eligible for an excise tax credit per gallon of pure ethanol (minimum 190 proof) blended with gasoline. The applicable credit amount was $0.51 for calendar years prior to 2009 and $0.45 for 2009 and beyond. Any excess over the blender's tax liability could be claimed as a direct payment from the IRS. (Reference 26 U.S. Code 6426)
- Biodiesel Income Tax Credit. A tax credit in the amount of $1.00 per gallon of biodiesel, agri-biodiesel, or renewable diesel was available to qualified taxpayers who delivered pure, unblended biodiesel (B100) into the tank of a vehicle or used B100 as an on-road fuel in their trade or business. (Reference 26 U.S. Code 40A)
- Biodiesel Mixture Excise Tax Credit. Biodiesel blenders registered with the IRS were eligible for a volumetric excise tax credit in the amount of $1.00 per gallon of pure biodiesel, agri-biodiesel, or renewable diesel blended with petroleum diesel to produce a mixture of at least 0.1% (by volume) of diesel fuel. Any excess over the blender's tax liability could be claimed as a direct payment from the IRS. (Reference 26 U.S. Code 6426)
- Alternative Fuel Infrastructure Tax Credit. A tax credit was available for a specified fraction of the cost of installing alternative fueling equipment for eligible fuel types except hydrogen. (Reference 26 U.S. Code 30C)

According to the AFDC, as of July 2009, the United States imposed two duties on imported ethanol: an ad valorem tariff of 2.5 percent and a surcharge of $0.54 per gallon, to be applied after the ad valorem tariff. The surcharge allowed for limited duty-free imports from designated Central American and Caribbean countries, not exceeding 7 percent of domestic production in the previous year.

Key federal tax and trade policies related to the biofuel industry are summarized in Table 12 [31].

Table 12. Key federal tax and trade policies for biofuels.

Year	Ethanol							Agri-Biodiesel		
	Cellulosic Biofuel Producer Income Tax Credit* ($ per gallon)	Volumetric Ethanol Excise Tax Credit* ($ per gallon)	Applied Tariff* (%)	Surcharge* ($ per gallon)	Production (million gallons)	Renewable Fuels Standard—Cellulosic (million gallons)	Renewable Fuels Standard—Other (million gallons)	Biodiesel Mixture Excise Tax Credit* ($ per gallon)	Renewable Fuels Mandate** (million gallons)	Production (million gallons)
2005		0.51	2.50	0.54	3,904	-	-	1.00	-	107
2006		0.51	2.50	0.54	4,884	-	4,000	1.00	-	259
2007		0.51	2.50	0.54	6,521	-	4,700	1.00	-	480
2008		0.51	2.50	0.54	9,262	-	9,000	1.00	-	677
2009	1.01	0.45	2.50	0.54	10,295	-	10,500	1.00	500	804
2010	1.01	0.45	2.50	0.54	11,504	100	12,000	1.00	650	921
2011	1.01	0.45	2.50	0.54	12,384	250	12,600	1.00	800	1,040
2012	1.01	0.45	2.50	0.54	13,185	500	13,200	1.00	1,000	1,149
2013	1.01	0.45	2.50	0.54	13,715	1,000	13,800	1.00	1,000	1,178
2014	1.01	0.45	2.50	0.54	14,508	1,750	14,400	1.00	1,000	1,174
2015	1.01	0.45	2.50	0.54	15,320	3,000	15,000	1.00	1,000	1,178
2016	1.01	0.45	2.50	0.54	15,990	4,250	15,000	1.00	1,000	1,184
2017	1.01	0.45	2.50	0.54	16,361	5,500	15,000	1.00	1,000	1,187
2018	1.01	0.45	2.50	0.54	16,736	7,000	15,000	1.00	1,000	1,184

** Data for 2010 and beyond are assumed to be extended at the 2009 level.*

***Amounts for 2013 and beyond to be determined by future EPA rulemaking, with a minimum of 1 billion gallons.*

Source: Food and Agricultural Policy Research Institute, FAPRI 2009 U.S. and World Agricultural Outlook Database

5.5.2. State Biofuels Tax Programs

Data Source: DOE, Office of Energy Efficiency and Renewable Energy, Alternative Fuels and Advanced Vehicles Data Center, Federal & State Incentives & Laws, http://www.afdc.energy.gov/afdc/incentives_laws.html

By the close of the 2008 legislative sessions, there were 106 tax incentive and tax rebate programs authorized in 40 states (see Figure 26). Examples include income and/or sales and use tax credits for the cost of construction, reconstruction, or acquisition of an alternative fueling facility; exemptions on taxes on alternative fuels used in official vehicles for federal or state government agencies; income tax credits for biofuel production facilities; and others.

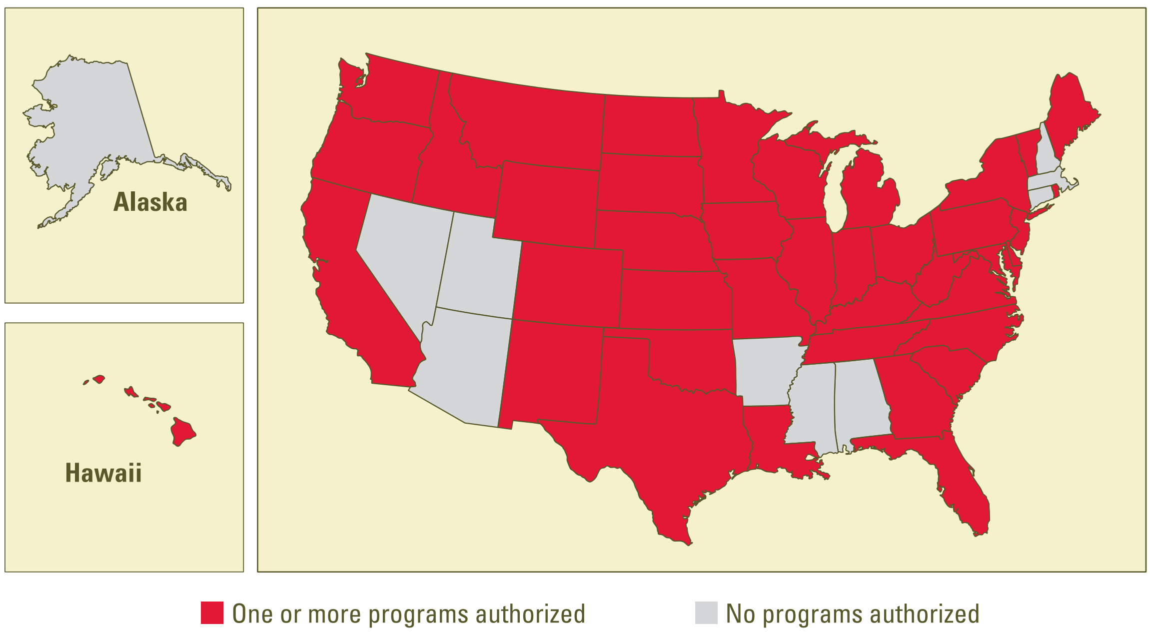

Figure 26. States with biofuel tax credits or rebate programs.

5.5.3. Federal and State Biofuel Use Mandates

Data Sources: Energy Independence and Security Act of 2007 (P.L. 110-140, H.R. 6), Sections 201-202; DOE, Office of Energy Efficiency and Renewable Energy, Alternative Fuels and Advanced Vehicles Data Center, Federal & State Incentives & Laws, http://www.afdc.energy.gov/afdc/incentives_laws.html

The Energy Policy Act of 2005 established the Renewable Fuel Standard program to increase the volume of renewable fuel that is blended into gasoline and other transportation fuels. The Energy Independence and Security Act of 2007, signed into law in December 2007, increased this standard to 9 billion gallons in 2008, with an increase of up to 36 billion gallons by 2022. In addition, the standard was expanded to require that a certain percentage of the renewable fuels must be advanced and/or cellulosic-based biofuels and biomass-based diesel. An advanced biofuel is defined as any renewable fuel derived from renewable biomass, other than ethanol derived from corn, and that achieves a required level of emissions reduction.

By 2008, 10 states had adopted mandates or standards for the use of ethanol or biodiesel (see Figure 27). The usage rates and implementation dates varied by state. Some states designed programs that were to begin in specific years, while other states designed programs that were to be triggered after achieving a minimum threshold of biofuel production within the state. By 2008, two states had passed resolutions in support of the 25x25 initiative, under which 25 percent of the total energy consumed in the United States would be produced by domestic agriculture.

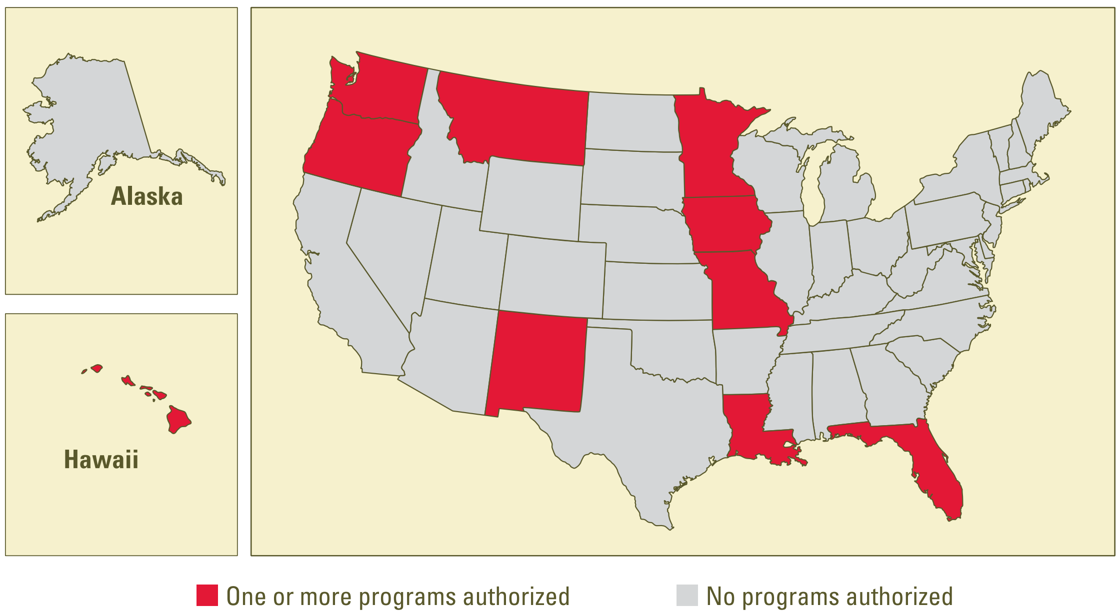

Figure 27. States with biofuel mandates or standards.

5.5.4. Estimating Total Biofuel Subsidies Nationally

Data Source: Koplow, D., Biofuels—At what cost? Government support for ethanol and biodiesel in the United States: 2007 update, Geneva: Global Subsidies Initiative of the International Institute for Sustainable Development, October 2007

There is such a multiplicity of state and Federal programs that summing the total amount of market, production, capital development, and consumption assistance associated with biofuels is difficult. For example, in 2008, Iowa had a blended motor vehicle fuel tax credit of 2.5 cents per gallon of E10 (fuel mixture of 10% anhydrous ethanol and 90% gasoline) that, which accrued to retailers. Since each gallon of blended gasoline contains 10 percent ethanol, the credit to retailers amounted to 25 cents per gallon of ethanol sold. The blenders of that ethanol would have taken the VEETC tax credit in the amount of 51 cents per gallon. That same gallon of ethanol may have come from a small ethanol plant that received a 10-cents-per-gallon tax credit. Had a customer purchased 10 gallons of E10 at an Iowa gas station, which would have contained 1 gallon of ethanol and 9 gallons of regular unleaded gasoline, the total subsidy from just these three sources for that ethanol gallon would have been 86 cents.

Piecing together all of the potential subsidies is important, however, for understanding the total public cost of ethanol production in the United States as it relates to local, state, and federal public accounts. Research conducted by Koplow and Steenblik [32] estimates the subsidies for ethanol, considering all measurable categories, ranged from $1.05 to $1.25 per gallon of ethanol produced in 2007. Total U.S. subsidy values from their estimates for 2007 range from a low of $6.94 billion to a high of $8.39 billion.

5.6. Government Spending on Bioeconomy R&D

Relevance

Government authorities implement policies and provide financial support for research and development (R&D) activities in the hope of stimulating technological innovation. The Federal Government justifies subsidizing bioeconomy R&D in terms of broader national goals such as increased energy independence, national security, and a cleaner environment. State governments support initiatives for development of new biofuels and other biobased products partly to support these national goals, partly to support more local concerns (e.g., rural development), and partly to promote new sources of jobs and economic growth and stability within their borders.

The level of government-funded R&D activity is widely viewed by the private sector as an indicator of the strength of the public sector's long-term commitment to the development of the bioeconomy.

Measurement

Government-supported R&D activities come in a variety of forms including, but not limited to, research conducted within Federal agencies themselves; research conducted by federally funded research and development centers; grants, loans, and loan guarantees in support of private industry efforts; federal and state support of biobased research and development in academia; and tax credits for qualified private sector R&D activities. These activities are generally measured in terms of the dollars expended for R&D efforts annually. Example measures include real spending over time, R&D spending as a fraction of all spending, or the value offsets to taxes in the cases of allowable R&D credits.

One challenge in measuring government support for R&D efforts is isolating pure bioeconomy R&D from other, ongoing R&D efforts by the various entities that receive government funding. For example, many bioeconomy R&D initiatives are found in public and private universities and research institutions that have demonstrated expertise in fields of science related to the bioeconomy, such as crop sciences. It is very difficult to distinguish between new bioeconomy R&D efforts and traditional R&D efforts in these fields. Another challenge is sorting out the amount of public R&D support for specific initiatives within entities that use a mix of federal, state, private, and institutional funding for their R&D efforts.

Data Availability

Data on federal direct spending and support for R&D are obtainable, but there are limits to the comprehensiveness and detail of the reports. Researchers with knowledge of specific Federal programs related to bioeconomy R&D can go to the Consolidated Federal Funds Report (CFFR) to identify the dollar amounts expended for those programs. The CFFR data may be used to track program expenditures over time or to identify the county or state recipient of those federal funds. Researchers need to have detailed program knowledge to identify relevant line items that describe their area of interest.

State-supported R&D efforts are more difficult to track than federally funded efforts, due to the lack of centralized data collection and reporting. A careful analysis of government census data might yield limited information on state R&D activities; however, an assessment of state-level activities specifically related to bioeconomy R&D would likely require detailed analysis of individual state budgets.

It is even more difficult to measure the value of R&D tax credits related to private-sector bioeconomy initiatives, as these credits are offered at both the federal and state level and have substantial variation in their definitions of qualified activities. In many cases, confidentiality rules prohibit the disclosure of detailed information about tax credit recipients, which precludes the identification and measurement of R&D activities specific to the bioeconomy.

Example indices are included on the following pages.

5.6.1. Recent Federal Funding Levels Budgeted for Renewable Energy Research and Development

Data Source: Table 17. Federal research and development budget authority for energy (270): FY 2007–09, from *Federal R&D Funding by Budget Function: 2007–09*, National Science Foundation, September 2008, available at http://www.nsf.gov/statistics/nsf08315

The National Science Foundation (NSF) publishes annual data on the R&D components of U.S. Federal agency programs by specific budget function. All activities covered by the Federal budget, including R&D, are classified into 20 broad functional categories. These include, for example, Energy (270), General Science and Basic Research (251), and Community and Regional Development (450). In most cases, these budget function classifications do not allow sufficient detail to easily identify programs specifically targeted at biobased product and programming research and development.

For illustrative purposes, Table 13 below contains an excerpt from the NSF report. Within the energy budget function, agencies within the Federal Government budgeted nearly 1 billion dollars for research and development activities related to renewable energy and energy efficiency in 2007. Preliminary and proposed amounts for fiscal years 2008 and 2009 are also shown below.

Table 13. Federal funding levels by budget function, 2007-09.

Funding Category and Agency (values in millions of dollars)	2007 Actual	2008 Preliminary	2009 Proposed	2008–09 (% change)
Total for Energy (270)	1,893	2,374	2,463	3.7
Department of Energy	1,797	2,283	2,369	3.8
Energy programs (271)	1,318	1,717	1,749	1.9
Energy efficiency and renewable energy	921	1,176	1,019	-13.4
Electricity delivery and energy reliability	97	100	100	0.0
Nuclear energy	300	441	630	42.9
Fossil energy (271)	469	563	620	10.1
Radioactive waste management (271)	10	3	0	-100.0
Nuclear Regulatory Commission (276)	76	71	77	8.5
Tennessee Valley Authority (271)	20	20	17	-15.0
Total for Agriculture (350)	1,857	1,852	1,616	-12.7
Agricultural research and services (352)	1,857	1,852	1,616	-12.7
Department of Agriculture (USDA)	1,857	1,852	1,616	-12.7
Agricultural Marketing Service	4	4	4	0.0
Agricultural Research Service	1,060	1,055	979	-7.2
Animal and Plant Health Inspection Service	27	27	27	0.0
Cooperative State Research, Education, and Extension Service	666	662	508	-23.3
Economic Research Service	75	77	82	6.5
Federal Grain Inspection Service	7	7	8	14.3
Foreign Agricultural Service	1	1	1	0.0
National Agricultural Statistics Service	5	7	7	0.0
Natural Resources Conservation Service	12	12	0	-100.0
Total for Natural Resources and Environment (300)	1,936	2,008	1,987	-1.0
Conservation and land management (302)	339	351	332	-5.4
Department of the Interior	35	34	39	14.7
Forest Service (USDA)	304	317	293	-7.6
Pollution control and abatement (304)	557	548	541	-1.3
Recreational resources (303)	200	199	200	0.7
Water resources (301)	22	26	22	-15.4
Other natural resources (306)	819	885	892	0.9

5.6.2 Federally Funded R&D Expenditures at Universities and Colleges, by Science and Engineering Field and Agency

Data Source: Table 2. Federally funded R&D expenditures at universities and colleges, by science and engineering field and agency: FY 2007, from *Universities Report Continued Decline in Real Federal S&E R&D Funding in FY 2007*, National Science Foundation, Directorate for Social, Behavioral, and Economic Sciences, available at http://www.nsf.gov/statistics/infbrief/nsf08320/nsf08320.pdf

NSF publishes annual data on federally funded R&D expenditures at universities and colleges. The data are detailed by broad science or engineering-related field. In most cases, these classifications do not allow sufficient detail to easily identify programs specifically targeted at biobased product and programming research and development.

For illustrative purposes, Table 14 below contains an excerpt from the NSF report on federal funding to universities and colleges.

Table 14. Federally funded R&D expenditures at universities and colleges by science and engineering field and agency in 2007.

Science and Engineering Field	All Federal R&D	DOD	DOE	HHS	NASA	NSF	USDA	Other*
All fields (in millions of dollars)	30,441	2,773	1,115	17,065	1,041	3,551	910	2,835
Computer sciences	1,014	272	36	54	24	402	39	98
Environmental sciences	1,835	167	94	59	250	595	67	514
Life sciences	18,348	442	140	15,179	90	576	714	1,021
Agricultural sciences	897	12	24	66	11	83	477	171
Biological sciences	6,199	145	64	4,942	36	422	183	310
Medical sciences	10,574	257	43	9,651	40	48	36	467
Life sciences, nec	678	28	8	520	3	22	18	73
Mathematical sciences	408	42	14	85	4	193	2	33
Physical sciences	2,677	342	389	475	357	785	9	181
Psychology	600	32	6	437	11	46	2	60
Social sciences	755	48	15	298	10	108	34	231
Sciences, nec	342	62	14	77	12	71	5	73
Engineering	4,462	1,366	407	398	283	774	39	620

DOD = Department of Defense; DOE = Department of Energy; HHS = Department of Health and Human Services; NASA = National Aeronautics and Space Administration; NSF = National Science Foundation; USDA = U.S. Department of Agriculture; nec = not elsewhere classified.

** Includes all other agencies reported.*

5.7. Private Capital Investment in Plant and Equipment

Relevance

Firms purchase new plants and equipment partly for replacement purposes, as existing physical capital wears out, and to expand future production capacity. Net capital investment in excess of equipment and plant replacement reflects producers' plans to increase output in the future. Net capital investment in the biobased products industry's plant and equipment is an important measure of growth of capacity and future output. Firms will not build new plants, expand existing plants, and buy new machinery unless they plan to produce more output.

Measurement

Measuring net capital investment in the biobased products industry runs into the same problem as measuring other output measures—how can one aggregate across different types of plants and equipment to come up with a meaningful indicator of net investment? A common measure is the published values of the capital costs of plants and equipment when new biofuel or other biobased production facilities are built. Such a measure describes gross investment in new production capacity; however, the net addition to domestic capacity is somewhat less as biobased production has likely replaced some of the growth that would have occurred in petroleum-based production.

Data Availability

The values of biofuel and bioproduct investments and overall capital stock are not well known. Investment prospectuses list anticipated costs, and one must assume that developers are duly diligent in their declarations. Information about publicly traded firms can be gleaned annually from EDGAR filings with the Securities and Exchange Commission. Lastly, information about annual capital expenditures and the gross value of depreciable assets (plant and equipment) can be obtained from the quinquennial economic census organized by six-digit NAICS, which prevents us, however, from distinguishing among biobased producers and other producers within the same grouping.

An example index is included on the following page.

5.7.1. Annual Capital Investment by Six-Digit NAICS (2002)

Data Source: Table 3. Detailed Statistics by Industry: 2002, from *All Other Basic Organic Chemical Manufacturing: 2002, Manufacturing, Industry Series*, 2002 Economic Census, U.S. Census Bureau

The table below illustrates the level of annual capital investment detail available from data sources. This table allows one to understand the nature of capital composition, the value of depreciation, and the estimated net value of capital stock at the end of the survey period. These data are, however, not in the type of detail to allow differentiation from ethanol plants, other bioproduct firms, and other chemical producers.

Table 15. Annual capital investment in plant and equipment by manufacturers of all other basic organic chemical manufacturing firms (2002).

NAICS 325199—All Other Basic Organic Chemical Manufacturing	$ Millions
Gross value of depreciable assets (acquisition costs) at beginning of year	54,011.6
Plus total capital expenditures (new and used)	2,340.7
Buildings and other structures (new and used)	190.9
Machinery and equipment (new and used)	2,149.8
Automobiles, trucks, etc., for highway use	15.5
Computers and peripheral data processing equipment	84.3
All other expenditures for machinery and equipment	2,050.0
Less total retirements	1,095.5
Gross value of depreciable assets at end of year	55,256.8

5.8. Company-Funded Research and Development

Relevance

Among the most visible activities taking place with regard to the bioeconomy are the research and development activities happening in industry, academia, and the Federal Government. These R&D activities are aimed at developing new biobased products and developing new and more efficient biotechnologies for producing new and existing products. Increased investment in R&D, like increases in physical plant and equipment, increases the likelihood of sizeable growth in the bioeconomy. Consequently, indicators of R&D activities are particularly important indicators of current bioeconomy activity and the future production of biobased commodities.

Measurement

In 2001, for the first time, NSF began collecting data on industrial R&D for biotechnology, although it's not clear that this effort has been sustained in a meaningful way. In any event, NSF's existing work on R&D indicators for the U.S. economy provides a natural starting point for the development of a measure of R&D expenditure on biobased product development and production technology. The construction of this measure would also provide measures of bioeconomic R&D expenditures broken down by character of work, performing sector, and source of funds. In order to separate the effects of inflation on R&D expenditures from "real" changes in R&D expenditures, these measures should be adjusted for inflation.

Data Availability

The NSF's National Science Board published measures of R&D expenditures (and other R&D indicators) in its biennial report, *Science and Engineering Indicators 2008* [33]. These include a measure of total R&D expenditures, as well as measures of R&D expenditure broken down by character of work (basic research, applied research, or development), performing sector (industry, universities and colleges, nonprofit institutions), and source of funds (industry, universities and colleges, nonprofit institutions).

5.9. Carbon Offsets from Biobased Production

Relevance

The production of biofuels has consequences for environmental quality and overall carbon emissions. It has been assumed by many that biofuel production is inherently “green” and beneficial as compared to other motor fuels and because they serve as a substitute for petroleum-based products. Those assumptions have been challenged recently, causing many assumptions about the net carbon content of biofuel production to be reconsidered [34]. If it cannot be determined either in the short run or the long run that biofuels have a more beneficial carbon outcome than the alternative, petroleum usage, then one of the strong foundations undergirding public financial support for biofuel development may be weakened.

Measures

Production processes and outputs can be measured at the plant or at the whole industry level. Of late there has been a shift to production life-cycle accounting that considers the entire production process, shifts in land use, and all relevant industrial input consequences when determining the net carbon gains attributable to this industry. Measurement outcomes also may vary depending on whether the level of scrutiny is country specific or global. To date, the carbon production of this industry has been measured by models of varying sophistication by ecologists, economists, and environmental scientists.

Data Availability

Findings are simulated from modeling exercises. There is no central, unified determination of net carbon production for the Nation’s existing or future biofuel and biobased industries.

5.10. Industrial Absorption and/or Consumer Acceptance of Biobased Products

Relevance

While ethanol possesses environmental attributes as a fuel oxygenate, its primary modern use is as a gasoline substitute. It also has an octane enhancement value in the fuel market that allows its use in engines with higher cylinder compression. The vast majority of existing automobiles in the United States are certified to accept up to a 10-percent blend of ethanol (E-10). There are flex-fuel vehicles certified to accept up to an 85-percent blend (E-85).

In 2006, there were 297,000 new E85-certified vehicles placed into use in the United States, according to the U.S. Energy Information Administration. Recent estimates indicate there may be as many as 7 million flexible-fuel vehicles (FFVs) in the United States. This represents about 3 percent of the 236 million registered U.S. passenger vehicles and light trucks. Although there have been additional sales of flex-fuel vehicles since 2006, the scarcity of flex-fuel vehicle fueling facilities further constrains market penetration of blends exceeding 10 percent ethanol. Accordingly, the near-term national ethanol absorption limit for ethanol is just over 10 percent by volume.

Due to the constraints within the existing automobile fleet, the United States hits what is called an ethanol blend wall when it reaches roughly 10 percent of all blended motor vehicle fuels, a wall that analysts believe will be confronted before the 15-billion-gallon conventional biofuels mandate is met. If success is achieved at producing an additional 3 to 4.5 billion gallons in advanced biofuels that are in the form of ethanol, then the blend wall will be hit sooner. There are two short-term remedies argued: increase both the sale of flex-fuel vehicles and the availability of E85 or blends that are higher than E10, or increase the allowed tolerance of existing automobiles in excess of the current E10 level.

Measurement

The current Renewable Fuels Standards call for the mandated consumption of 15 billion gallons of conventional biofuels by 2015, a large portion of which will likely be corn-based ethanol. There is also a blend requirement of 5.5 billion gallons of advanced biofuels, which would include biodiesel, cellulosic, and other advanced sources.

Output from the Nation's ethanol plants is compiled by virtue of its use as a fuel extender and as an oxygenate in areas of the United States that periodically mandate ethanol blends. Overall motor vehicle fuel production in the United States is tracked closely over time, as well. Recent data indicate that historic high fuel prices resulted in decreased motor vehicle travel and decreased consumption of motor vehicle fuels. Biodiesel production and blending is also an important consideration, but the volume of production and use is very small relative to ethanol use.

The United States also imports ethanol, primarily from Brazil. Prior to 2003, imported ethanol ranged from 0.5 to 1.3 percent of the total U.S. supply. As ethanol prices climbed sharply in the 2004 through 2006 period, due in part to disruptions in the U.S. energy supply because of natural disasters and the elimination of MTBE as a fuel oxygenate enhancer, imported ethanol climbed sharply to over 13 percent of U.S. supplies in 2006. Thereafter, as U.S. ethanol production expanded rapidly, imports declined to the 5 to 6 percent range. There is a growing capacity to produce large amounts of sugar-based ethanol, which is much more efficient when compared to current U.S. feedstocks, but a protective tariff of $.54 per gallon currently limits the flow of ethanol imports into the United States.

Data Availability

The U.S. Energy Information Administration provides monthly and annual statistics of motor vehicle fuel usage and of ethanol production and ethanol blending in the United States. That agency also produces data on the use of vehicles that consume alternative fuels, to include flex-fuel vehicles that can operate on a variety of blends up to 85 percent ethanol. That same source contains information on biodiesel production and usage as well.

Example indices are included below.

5.10.1. Ethanol Absorption as a Motor Vehicle Fuel

Data Source: U.S. Energy Information Administration

The fraction of motor vehicle fuel that contains ethanol rose slowly during the 1980s through 2002. Beginning in January 2003, the fraction rose above 2 percent. Thereafter it rose quite rapidly, reaching an estimated volume percentage of just over 6 percent.

As ethanol is now primarily an unleaded gasoline substitute and octane enhancer, the replacement value can be measured in terms of the energy and octane that is added by the ethanol blend. Ethanol has two-thirds of the energy value of an equivalent volume of unleaded motor vehicle fuel. By that measure, ethanol accounts for just over 4 percent of the energy supplied in modern motor vehicle fuels.

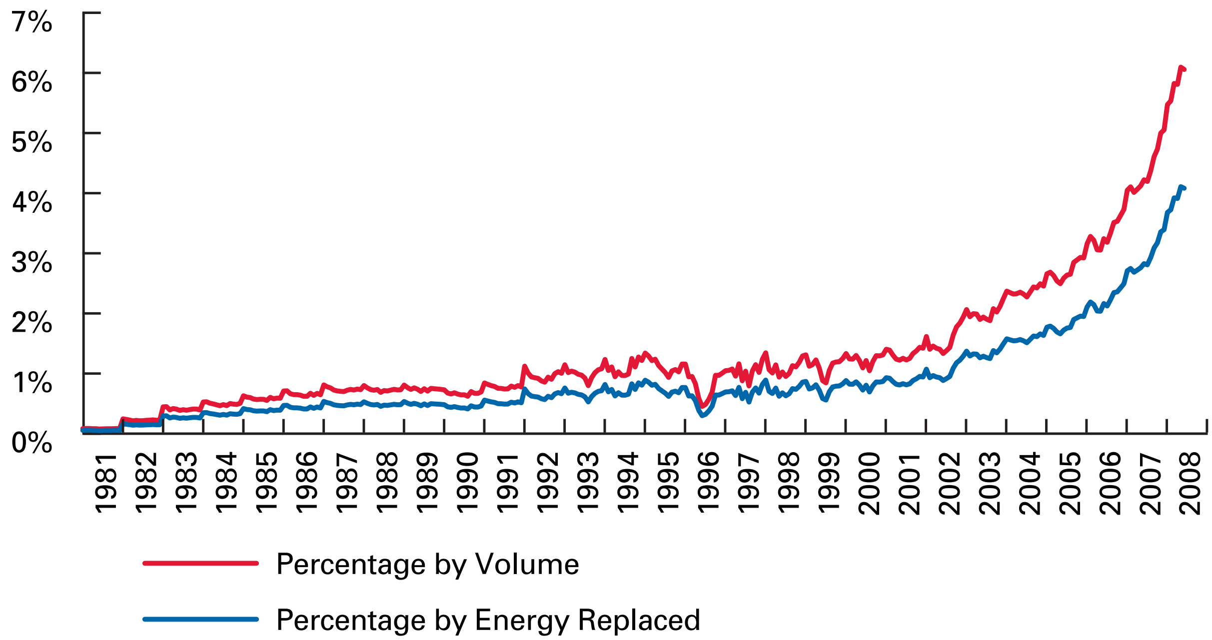

Figure 28. Ethanol absorption as a motor vehicle fuel.

5.10.2. Biodiesel Use as a Diesel Fuel Substitute

Data Source: U.S. Energy Information Administration

Biodiesel can be used as an additive or as a fuel extender for Number 2 diesel fuel. It can be made from both animal fats and vegetable oils, and the production process is relatively simple. Increases in biodiesel production in the United States are quite recent in nature, but the level of production is constrained severely by input costs.

When the market value of soybeans is high, it is unprofitable to produce biodiesel. The U.S. supply of fats and greases had been nearly completely utilized in industrial processes prior to the expansion of biodiesel production, so there is also a limited supply of that feedstock.

Nonetheless, biodiesel production has grown sharply in recent years. In 2001, the United States produced just 8.6 million gallons. In 2007, the United States produced 491 million gallons. Still, as of 2007, biodiesel consumption represented just 1.2 percent of the amount of total highway use of Number 2 diesel.

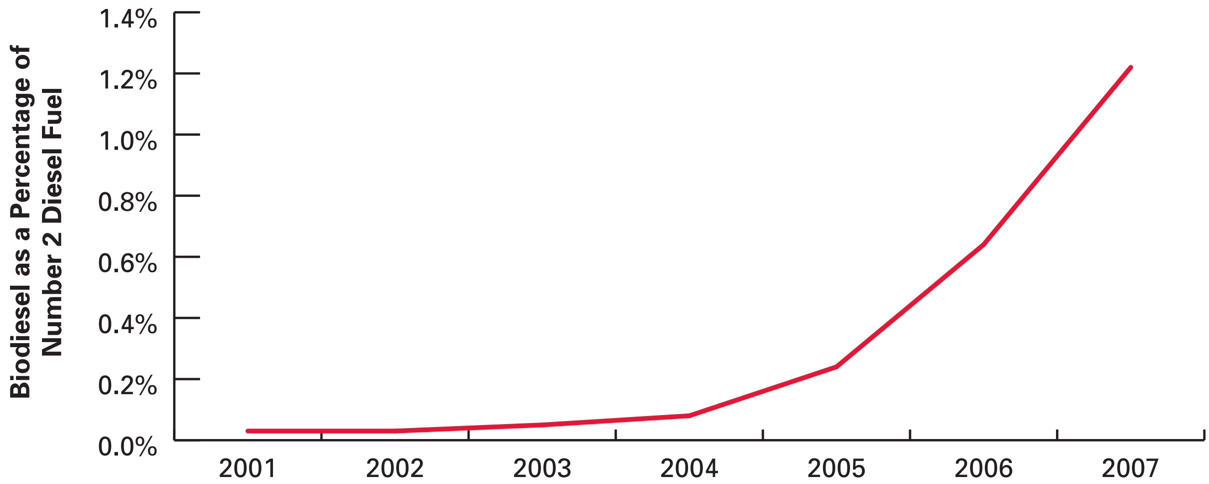

Figure 29. Biodiesel use as a Number 2 diesel fuel additive.

5.11. Production Levels (Sales) of Chemical-Based (and Fiber-Based) Products

Relevance

The production levels of chemical-based and fiber-based products serve as indicators of current demand for biobased products, either as inputs to other production or as end-use products.

Measurement

Biobased chemical and fiber products are produced by firms across a broad array of industries. Given the variety in the types, units, and value of these products, aggregate production levels are best measured by the dollar value of products that are sold.

Most of the publicly available data on firm sales are tabulated at the industry level under the NAICS. This creates two measurement problems for biobased chemical and fiber products. First, very few industry codes under the current NAICS are specific to firms producing biobased products. NAICS industry definitions are designed to group like firms based on similarity in their production processes. As a result, the definitions do not necessarily align with the specific production inputs used by the firms. Second, firms are assigned to a particular industry based on their primary or principal activity, which is generally defined as the activity with the highest share of current production costs or capital investment, but which may also be measured using shares of revenues, shipments, or employment. For many biobased products, especially new and emerging products, sales of these product lines are likely to represent a minority share in many firms. Even if NAICS codes specific for biobased products were added to the current system, firm sales for these smaller product lines would be missed.

Ideally, this indicator would be measured using product-level data so that sales of all biobased chemical and fiber products could be accounted for regardless of the industry in which they are produced. A current initiative called the North American Product Classification System (NAPCS) is underway to develop a complement to the NAICS. The NAPCS will classify industrial activity based on outputs rather than production processes. Until such time as data are widely published under the NAPCS, individual firm surveys will provide the most reliable way of measuring this particular indicator.

Data Availability

The economic census, conducted by the U.S. Census Bureau every 5 years, provides highly detailed and publicly available data on industry-level sales on an NAICS basis. The Census Bureau supplements these data with annual industry surveys; however, the survey data are not collected for all industries. As discussed above, the current level of industrial detail under the NAICS does not allow for accurate measurement of the actual sales of biobased products as distinct from other, similar products. However, these data are useful in measuring sales by industries that have a high likelihood of producing biobased products.

The U.S. International Trade Commission recently released a survey of the chemical and biofuel industry [8]. Results are reported from survey respondents from the ethanol, biodiesel, biobased-pharmaceuticals, and biobased-chemicals (except pharmaceuticals) industries.

An example index is included on the following page.

5.11.1. Indexed Change in Sales by U.S. Biochemical Companies

Data Source: *Industrial Biotechnology: Development and Adoption by the U.S. Chemical and Biofuel Industries*, Investigation No. 332-481, Publication 4020 (July 2008), U.S. International Trade Commission, available at http://www.usitc.gov/publications/332/pub4020.pdf

Figure 30 displays the change in sales of the biochemical (nonpharmaceuticals) survey respondents, scaled to an index of 100 for the year 2004. Nonpharmaceutical biochemicals are defined in the referenced work as including enzymes and microorganisms, commodity chemicals, specialty chemicals, intermediates, polymers, food additives, flavors, and fragrances.

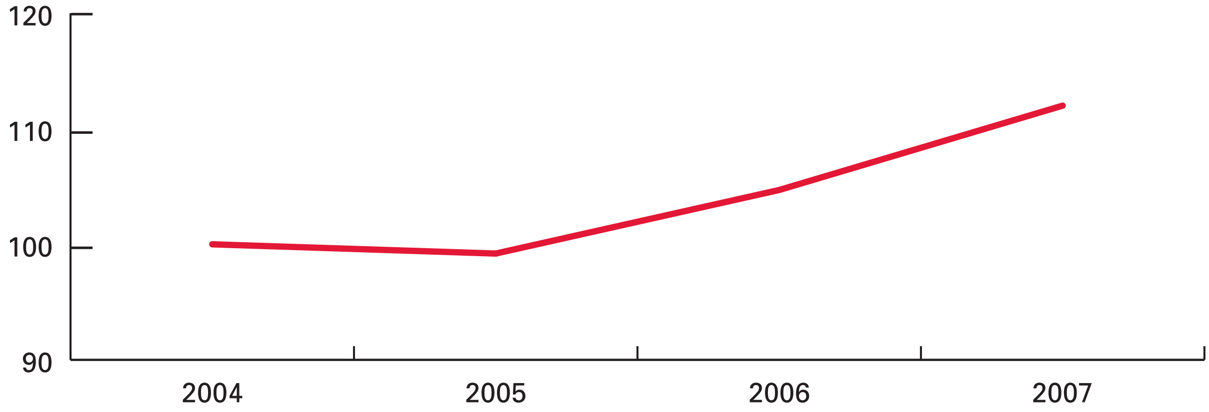

Figure 30. Sales by U.S. biochemical companies (scaled to an index of 100 for the year 2004).

5.12. Emissions from Biobased Production

Relevance

As biobased industries such as ethanol production reach a sufficient size, states and other interest groups are initiating efforts to more closely monitor the contributions of these industries to overall emissions levels in states and in the U.S. as a whole. Biofuel production is a form of chemical manufacturing. The processes involved consume high amounts of energy and input chemicals; require fresh water; and yield air, water, and solid emissions. Of most concern are emissions that result from fuel consumption. Most of the fuel used for biofuel production is coal or natural gas based. The emissions that evolve from the processing of the feedstock, such as carbon dioxide (CO_2), raise less concern since those materials were recently captured by the feedstock from the environment.

Measurement

The content and amounts of air, water, and other waste emissions from biobased production processes are primarily measured at the individual plant level. For aggregate measures of total emissions by broad categories of biobased activity at the state or national level, two key approaches may be used. In a top-down approach, aggregate activity such as total statewide fossil fuel combustion is used to estimate emissions. In a bottom-up approach, facility-specific estimates are prepared based on actual plant data and are then aggregated to the statewide level. It is supposed that a bottom-up approach yields more realistic estimates of emissions. Regardless of approach, emissions are measured indirectly based on the amount of fuels consumed, water input and output, and existing research on mathematical relationships between inputs and emissions.

Data Availability

Depending on its size and industry, an industrial facility may be required to obtain a variety of state and federal construction and operating permits that include information about that facility's air and water emissions. These permitting processes generate a wealth of data, and much of it is available from various state environmental agencies and the U.S. Environmental Protection Agency. Some states have begun to legislate annual reporting by their environmental agencies on total greenhouse gas emissions by various producing and consuming sectors within the state.

National improvements in standardizing the reporting of biobased product emissions across states and regions are driven by the implementation of the U.S. Environmental Protection Agency's Emission Inventory Improvement Program (EIIP), as updated in 2006. The program is a top-down approach to calculating estimates of greenhouse gas emissions at the state level, using a common spreadsheet template that has several categories requiring specific information about fuel and other inputs usage as well as outputs from industrial activities. In specific, these spreadsheets require throughput itemizations, fluorocarbon emissions disclosure, biomass throughputs estimates, CO_2 stack test results if applicable, and information on continuous emissions monitoring equipment. As in the case of Iowa, there are additional requests of ethanol refiners to include fermentation-related emissions in those compilations.

The EIIP data can eventually be analyzed by type of industry, as well as by the various categories of emissions. Ultimately, the data can be grouped by state, region, or aggregated to the national level. The major value of the EIIP is that it provides extensive methodological and categorical assistance to states to further develop their monitoring and emissions analysis capacities. It also can provide baseline values to monitor emissions trends by industry type.

Compilations and surveys from the National Science Foundation (NSF) provide the most comprehensive look at federal R&D spending across various public and private funding sources. The NSF collects and publishes a variety of R&D statistics through its Division of Science Resources Statistics using surveys and administrative data sources. One survey tracks federal obligations and funding for research and development in science and engineering, as reported by 15 federal departments and their 72 subagencies. Section 5.6.1 illustrates the type of data available from this survey. Another NSF survey provides information about academic R&D funding by source and discipline. This is illustrated in Section 5.6.2. The NSF's National Science Board publishes these and many other R&D indicators in its biennial report, *Science and Engineering Indicators 2008* [33].

An example index is included on the following page.

5.12.1. Estimated Greenhouse Gas Emissions by Sector in Iowa, 2007

Data Source: *2007 Greenhouse Gas Emissions from Selected Iowa Source Categories, (2008)*, Iowa Department of Natural Resources, Environmental Services Division, Air Quality Bureau, available at http://publications.iowa.gov/6580/1/2007_Greenhouse_Gas_Inventory.pdf

The accompanying figure demonstrates the comparative emissions emanating from modern biofuel operations, both wet and dry milling, in the state of Iowa. Emissions from fossil fuel consumption at Iowa's 28 dry milling facilities were estimated to be 2.33 million metric tons of CO_2 equivalent in 2007. Greenhouse gas emissions from fermentation processes at Iowa's dry and wet milling operations totaled 5.29 million metric tons. The majority of these emissions would have entered the environment anyway as the biomass was used elsewhere and subsequently decayed. Biomass combustion contributed another 0.13 million metric tons. The emissions from fossil fuel consumption by 276 industrial facilities in Iowa that are permitted under Title V of the 1990 Federal Clean Air Act Amendments are also shown in the chart. Title V facilities, which are commonly referred to as major sources, are the largest sources of air pollution recognized by the Federal Government. Emissions from Iowa's Title V facilities totaled 52.06 million metric tons in 2007.

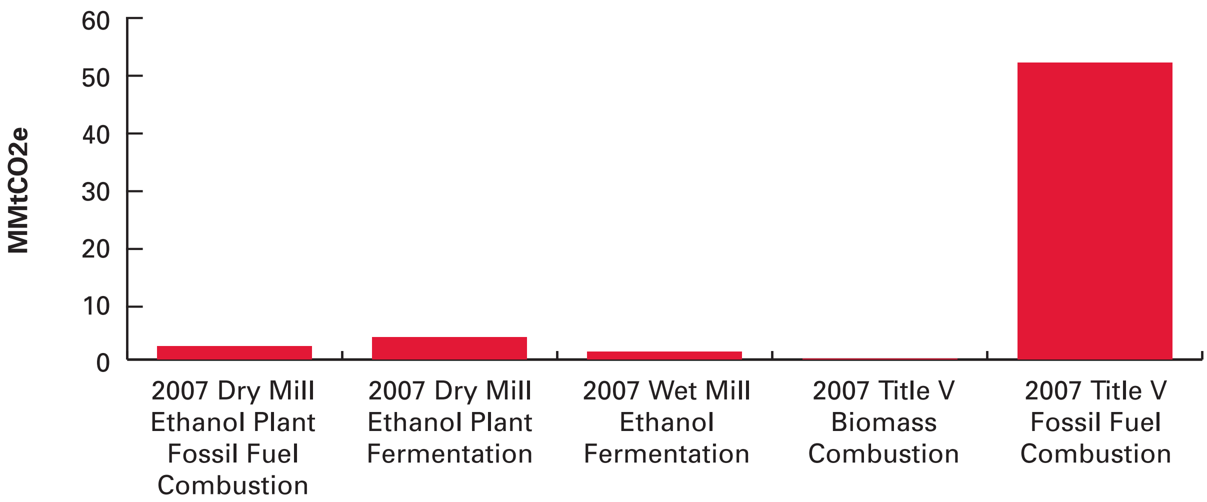

Figure 31. Estimated greenhouse gas emissions in million metric tons (MMt) by sector in Iowa.

5.13. Biofuels Price Levels

Relevance

The price of biofuels is determined by the cost of production, the value of governmental subsidies, and the demand for ethanol and biodiesel as fuel additives and fuel extenders. There have been very strong swings in the prices received for biofuels over the past several years that have been functions of overall production levels, natural disasters like Hurricanes Katrina and Rita, the implementation of Federal laws for fuel additives, and the biofuel mandates.

This price volatility between ethanol and unleaded gasoline is very evident in recent years. The average wholesale price of ethanol in 2005 was just 6 percent higher than the year previous, but the price of unleaded fuel increased by 32 percent. In the next year, the average price paid for ethanol shot up 43 percent while unleaded fuel rose a more modest 17 percent. In 2007, the average price of ethanol declined by 13 percent while the average price of unleaded gasoline rose 15 percent.

In the long run, most firms require price stability to effectively plan annual and future operations and to assure overall profitability. Unfortunately for the biofuels industry in particular, and for the entire energy sector in general, there have been very strong price swings that are sometimes not easily explained or predicted.

Measurement

The daily, weekly, or average prices received for ethanol and biofuels, whether on a contract basis or on a rack-wholesale basis, are the primary types of prices that are tracked. Biofuel prices are also tracked in relationship to the value of the fuels for which they are a substitute or an additive.

Data Availability

Biofuel price information is collected from a variety of proprietary, university, and other sources. The Chicago Board of Trade lists historic and futures prices; data from rack sales at the wholesale level can be obtained via Web sources from, for example, Omaha, Nebraska, or Pekin, Illinois; data can be purchased from commodity news services like DTN; and university organizations such as the Center for Agricultural and Rural Development at Iowa State University and the Food and Agricultural Policy Research Institute (University of Missouri and Iowa State University) have databases and charts that are updated regularly.

An example index is included on the following page.

5.13.1. Ethanol Futures Prices

Data Sources: Daily price data from the Chicago Board of Trade; Data compiled by the Center for Agricultural and Rural Development, Iowa State University

The volatility in ethanol prices is clearly evident from the following graph. In early 2005 prices hovered in the $2 to $2.25 range. Hurricanes Katrina and Rita yielded a strong spike. The phaseout of MTBE as a fuel additive resulted in a strong upward bid on ethanol as an additive, driving prices in excess of $4. Prices stabilized, staying between $1.80 and $2.50 for a sustained period, before rising sharply in the energy price spike of early 2008.

Figure 32. Ethanol futures prices.

5.14. Direct Value Added (GDP) from Biobased Production

Relevance

What is the relative importance of biobased production in the economy, and how is it changing over time? Net national economic impact is measured in value added or its equivalent, GDP. Value added or GDP is the measure of the payments that are made to production factors and, indirectly, to governments in producing goods and services. It is how we measure the U.S. economy.

The size and the contribution of the Nation's biobased productivity ultimately will be measured in those terms. As the industry develops and matures, analysts and policy makers will want to know the number of jobs associated with the firms and their contributions to the Nation's GDP.

Measurement

One way to answer the question about the importance of the overall biobased industrial category is to construct a measure of biobased production analogous to GDP, which is produced quarterly by the U.S. Department of Commerce's Bureau of Economic Analysis. A biobased GDP would measure the market value of biobased products produced in a given period, expressed as dollars worth of output per year. Movements in the biobased GDP from one year to the next can be interpreted as annual changes in overall biobased production. The biobased GDP-to-GDP ratio can be used to measure the relative size of the biobased products industry, and changes in this ratio over time can be used to measure changes in the relative size of the biobased products industry or its overall profitability.

The economy's biobased GDP could be constructed by adding up the value of the production of the array of goods and services that define biobased output. Consequently, an important by-product of the biobased GDP indicator will be indicators of the production of the various component outputs. These indicators are of interest in and of themselves. They can also be used to help determine the relative importance of the different sources of growth in biobased GDP.

At first glance, the construction and interpretation of a biobased GDP seems very straightforward. However, as with GDP, issues such as distinguishing intermediate and final goods (to avoid double counting), removing the effects of inflation (to avoid misinterpreting movements in biobased GDP due to price changes versus output changes), and properly accounting for the biobased service sector would need to be addressed. These are relatively minor concerns since methods have been designed by the BEA to resolve analogous problems in the computation of GDP. The most pressing concern is clearly the lack of data on biobased production at the industry level.

Data Availability

Nationally, GDP is derived from BEA national income and product accounting (NIPA) procedures on a quarterly and annual basis. Candidate periodic industrial survey data are available at the BEA but are currently not analyzed in a manner or aggregated such that specific biobased product industrial activity can be identified, let alone contributions to GDP estimated. For example, the BEA will not publish GDP values specifically for the ethanol industry. The values are subsumed within the organic chemical industrial classification.

Small- or large-area estimates can be made from ethanol impact models that are regional, state, or national in construction, based on current information about ethanol production direct requirements.

An example of how this index might be generated is included on the next two pages.

5.14.1. Gross Domestic Product from Typical Midwestern Ethanol Production Facilities—A Micro-Area Assessment

Data Sources: Analysis based on input-output model development by David Swenson, Iowa State University; Tiffany, D. and Eidman, V. R. (August 2003), Factors associated with success of fuel ethanol producers, Staff Paper P037, University of Minnesota; Swenson, D. and Eathington, L. (September 2006), Determining the regional economic values of ethanol production in Iowa considering different levels of local investment, Department of Economics Staff Report, Iowa State University.

Value-added production at the ethanol plant level can be simulated using a basic model of a typical operation, where all production costs and value-added payments are considered. This example looks at the operating characteristics of a 50-million and a 100-million gallon per year (MGY) ethanol plant in 2005 and in 2008. In each scenario, average prices paid for labor, corn, natural gas, electricity, debt financing, and capital development were applied for the years of the analysis. For example, the average corn input price for 2005 was $1.96 per bushel and the average price received for ethanol per gallon was $1.78. Average capital costs in 2005 were $1.25 per capacity gallon; for 2008 they were $2.15 per gallon. Debt was assumed for 50 percent of total costs using a 9-percent interest rate in 2005 and a 12-percent rate in 2008. For 2008, this analysis estimates that the average corn price will be $4.44 per bushel and the average price received for ethanol will be $2.38.

Table 16 reveals the results for 2005 and for 2008. In nominal terms, a 2005 50-MGY ethanol plant produced $22.11 million in total value added, and a 100-MGY plant generated $44.33 million. Those amounts decline sharply for 2008. In 2008, a 50-MGY plant produces $12.24 million using the assumptions in the modeling exercise. That is 45 percent less than 2005. The $22.5 million for the 100-MGY plant is 49 percent less.

Table 16. Value-added determination for ethanol plants ($).

	2005		2008	
	50 MGY	100 MGY	50 MGY	100 MGY
Total output	108,323,875	216,647,750	155,384,386	308,676,399
Less:				
Corn	38,500,000	77,000,000	87,214,286	174,428,571
Natural gas	16,689,750	33,379,500	16,535,750	33,071,500
All other	31,024,475	61,942,932	39,396,812	78,677,447
Equals:				
Value added	22,109,650	44,325,318	12,237,538	22,498,881
Workers	2,430,343	3,124,727	2,649,074	3,405,953
Investors	18,787,842	39,429,663	8,134,500	16,197,000
Government	891,464	1,770,929	1,453,964	2,895,929

How or to whom value accumulates is also important, especially in the context of regional economic development and the push to stimulate local ownership of ethanol plants. In 2005, the amount of value added flowing to investors or partners versus the amounts to labor in these examples was almost 8 times greater for 50-million gallons per year (MGY) plants and 12.6 times greater for a 100-MGY plant. Those respective ratios declined to 3.1 and 4.8, respectively, in 2008 as returns tightened.

Assumptions made and prices input to the model are included in Table 17 and the list that follows.

Table 17. Prices and assumptions.

	2005	2008
Corn/bushel	$1.96	$4.44
Natural gas/MBTU	$8.67	$8.59
Electricity/KWhr	$0.06	$0.07
DDGs/ton	$60.57	$135.10
Interest	9%	12%
Capital cost per gallon	$1.25	$2.15
Amount financed	50%	50%
Ethanol/gallon	$1.78	$2.38
Production levels	110%	110%
Ethanol gallons per bushel	2.80	2.80

Electricity is in kilowatt hour (KWhr) and DDGs refer to Distiller's Dried Grains with Solubles.

1. Historical prices were obtained from the U.S. Department of Agriculture (USDA) and from the U.S. Department of Energy (DOE). 2008 prices and assumptions are from the Food and Agricultural Policy Research Institute, Iowa State University and the University of Missouri–Columbia.
2. The model for estimating value added was derived from Tiffany and Eidman’s research [35] as modified by Swenson [36].
3. This value for dried distillers’ grains assumes that a third of the volume is sold as dry, a third as modified dry, and a third wet.
4. The capital costs per nameplate capacity were obtained from representative prospectuses from the measurement period.
5. It is common to assume that U.S. plants are producing at 110 percent of their capacity or more. However, recent analysis questions this supposition—declared capacity is in excess of production. This research uses the 110 percent factor, recognizing that it very well may be excessive.
6. Modern plants are more efficient than older plants. Newer plants may produce as much as 2.8 gallons of ethanol per bushel of corn, whereas older plants may produce less, perhaps just 2.6 gallons per bushel during the initial distillation process. The amount of anhydrous ethanol that results from further processing is less due to the removal of any remaining water.

5.15. Production Levels (Gallons) of Biofuels

Relevance

Blending of biofuel in the United States is mandated to increase sharply. According to Federal law, the United States was required to have used 9 billion gallons of conventional biofuel in 2008. By 2015, the amount mandated is 15 billion gallons from conventional biofuels, including corn-based ethanol, and another 5.5 billion from advanced sources—ethanol derived from biomass, primarily.

The levels of production in the United States in 2008 for both ethanol and for biodiesel are somewhat less than the built capacity to produce those fuels. This is due largely to the rapid pace of expansion in those industries—expansion that has resulted in rapid capacity increases while the demand has increased much more incrementally. The propensity to produce and to blend biofuels with motor fuels and with diesel fuels, mandates and subsidies notwithstanding, is a function, importantly, of the price of the products. When ethanol is in large supply and its price is very low compared to unleaded gasoline, there is a strong incentive for blending. When the price is the same as unleaded gasoline (after factoring in federal credits) or higher, then blenders may demand less.

Measurement

Production can be measured at the plant level, by state, by kind of ethanol producer, and in the aggregate. Production is measured in gallons or barrels (42 gallons).

Data Availability

Monthly national production estimates are provided by the U.S. Energy Information Administration.

Example indices are included on the following pages.

5.15.1. Ethanol Production

Data Source: U.S. Energy Information Administration

U.S. ethanol production has rapidly expanded in recent years. Between 1990 and the end of 1999, production expanded at a compounded rate of 0.7 percent per month. From 2000 through the end of 2004, the compounded monthly rate of growth doubled to 1.4 percent. From the beginning of 2005 through June 2008, the industry expanded at a 2.1 percent compounded monthly rate. Although there has been a slowdown in new plants coming on line in part due to high construction costs, project delays, and narrowing crush margins, production has continued to expand as existing plants are expanding their facilities and larger plants are coming on line.

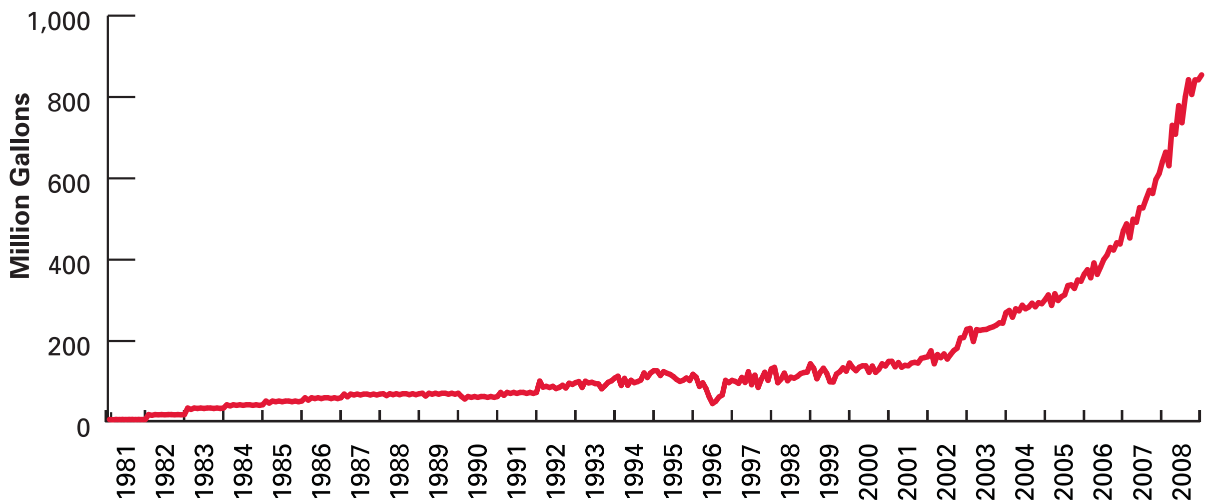

Figure 33. U.S. monthly ethanol production.

5.15.2. U.S. Biodiesel Production

Data Source: U.S. Energy Information Administration

U.S. biodiesel production has expanded this decade as well. The United States produced just 8.6 million gallons of biodiesel from oilseeds and animal fats in 2001. By 2007, production exceeded 491 million gallons. By way of comparison, in 2007 the United States produced 6.5 billion gallons of ethanol, over 13 times more ethanol by volume than biodiesel.

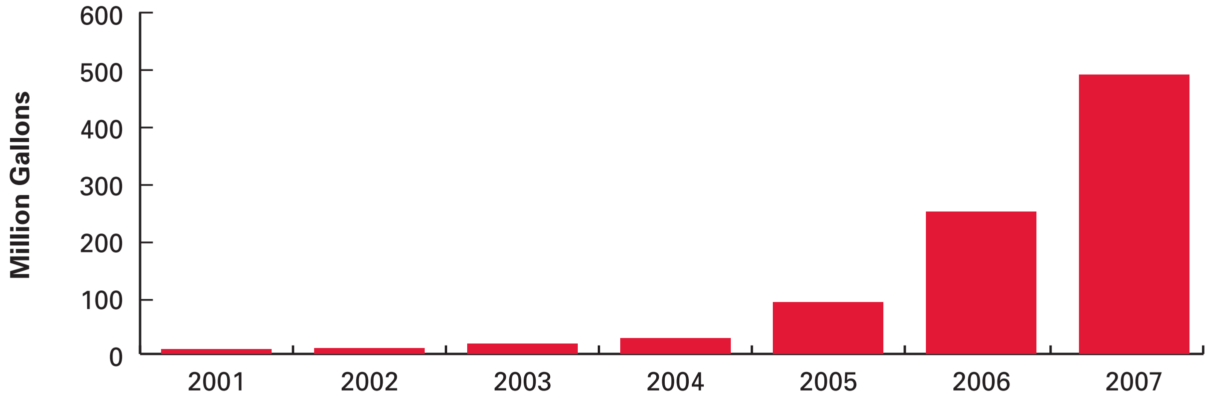

Figure 34. U.S. annual biodiesel production.

5.15.3. U.S. Biodiesel Production and Capacity Utilization

Data Source: National Biodiesel Board

The Nation's capacity to produce biodiesel expanded sharply during this decade. According to the National Biodiesel Board, there were 50 million gallons of production capacity in 2000, although just 8.6 million gallons were produced, a capacity utilization rate of 17 percent. Capacity doubled annually from 2003 through 2006, and then it nearly quadrupled from 2006 to 2007, where capacity had grown to 2.24 billion gallons and capacity utilization in producing 491 million gallons of biodiesel was 22 percent. There is a very large amount of underutilized capacity for biodiesel production due to the high prices of the primary feedstock.

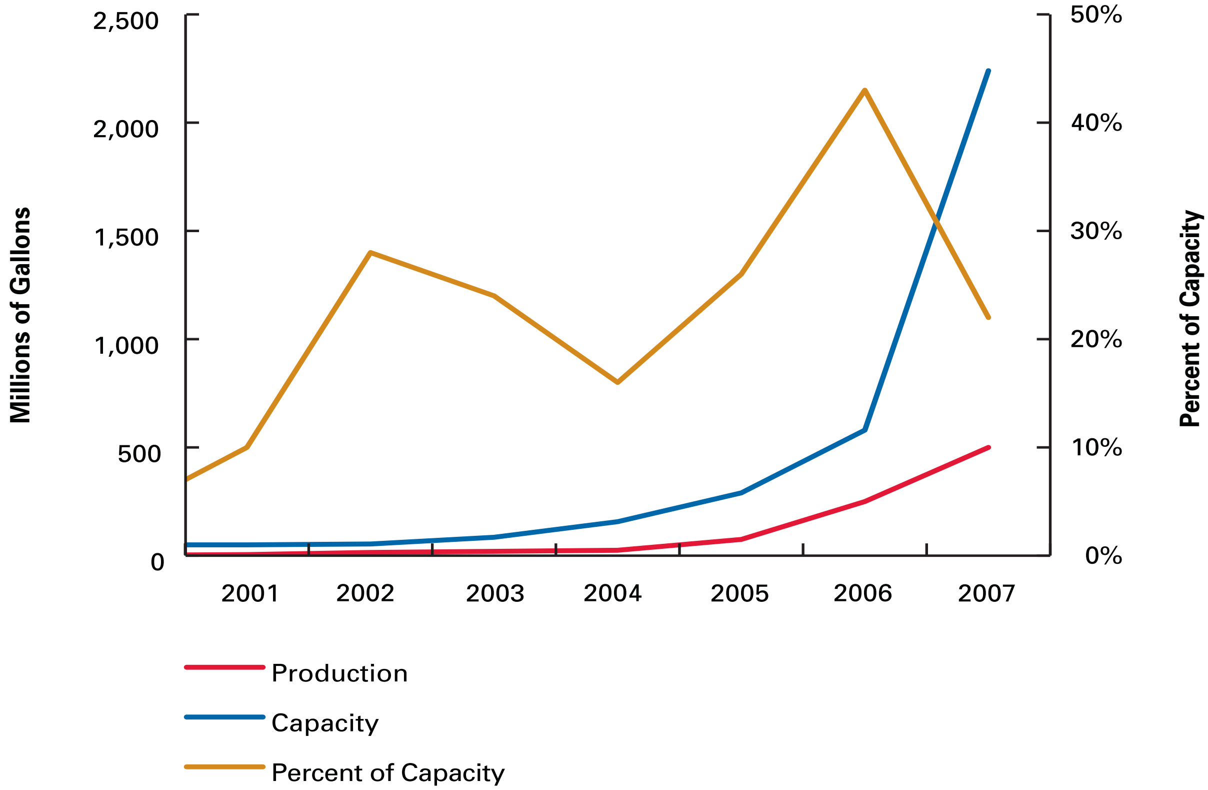

Figure 35. U.S. biodiesel production and capacity utilization.

5.16. Quantity (Tons/Gallons) of By-Products from Biofuel Production

Relevance

For modern biofuel operations to maximize their profitability, they need to develop as many uses of production by-products as possible. Currently, corn ethanol production yields a leftover commodity that can be dried. The term for this is dried distillers' grains or DDGs. The other primary by-product of ethanol production is CO_2, but much more CO_2 is produced than is currently demanded. It is typically vented into the atmosphere if a local market for it does not exist. When a bushel of corn is processed, a third of its weight becomes ethanol, a third DDGs, and a third CO_2. Distillers' grains are sold primarily as cattle feed as wet (undried), modified (partially dried), and dried. The more drying involved, the higher the feed value and the price.

The primary by-product of biodiesel production is glycerin. It has commercial uses in soaps and explosives, and there is a potential for glycerin to serve as an animal feed supplement, especially as a boost to caloric intake. From 10 to 12 percent of fats are glycerins, so the amount of glycerin produced depends on the type of feedstock employed. There are no other soybean or oilseed products that are part of the biodiesel production process since the soybean oil is separated from the remainder of the bean prior to biodiesel production.

Measurement

The amounts of distillers' grains, CO_2, or glycerins can be estimated as fixed coefficients of the feedstock into the biofuel process.

Data Availability

While there are daily price data for biofuel by-products, there are no known centralized collections of amounts.

6. Analysis of Economic Indicators

The majority of the indicators highlighted in Chapter 5 focus on a segment of the bioeconomy. In this chapter, further economic analysis is provided that demonstrates how indicators may be combined to assess various aspects of growth, profitability, and uncertainty in the bioeconomy. This includes an analysis of composite indicators to aggregate multiple aspects of the industry and a discussion of biofuels operating margins to demonstrate profitability.

6.1. Composite Index

There are two general types of aggregate indicators—diffusion indices and composite indices. Diffusion indices, like the PMI developed by the Institute for Supply Management [37], gauge the near-term condition of an industry, as espoused by a representative number of companies. Composite indicators aggregate several economic indicators into a single dimensionless number whose movements over time reflect changes in the overall state of the sector of the economy being studied.

6.1.1. Bioeconomy Diffusion Index

Diffusion indices provide a measure of how widespread (diffused) a business cycle movement has become, whether in expansion or contraction [38]. The index is based on an assessment of the change in a particular group over a set time period. The group might be a set of specific companies or a set of different economic indicators [37,39].

The Institute for Supply Management's PMI index is an example of a diffusion index, which is computed from the results of a survey of specific companies. Each month, over 350 manufacturing companies are asked to assess their performance during the current month, compared with the previous month. Different business activities are reported as being better, the same, or worse than before. A composite index is computed by equally weighting five seasonally adjusted indices: new orders from customers, production, employment, supplier deliveries (speed), and inventories.

Diffusion indices are a weighted average of the data. The index is computed by adding the percent of the group that improved (x 1.0), plus the percent that did not change (x 0.5), plus the percent that declined (x 0.0). An index over 50 indicates general improvement compared with the previous month. A reading under 50 represents a deterioration or contraction. A reading of 50 indicates a balance within the group of those increasing/growing and those decreasing/contracting. An index of 100 implies that business activity improved in the entire group, while an index of 0 implies that performance within the entire group declined.

Diffusion indices can be based on the same data as a composite index (see Section 6.1.2). The index generally follows similar trends but, in some cases, can actually move in a different direction. A composite index provides a quantitative measure of the strength of the economy, as denoted by the component indicators. The index will capture both small and large changes in the group. A diffusion index captures how pervasive the trends are within the group. If the group is composed of appropriate economic indicators, the turning point in a business cycle can be captured.

Diffusion indices can cover an entire industry. The PMI, computed by the Institute for Supply Management, provides a measure of the condition of the manufacturing industry in the United States [37]. Indices can also be focused on a portion of the country, as is the Mid-American Business Conditions Index published by Creighton University [40]. Indices also describe the diffusion of a particular economic measure across many economic sectors. The employment change diffusion index by the Bureau of Labor Statistics is an example of this type of index [41]. A diffusion index can also be computed based on the direction of movement of other indices [39].

It is relatively straightforward to begin the development of a bioeconomy diffusion index. Companies could be recruited to participate from each of the principal sectors of the bioeconomy—fuels, chemicals, end-use products, and power. Since a bioeconomy GDP is currently not available, it is not possible to accurately weight the different sectors before aggregation. Until GDP-based weightings become available, the different sector indices could be reported separately. Alternatively, a uniform weighting could be applied or a weighting based on estimates of employment size within the different sectors could be used.

A variety of growth-related questions needs to be asked to give an accurate indicator of the condition of the industry. Using the PMI index as a foundation, it might make sense to use the following questions, posed to both manufacturers and distributors of biobased products:

- Have new orders for biobased products increased, stayed the same, or decreased from the previous month?
- Has production of biobased products increased, stayed the same, or decreased from the previous month?
- Has total employment associated with biobased product lines (production/distribution and administrative services) increased, stayed the same, or decreased from the previous month?
- Have inventories of biobased products increased, stayed the same, or decreased from the previous month?

Since the supply chain of biobased products companies is typically very short compared with more complex nonbiobased products (e.g., automobiles), it may not make sense to include a question regarding suppliers. A supplier component index would likely not provide a valuable near-term assessment of how the biobased products industry is performing, especially for companies that are purchasing agricultural commodities (e.g., ethanol plants) or ag-based oils. These “supplies” to the industry affect the cost of the final biobased product, but the production of these “supplies” is not connected in real time because of the large volume of commodities in storage due to the length of the temporal cycle of production agriculture.

The questions posed to companies must specifically address the biobased products produced or distributed at the facility. A recent survey of biobased products companies showed that many companies produce both biobased and nonbiobased products [14]. Figure 36 displays the distribution of companies by sales attributed to biobased products. Two-thirds of the respondents stated that 80 percent or more of their sales come from biobased products. Conversely, 23 percent of the companies had less than 40 percent of their sales from biobased product lines. As the fraction of sales from biobased products decreased, the size of the company tended to increase. Failing to account for these variations in biobased production intensity can lead to inaccurate estimates of the size and condition of the industry.

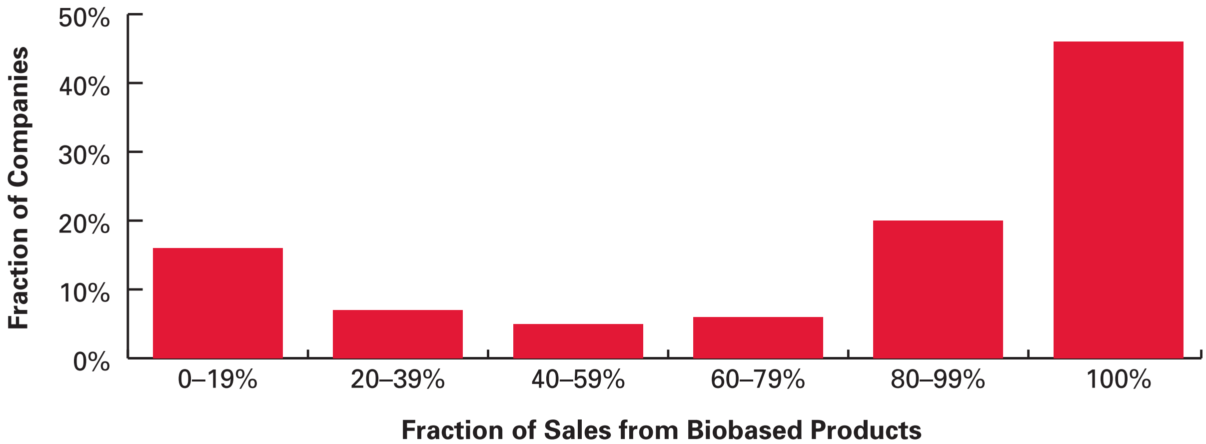

Figure 36. Company sales from biobased products [14].

The results of the recent Iowa State University survey of biobased product companies can be used to demonstrate how a diffusion index can be computed [14]. The surveyed companies were asked, "Are your biobased product sales increasing, staying the same, or decreasing?" A diffusion index of 85 results, on a 0-to-100 scale, was based on the respondents' answers. If the results are weighted based on the number of biobased product employees reported by each company, an index of 91 results. The index could have been this high because of widespread growth in the industry. Alternatively, the value could be overstating the current condition of the industry. The survey was conducted in the summer of 2008 before the U.S. economic slowdown accelerated. Also, respondents were not asked to specify a time period over which to report a change in sales.

For an index of this type to be of value to industry, the survey would have to be conducted monthly, like the variety of other diffusion indices that are currently reported. Data for a component biofuel index may be straightforward to collect. A more thorough analysis of the end-use biobased products industry needs to be completed before an accurate biobased products component index can be computed to make certain that the surveyed group is an accurate representation of the industry as a whole.

6.1.2. Composite Indicator of the Bioeconomy

A second composite index is proposed here that aggregates several previously used indicators. A composite index summarizing information contained in an array of individual indicators will help the public, industry, media, and policy makers see an overall picture that is not so obvious from the component indicators themselves. Put another way, the introduction of a composite bioeconomy index will provide a focal point to facilitate and enhance public- and policy-oriented discussions regarding the state of the bioeconomy. In addition, by providing information regarding the state of the bioeconomy in an accessible and easily comprehensible form, the bioeconomy index will contribute toward greater public understanding of the bioeconomy, its growth, and its role in general economic activity.

The public is already familiar and comfortable with a variety of composite indices such as the Consumer Price Index (CPI) and the Dow-Jones Industrial Average (DJIA), which provide information about the economy's inflation rate and stock market, respectively [42,43]. In addition, the Consumer Confidence Index, previously discussed, provides valuable information to businesses and policy makers about consumer attitudes concerning the condition of the U.S. economy.

The monthly CPI is constructed by the BLS, which specifies a particular "basket of goods and services" assumed to characterize the purchases of a "typical" household. This basket will include food and beverage items, apparel, medical care services, recreation activities, housing services, and so on. The fact that the available goods and services and the quality of goods and services are changing over time complicates the construction and interpretation of the CPI and is an important problem facing the BLS on a continuous basis. Each month, employees of the BLS determine the cost of buying this basket. If the cost of buying the basket increases, say, by 0.5 percent from one month to the next, the CPI is increased by 0.5 over its previous value. The index is set at 100 for an arbitrarily selected base period. For example, the April 2007 CPI is 206.686 and the March 2007 CPI is 205.352. From this, one can infer that the cost of living grew by 0.6 percent between March 2007 and April 2007. As well, the cost of living has more than doubled from the base period, 1982–1984, when the CPI was 100.

The DJIA is produced and maintained by *The Wall Street Journal*. Thirty stocks, traded on the New York Stock Exchange (NYSE), are used in the construction of the DJIA. The thirty stocks are highly reputable and major stocks, widely held by individual and institutional investors. The stocks included in this group of 30 stocks change over time, but infrequently. A portfolio of the 30 stocks (i.e., a certain number of shares of each stock) is specified. The market value of the portfolio is defined by adding up the price per share times the number of shares held for each of the 30 stocks in the portfolio. Changes in share prices change the value of the portfolio. If the value of the portfolio increases by, say, 2 percent, then the DJIA will increase by 2 percent. The value of the DJIA at the close of the NYSE on June 11, 2007, was 13,424.96 and the closing value on June 12, 2007, was 13,295.01. Note that these are not dollar values; they are simply numbers. One can infer that the value of the DJIA stock portfolio fell by nearly 1 percent on June 12. Although the DJIA only measures changes in the DJIA portfolio, movements in the DJIA are widely interpreted by the public as reflecting trends in the overall stock market.

Composite indices, such as the CPI, DJIA, and CCI, have at least a couple of common features.

First, composite indices are dimensionless numbers (i.e., they have no meaning in and of themselves). The April 2007 CPI value of 206.686 is only meaningful in comparison to other CPI values. The June 12, 2007, DJIA value of 13,295.01 is only meaningful in comparison to other DJIA values. The May 2007 CCI value of 108.0 is only meaningful in comparison to other CCI values. Instead, it is the direction and magnitudes of changes in composite indices that are meaningful.

Second, composite indices depend on what components are used in their construction and the relative importance assigned to the components. For example, the CPI is derived by looking at the prices of a particular sample of goods and services, and the DJIA is derived by looking at the prices of a particular sample of stocks. Once the sample of goods and services (or stocks) is chosen, the importance or weight that each good or service (or stock) is given in constructing the index must be determined. In constructing the CPI, the number of units of each good in the basket must be determined. In constructing the DJIA, the number of shares of each company's stock that will make up the portfolio must be determined. Prices of items that make up a relatively large (small) share of a typical household's expenditures get a relatively large (small) weight in the construction of the CPI. Prices of stocks that make up a relatively large (small) share of the DJIA portfolio get a relatively large (small) weight in the construction of the DJIA. The CCI asks a number of questions and asks respondents to select from a small number of possible answers. For example, respondents are asked to characterize current business conditions as "good," "bad," or "normal" and are asked whether they plan to buy a new car within the next year (i.e., "yes," "no," or "uncertain"). The percentages of respondents answering a particular question in a particular way make up the components that are aggregated into an index. The Conference Board must decide whether to weight each question equally or to assign more weight to certain questions than to others.

Another important economic index, which may be conceptually closer to the index proposed here, is the Conference Board's *Leading Economic Index* [44]. The *Leading Economic Index* is a monthly index that combines information about an array of macroeconomic activity in a single number to convey information about whether the economy is heading toward an expansionary or recessionary future. The 10 indicators that make up this index include the average weekly hours worked by manufacturing workers, the average number of initial applications for unemployment insurance, the amount of manufacturers' new orders for consumer goods and materials, the speed of delivery of new merchandise to vendors from suppliers, the amount of new orders for capital goods unrelated to defense, the amount of new building permits for residential buildings, the Standard & Poor's (S&P) 500 stock index, the inflation-adjusted monetary supply, the spread between long and short interest rates, and consumer sentiment. Changes in each one of these are thought to precede changes in future overall economic activity; however, each can change for other reasons so that none is a perfect predictor of future economic activity. Combining or averaging these indicators into a single measure filters out some of the "idiosyncratic" movements in the individual indicators, providing a more reliable (though still imperfect) measure of future aggregate economic activity. In practice, several consecutive monthly declines in the leading indicators are thought to portend the onset of a recession within the following 6-to-9 months.

The proposed composite index of bioeconomy indicators is like the index of leading indicators in the sense that it is composed of quantities that cannot be easily or naturally aggregated but are combined through a weighted average into a dimensionless number (or index) whose changes in magnitude and sign are meaningful. After selecting key indicators, the problem is then to decide how to weight them to derive the composite index.

The simplest weighting approach is to weight the indicators equally. Ignoring the dollar, time, or other dimensions associated with an indicator, simply add up the numbers to get the composite index. In practice, this approach would be modified in a couple of ways. First, if the indicator numbers differ from one another by orders of magnitude, changes in those components with the largest order of magnitude will drive the index. So, the component indicators should be rescaled to be of the same order of magnitude before being averaged. Second, it is common to select a “base year” for which the index is defined to be 100. Then, for example, if for some year the average value of the component indicators is 10 percent larger than the average value for the base year, the value of the index for that year would be 110.

The equal-weighting approach is conceptually simple and straightforward to implement. However, implicit in this approach is that the “common bioeconomic effect” driving the individual components is equally important, relative to the idiosyncratic effects present in these components. It would seem that components reflecting relatively small (large) idiosyncratic effects ought to be given a relatively large (small) weight in the construction of the index.

Assigning different weights to different indicators raises the issue of how these weights should be selected. That is, how can one determine the relative importance of the various component indicators? This can be done subjectively or objectively. A subjective weighting scheme assigns differential weights to different components according to an informed subjective valuation of their relative importance in the construction of the index. An objective weighting scheme derives the weights from a formal statistical model (see, e.g., Stock and Watson [45]). An advantage of the objective approach is that the derived weights are optimally derived from a set of explicit assumptions. That is, the approach is formal and transparent. A major practical disadvantage of this approach, particularly in the bioeconomy setting, is that the derivation of the weights based on formal statistical methods will require many observations over time of the component measures in order to uncover the “regularities” needed to estimate the appropriate weights.

In the short run, the subjective weighting scheme is likely to be the best available approach. As databases for the bioeconomy become longer and more regular, consideration of more objective procedures can be seriously examined.

To gauge the overall condition of the bioeconomy, a composite indicator that takes into account changes in the biofuel, biochemical, biobased end-use product, and biopower sectors of the economy could be developed. Due to the lack of sufficient data on the bioeconomy, an illustrative composite index is developed for the biofuels sector. As more data becomes available in the other sectors of the bioeconomy, a parallel approach could be used to calculate a composite index for other sectors and ultimately for the entire bioeconomy.

An example index is constructed here using monthly data for the period 2000–2008 and for the ethanol industry. The components of the index are:

- Ethanol price;
- DDG price;
- Oil price;
- Total U.S. production;
- Gross margin (ethanol plus DDG revenue minus corn and natural gas costs);
- Corn price;
- Total U.S. employment;
- Capital cost.

For each of these indicators, an index with a base year of 2003 is created. Then the correlation coefficient between the gross margin and each component of the composite index is used as weights for the different components of the composite index (CI). Finally, the CI is the sum of each index component times its estimated weight:

$$CI_t = \sum_i w_i I_{i,t}$$

Where w_i and $I_{i,t}$ are the weight and index of element i at period t, respectively. Given the weights used for this index (correlation of each component with the gross margin), an increase in the CI implies that the industry is better off, while a decrease implies that the industry is worse off.

The time paths of the different components of CI are shown in Figures 37 and 38.

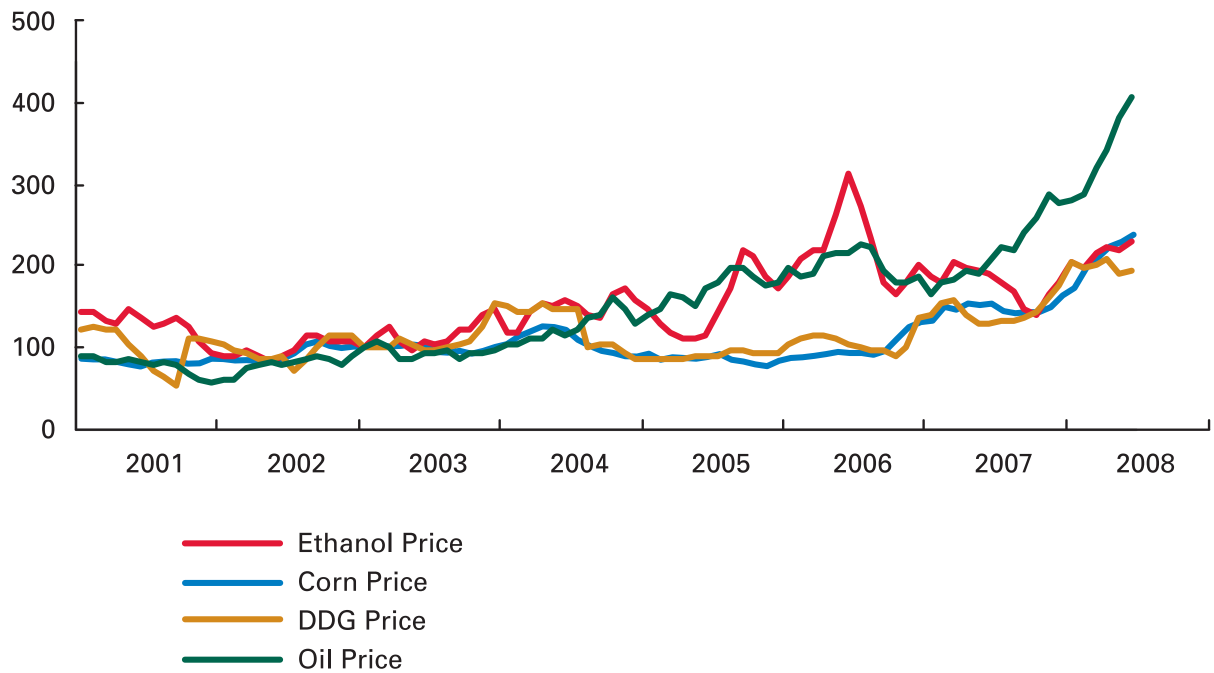

Figure 37. Components of a hypothetical bioeconomy composite scaled to index of 100.

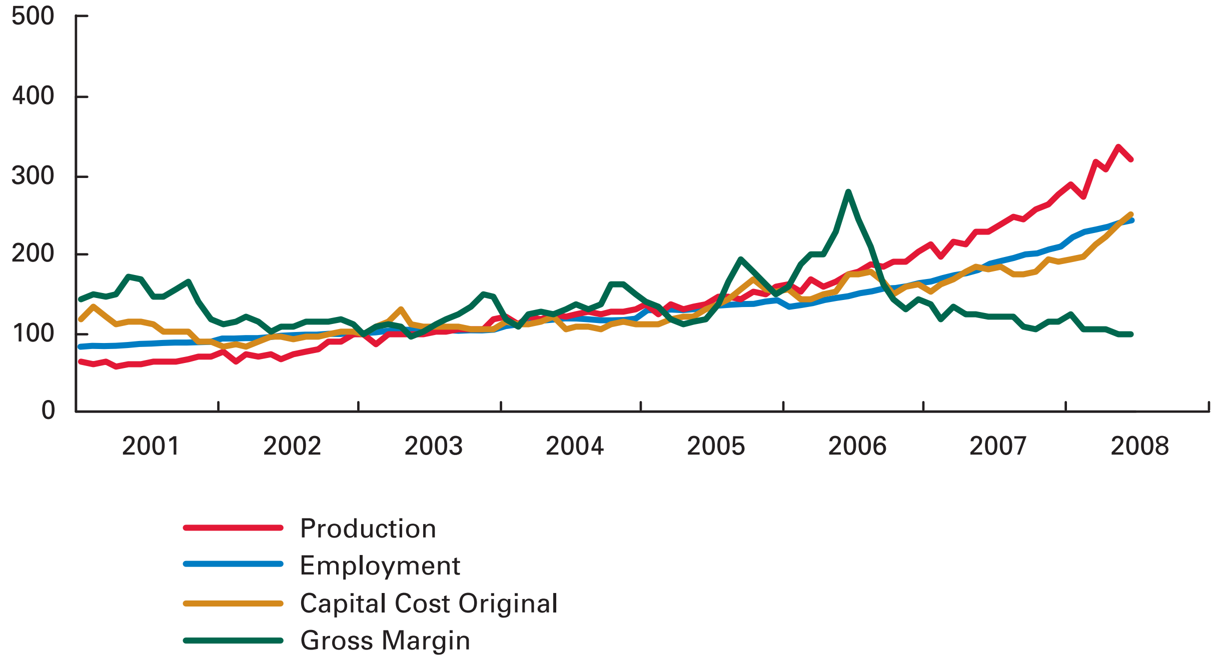

Figure 38. Additional components of a hypothetical bioeconomy composite scaled to index of 100.

Finally, a calculated composite index is depicted in Figure 39.

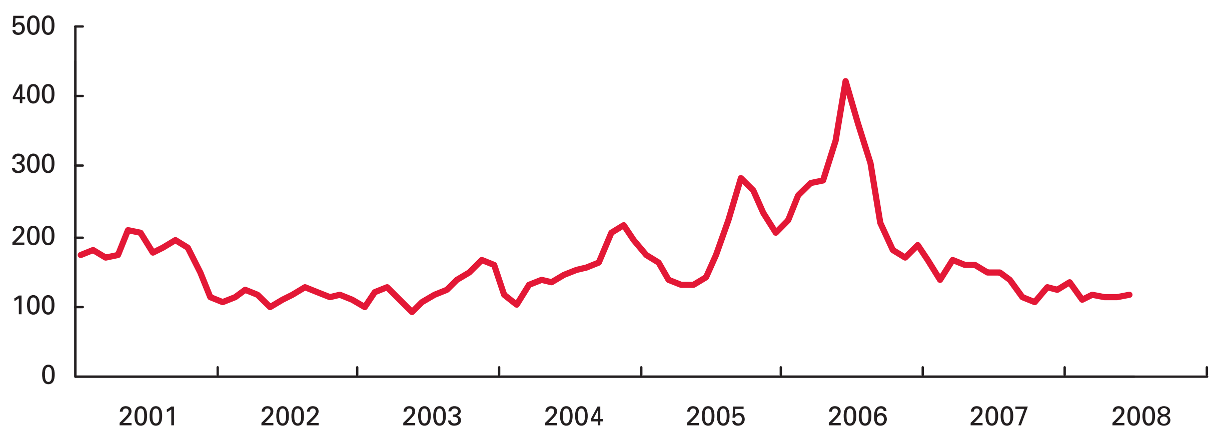

Figure 39. A hypothetical bioeconomy composite scaled to index of 100.

The positive attributes of a composite index are evident in Figure 39. A single curve is used to represent the profitability or "health" of the ethanol industry. Changes in the industry over time are evident. For instance, the drop in the index during 2001 occurred due to adverse movements in a number of individual components of the industry. Oil and ethanol prices declined, gross margins narrowed, and ethanol supply increased—all factors reducing sector profitability.

The increase in the composite index from July 2005 to July 2006 was driven by the Energy Policy Act of 2005 impact on the demand for ethanol as an oxygenate and by increasing oil price, both resulting in higher energy prices and a higher gross margin.

The more recent drop in the composite index during the last half of 2006 was due to adverse movements of various components of the composite index as well. Gross margins decreased and ethanol supply increased significantly relative to demand, causing ethanol price to decline. Even though oil price increased, the gains were offset by significantly higher feedstock costs and tighter margins.

The downside of a composite indicator is evident as well. Since the index, by definition, is an aggregation of other data, a deeper understanding of the reasons for an increase or decrease in the index requires further analysis. Another downside to the composite index used in this illustration is the frequency of public data reporting. Significant changes may occur in the industry, but there may be more than a 3-month lag before the index can be updated due to lags in data reporting. Even then, some of the components (capital costs and labor) used in this composite index illustration can only be approximated from general capital cost indices and labor-output ratios.

The above illustration is only for the biofuels industry. Expanding the composite index to the biochemicals, end-use biobased products, and biopower sectors is complicated by the current lack of industry data. The cost of collecting such detailed data is high, and until other biobased product sectors achieve a certain size, like the biofuels sector, it is unlikely that such periodic data will be collected unless a strong case can be made for public funding of such efforts.

6.2. Biofuel Operating Margins

The most expensive and volatile inputs into ethanol are corn and the energy required to process the corn into a fuel and marketable by-products. Most U.S. plants use natural gas as their primary industrial energy source, although some newer plants are engineered to use coal. If the price of natural gas and corn is subtracted from the wholesale price per gallon of ethanol produced, the result is called the gross margin. This is the revenue that is leftover to pay all other costs as well as payments to investors. By tracking this margin over time, periods of constrained profitability, windfalls, and volatility can be witnessed. Refinements to this margin can be made by estimating other average operating costs and adding them to the natural gas costs as well as netting the cost of corn in light of sales of DDGs.

Figure 40 displays estimated ethanol operating margins for a nearly 3-year period.[3] The values displayed include estimates of other operating costs, in addition to corn and natural gas costs, so the margin values more closely approximate net revenues. It is evident that from the fall of 2005 on, there have been several volatile periods in the ethanol operating margins.

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[3] All data for the analyses in this section were obtained from the Center for Agriculture and Rural Development, Iowa State University. For the ethanol margins, corn and ethanol prices are from Chicago Board of Trade nearby futures for the day of analysis. Energy prices are derived from the nearby futures prices for natural gas. For the biodiesel margins, biodiesel and soybean oil prices are taken from USDA-Agricultural Marketing Service reports for Iowa. All other cost estimates are from engineering studies and actual plant-level analyses.

From September 2005 through the end of 2006 there were generally robust margins owing to natural disasters affecting domestic oil production, policy changes that increased the liability of using MTBE as a reformulated fuel additive, and general appreciation in gasoline prices, of which ethanol is an energy substitute. Since then, however, gross margins have eroded sharply. Estimated margins in the current period resemble those at the beginning of this measurement cycle—a period when the industry was considered to be in stress. Investors and other interested parties track both the daily margins and the trend in margins when gauging the overall condition and profitability of the ethanol industry.

The persistent downward trend in operating margins is a problem for the industry because this stifles new investment. Even though the wholesale price of ethanol implicitly contains the federal per-gallon subsidy, recent prices are still not high enough to assure a competitive return on investment. Indeed, it is assumed that many firms were not able to cover average costs for much of late 2008 and for the first half of 2009. In such a market, rational investors will turn elsewhere.

There have been suggestions to increase the blending rate nationally to something greater than 10 percent as a mechanism to mandate consumption and boost ethanol industry prospects. Alternatively, risk-reducing subsidies may be necessary at the federal level to ensure that the Energy Independence and Security Act mandate for ethanol produced from corn ethanol sources is achieved by 2015.

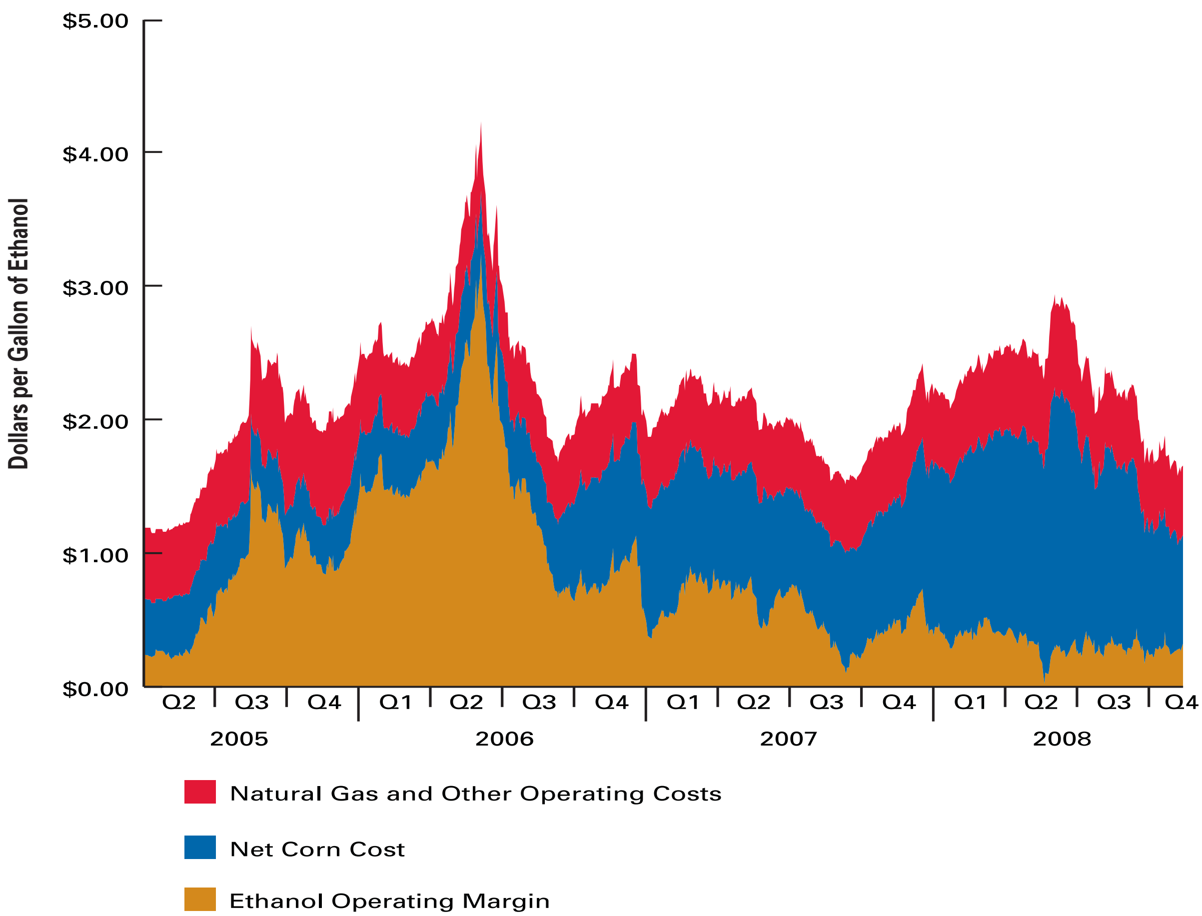

Figure 40. Estimated ethanol operating margins.

Implied profitability of biodiesel operations can be measured in a manner similar to that to ethanol. Like ethanol, the major input cost is for the feedstock. If the oilseed costs and an average of all other costs per gallon of production are subtracted out, an expected operating margin can be derived—the margin from which payments will be made to workers and investors.

Figure 41 displays estimated biodiesel operating margins for a nearly 2-year period. There was a persistent increase in the price of biodiesel in the last quarter or so of 2007 through the middle of 2008 before declining sharply. It is also evident that this industry struggled with profitability from the last quarter of 2007 through the first quarter of 2008. Since then, operating margins have improved considerably and have maintained at fairly consistent levels throughout the remainder of 2008 despite sharp declines in the price of biodiesel.

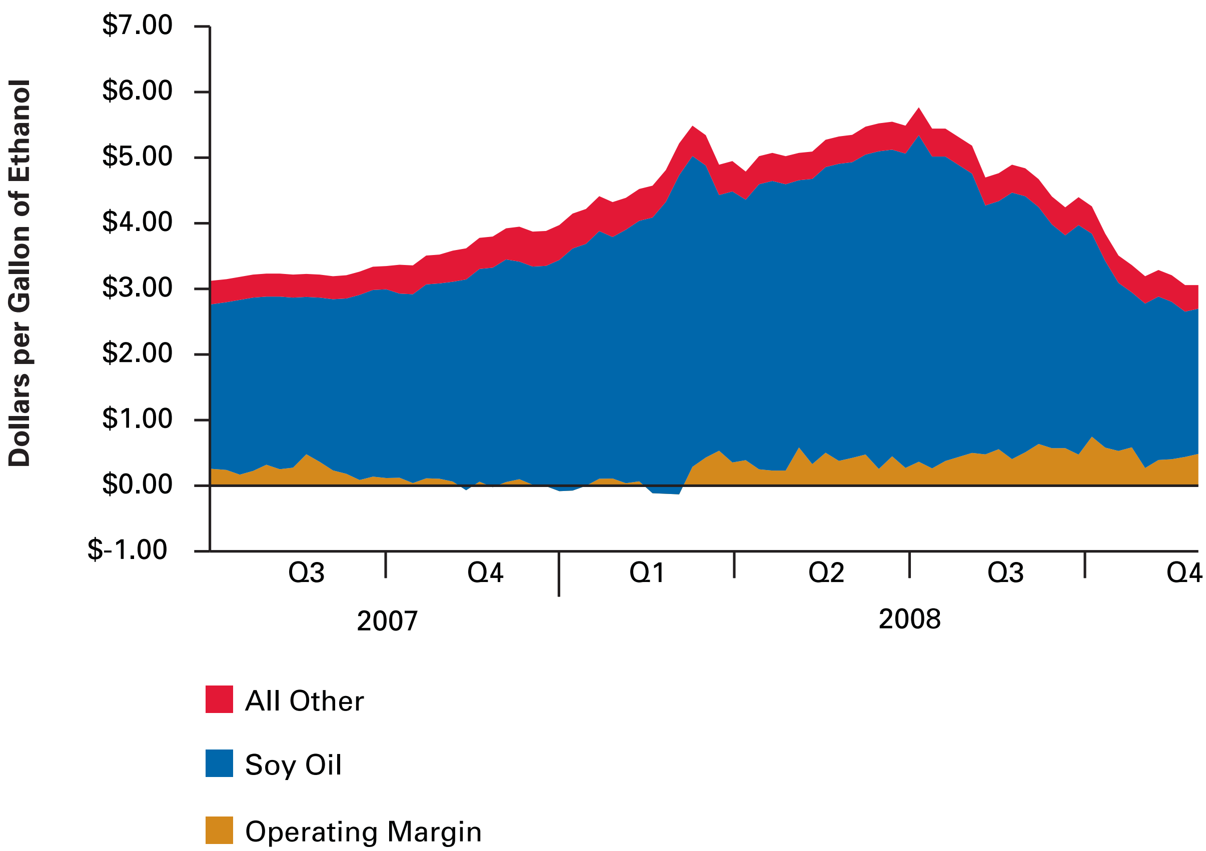

Figure 41. Estimated biodiesel operating margins.

7. Recommendations

A variety of indicators have been proposed to describe the current and expected future state of the U.S. bioeconomy. The availability of such indicators provides the public, media, industry, and policy makers with valuable information to inform decision makers formulating policy, legislation, and business strategies. It is tacitly assumed that if the industry is robust, then improvements in national security will occur and economic development opportunities in America will grow. An analysis of the degree to which this occurs was beyond the scope of this report.

As the biobased products industry expands in the United States and biobased feedstocks replace petroleum feedstocks, one would expect both employment and value-added growth within the industry and within certain regions. While the biobased products industry grows in some regions, other industries and regions might possibly lose employment and their share of GDP may be reduced—for example, the petroleum industry. An analysis of the impact of the bioeconomy on peripheral industries and regions was beyond the scope of this report.

The proposed indicators include "bottom line" measures of current economic production, like a GDP-type measure of biobased production. Additional indicators of the potential for future bioeconomy activity are also proposed, including investment in physical capital (plant and equipment) and investment in research and development (of new products and technologies). It is important to note that the construction of these indicators will be built on more disaggregated data series, which in themselves can serve as indicators of more specific biobased activity.

Many potential indicators that were identified as important measures of bioeconomy activity cannot currently be calculated because appropriate data are not collected, these data are confidential or suppressed to protect the identity of the firm, or the data are not readily measurable. Recommendations regarding future studies of some specific bioeconomy indicators are discussed in Section 4.3. The discussion below includes recommendations that, if addressed, will support the development of a variety of indicators, will help improve the accuracy of indicators, and will assist in the development of indicators that can be released in a more timely fashion so better-informed business and policy decisions can be made.

To have consistent and comprehensive bioeconomy indicators, it will be necessary for the Federal Government to collect the necessary data and develop these other indicators. New federal data requirements should be built on existing data gathering and analysis frameworks. Still, refinements to existing systems will need to be made. Changes may need to be legislated, including adding into the tax code the authority to share data. Changes may also need to be made to a number of classification systems.

What Government Could Do

1. Establish an Advisory and Policy Planning Committee

Officials of USDA, DOE, BEA, BLS, NIST, and possibly NSF could regularly communicate on the topic of bioeconomy indicators. USDA tracks input commodities, usage, and overall supply and supply management issues, etc. DOE is looking at commodity production and usage. BEA is analyzing inter-industrial transactions and the generation of industrial product. These groups could come together on a regular basis, legislatively mandated if necessary, to accomplish the following tasks:

- Communicate plans for future data gathering.
- Establish protocols for sharing data, mindful of all existing Federal rules and restrictions.
- Support international dialog on the measurement and analysis of the biobased products industry. Indicators need to aggregate in a systematic way from the firm, to the country, and then to international measures of the bioeconomy.

The USDA Office of Energy Policy and New Uses may be a natural choice to lead an effort to enhance communication. A subcommittee could be set up to select a short list of indicators, collect data if available, spearhead the collection of new data, and use a scorecard to regularly report the data.

2. Formalize Biobased Industry Measurement Standards

There are widely varying views of what is and is not part of the burgeoning bioeconomy. Clear and consistent definitions must be developed between government agencies and the private sector to allow consistent estimates of data—labor, value of production, etc. Questions that need to be answered include the following:

- What portion of the biobased products supply chain should be included in economic analyses? For instance, should the development of enzymes or the distribution system for ethanol be incorporated, or should the focus be on manufactured output (fuels, chemicals, end-use consumer products, etc.)?
- Should contributions from landfill gas and municipal solid waste be included within the biopower sector or should the focus be on wood and agricultural feedstocks?
- Should industrial by-products from conventional sources (pulp and paper mills) be included?
- Should measured activity only include products deemed as “new uses”?
- Should “new” be defined as it currently is in the BioPreferred program?
- Should the focus only be on direct impacts, or should indirect and induced impacts be measured?

The USDA Office of Energy Policy and New Uses may be a natural choice to lead an effort to select the segments of the bioeconomy that will be analyzed in more detail. In the short term, the focus should be on outputs from the manufacturing sector. Individuals responsible for data gathering within BEA, BLS, etc., need to be consulted to make certain that it is possible to economically gather the data, given the extent of the effects that various definitions might have.

3. Develop a Biobased Industry and Commodity Usage Survey

An assortment of information is available on the biofuels sector, but data on other segments of the biobased products industry are scarce. New data could be collected to create additional bioeconomy indicators and to improve awareness of the entire industry. Some information that might be appropriate to include in a bioeconomy scorecard includes the following:

- Biobased contribution to gross domestic product
- Sales of biobased chemicals
- Sales of biobased intermediates and end-use products
- Private capital investment in plants and equipment
- Biofuel subsidies
- Fraction of employees involved in biobased production

New surveys and additional questions added to existing surveys will be required to gather a significant portion of this information. Currently, the National Science Foundation and the U.S. Department of Commerce cooperate to conduct special industry surveys involving approximately 25,000 companies. The U.S. Census Bureau serves as the collecting and compiling agent for this annual survey of industrial research and development. Collaboration such as this might serve as a prototype for the development of a similar survey that measures biobased industrial activity and biobased commodity usage.

4. Review and Revise the North American Industry Classification System

The NAICS will likely need to be modified to effectively gather biobased industry data. Since the NAICS system was developed based on the idea that producing units should be grouped based on similarity of production processes, and since there is such diversity among the variety of biobased products, this could be problematic. An argument could be made that the biobased products industry is too woven into the economy overall and therefore it would be too burdensome to gather the information. In fact, the Economic Classification Policy Committee of the Office of Management and Budget is currently soliciting public comment to reduce the number of six-digit classifications [46]. The effort should better align the NAICS classifications with the reduced number of groupings within the Annual Survey of Manufacturers conducted by the U.S. Census Bureau. The reduction in categories is being made, in part, because of the burden to survey respondents and production costs.

Despite a possible consolidation of NAICS industries, it may still be appropriate to add new biobased industry subsectors. To be considered for a sub-classification, the industry subsector should use similar production processes, use similar resources, be of an appropriate size, and contain a sufficient number of establishments.

The complexity of the biobased industry sector makes it difficult to group companies by a few production process-oriented NAICS codes, since processes vary between the different subsectors. However, since biofuels, biochemicals, and a large fraction of the end-use biobased products fall under the chemicals NAICS sector, an argument could be made that production activities are sufficiently related that much of the industry could be grouped at the five- or six-digit level.

The primary differentiator between the biobased products industry and many other industry sectors is the use of renewable resources as a production feedstock—specifically, forest, marine, and agricultural feedstocks destined for nonfood/feed products. It may be possible to consolidate a large segment of the biobased products industry under a sector similar to NAICS 325191—Gum and Wood Chemical Manufacturing, which includes establishments primarily engaged in distilling wood or gum into products and manufacturing wood or gum chemicals.

The size of the biobased products industry, in terms of full-time and part-time employment, appears to be the same order of magnitude as some of the smaller three-digit industry subsectors currently reported by BEA. The smallest three-digit subsector reported by BEA is the pipeline transportation industry, which falls under the transportation and warehousing sector.

In total, there are over 2,000 establishments engaged in making biobased products. Aggregation at the national level would not likely reveal any sensitive information about individual firms. Reporting at the state level may not be possible in some states that have a limited number of establishments.

Since the biobased products industry has been growing, since policies have been put in place to help grow the sector further, since the industry is being closely watched, and since industry data are limited, changes to the NAICS system might be possible. This work would need to begin immediately so that, if appropriate, changes could be adopted in the next revision of the NAICS in 2012.

5. Focus on Pertinent Bioeconomy Indicators

Biobased feedstocks are varied and have been part of the U.S. production process for centuries. Isolating major changes in production inputs and outputs is of more recent concern. Toward that end, policy makers and planners could concentrate on measuring sets of key indicators that give a sense of the scope and depth of biobased product usage and change in recent years.

To begin with, it is recommended that the Federal Government focus on a handful of key indicators that cover the various segments of the bioeconomy.

- Compile reliable summaries of annual government support of biobased industrial activity by type of support and amount.
- Compile reliable summaries of all biofuels and biobased chemical sales.

As government agencies develop better and more reliable measurement and reporting protocols, additional items or subcategories can be explored.

What the Private Sector Could Do

There will be many obstacles associated with gathering much of the data discussed in this report. The first step must be to decide what data should be collected and by whom. While industry must cooperate with existing government programs, they are not bound to participate in nongovernment surveys designed to measure industrial growth or production characteristics.

Industry may be better served to lead the development of standardized and regular industry measures designed to provide planning and guidance information for the industry itself. For example, it may be more appropriate for an industry association to develop an industry-focused leading diffusion indicator or other indicators of biobased industry performance over time. It may also be more appropriate for industry to conduct special surveys on workforce needs, product acceptance, and regulatory issues.

8. Acknowledgements

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Appendix A. End-Use Biobased Product Categories

The Food, Conservation, and Energy Act of 2008 (FCEA) reauthorized and expanded provisions related to the Federal biobased procurement and labeling statute originally established by Section 9002 of the Farm Security and Rural Investment Act of 2002. The statute includes provisions to encourage the procurement of biobased products by Federal agencies and a voluntary biobased labeling program. USDA refers to the programs collectively as the BioPreferred program.

As defined by FCEA, “biobased products” are products determined by the U.S. Secretary of Agriculture to be commercial or industrial goods (other than food or feed) that are composed in whole or in significant part of biological products, including renewable domestic agricultural materials and forestry materials or intermediate ingredients or feedstocks.

The goals of the BioPreferred program are to lessen U.S. dependence on foreign oil and to promote economic development by creating new jobs in rural communities and new markets for farm commodities through the growth of the biobased products industry. Federal agencies are required to give preference to BioPreferred-designated biobased products when the product is reasonably available, reasonably priced, and comparable in performance to the non-biobased alternative.

The development of a list of items (or generic groupings of biobased products) for preferred procurement is a core element of the program. Once an item is designated, every manufacturer/vendor producing and marketing products that fit within that item can claim preferred procurement status for their products when marketing to Federal agencies. Manufacturers must certify to Federal agencies that the biobased content in their products is consistent with the definition in the statute of biobased products and that their products will meet the minimum content level set by USDA or provide third-party testing of the biobased content of their products. They must also provide information on the environmental footprint of their product if requested by a Federal agency.

USDA contracted with Iowa State University to perform three tasks within the BioPreferred program—item designation, testing and research, and coordination of test cost sharing. Item designation includes the identification and collection of company and product information, biobased content testing, recruiting participants for and facilitating Building for Environmental and Economic Sustainability (BEES) model analyses, and investigating and analyzing potential designation items and biobased product markets.

To date, Iowa State University has identified over 15,000 biobased products produced by over 2,100 manufacturers. Over 900 products have undergone biobased content testing; life-cycle cost analyses have been completed for nearly 200 products.

Table A.1 includes the complete list of items that have been classified as of October 2008. This list includes items that have been designated as preferred, items that are currently under review by USDA, and items that have yet to be tested. The list is sorted by the number of companies that have been located to date that sell the type of product listed, together with the number of distinct products within the category.

Table A.1. BioPreferred items designations as of October 2008 [47].

Item Name	Number of Companies	Number of Products
Bath products	360	947
Candles and wax melts	208	605
Lotions and moisturizers	199	685
Facial care products	165	1932
Intermediate feedstocks	159	529
Multipurpose cleaners	126	237
Gasoline fuel additives	113	115
Lip care products	113	190
Graffiti and grease removers	99	196
Hand cleaners and sanitizers—Hand cleaners	99	197
Industrial cleaners	87	199
Animal cleaning products	85	374
Fertilizers	72	467
Mulch and compost	71	236
Bathroom and spa cleaners	69	125
Glass cleaners	67	77
Hair cleaning products	67	307
General purpose household cleaners	66	113
Massage oils	62	216
Sewage system maintenance products	59	125
Laundry products—General purpose	56	128
Carpet and upholstery cleaners—General purpose	53	77
Insecticides	51	356
Air fresheners and deodorizers	50	80
Cosmetics	48	440
Diesel fuel additives	47	67
Floor cleaners and protectors	47	86
Dishwashing detergents	45	73
Disposable containers	44	133
Disposable tableware	44	191
Personal insect repellents	42	72
Cut, burn, and abrasion ointments	41	71
Films—Nondurable	40	101
Hydraulic fluids—Stationary equipment	40	182

Item Name	Number of Companies	Number of Products
Foot care products	39	72
Sorbents	39	86
Hydraulic fluids—Mobile equipment	38	175
Wood and concrete sealers—Penetrating liquids	38	140
Leather, vinyl, and rubber care products	37	85
Sun care products	37	142
Floor coverings (noncarpet)	36	336
Insect control products	34	81
Parts wash solutions	34	47
Chain and cable lubricants	33	66
Erosion control	33	172
Microbial cleaners	33	73
Shaving products	33	81
Topical pain relief	33	55
Bioremediation materials	32	57
Clothing	32	735
Concrete and asphalt cleaners	32	43
Solid fuel additives	31	83
Paint removers	30	42
Aromatherapy	29	71
Furniture cleaners and protectors	29	43
Laundry products—Pretreatment/Spot removers	29	33
Penetrating lubricants	29	51
Animal repellents	28	108
Concrete and asphalt release fluids	28	44
Disposable cutlery	28	64
Gear lubricants	28	76
Other	28	68
Fuel oil	27	27
Fungicides	27	70
Agricultural spray adjuvants	26	49
Multipurpose lubricants	26	46
Corrosion preventatives	25	256
Food cleaners	25	28
Packaging materials	24	39

Item Name	Number of Companies	Number of Products
Plastic insulating foam for residential and commercial construction	24	44
Plastic products	24	26
Herbicides	23	49
Composite panels—Plastic lumber	22	37
Deodorant	22	59
Carpets	21	103
Metal cleaners	21	31
Shipping pallets	21	21
Two-cycle engine oils	20	31
Adhesive and mastic removers	20	30
Animal skin, hair, and insect care products	20	29
Compost activators and accelerators	20	33
Dust suppressants	19	29
Greases—Multipurpose	19	43
Hair styling products	19	93
Metalworking fluids—General purpose soluble, semisynthetic, and synthetic oils	18	45
Lithographic offset inks (sheetfed)	17	53
Metalworking fluids—straight oils	17	65
Asphalt and tar removers	16	20
Corrosion removers	16	27
Paints and coatings (interior)	15	148
Automotive care products	14	39
Dethatchers	14	15
Office paper	14	30
Oven and grill cleaners	14	17
Paints and coatings (exterior)	14	108
Sanitary tissues	14	21
Wood and concrete stains	14	38
Animal medical care products	13	28
Animal odor control and deodorant	13	16
Antispatter products	13	23
Organic furniture	13	100
Forming lubricants	12	22
Fuel conditioners	12	29

Item Name	Number of Companies	Number of Products
Greases	12	13
Adhesives	11	22
Aquaculture products	11	19
Bedding, bed linens, and towels	11	23
Composite panels—Acoustical	11	22
Composite panels—Interior panels	11	26
Films—Semidurable films	11	23
Interior wall and ceiling patch	11	22
Pneumatic equipment lubricants	11	24
Roof coatings	11	17
Floor strippers	10	12
Ink removers and cleaners	10	25
Inks (specialty)	10	32
Slide way lubricants	10	15
Woven fiber products	10	41
Aircraft cleaners	9	12
Allergy and sinus relievers	9	10
Animal habitat care products	9	11
Durable foams	9	9
Lithographic offset inks (news)	9	25
Sealants	9	12
Women's health products	9	13
Cellulose and batt insulation	8	14
Composite panels—Structural interior panels	8	24
Electronic components cleaners	8	9
Greases—Food grade	8	16
Perfume	8	15
Specialty precision cleaners and solvents	8	11
Blast media	7	13
Body powders	7	9
Fiber-based furniture	7	46
Lumber, millwork, underlayment	7	13
Marine products	7	16
Biodegradable foams	6	6
Carpet and upholstery cleaners—Spot removers	6	8

Item Name	Number of Companies	Number of Products
De-icers—General purpose	6	14
Engine crankcase oil	6	12
Fingernail/Cuticle products	6	9
Heat transfer fluids	6	7
Oral care products	6	33
Other lubricants	6	11
Printing chemicals	6	10
Animal bedding	5	20
Asphalt restorers	5	7
Composite panels—Structural wall panels	5	14
Filters	5	6
Greases—Truck	5	9
Hand cleaners and sanitizers—Hand sanitizers	5	13
Polyurethane coatings	5	5
Rope and twine	5	12
Soil conditioners	5	11
Wood and concrete sealers—Membrane concrete sealers	5	10
Artistic supplies	4	9
Fire retardants	4	6
Firearm lubricants	4	9
Fluid-filled transformers—Synthetic ester-based	4	9
Greases—Rail track	4	13
Lab chemicals	4	8
Laundry—Dryer sheets	4	5
Masonry and paving systems	4	4
Toys	4	18
Transmission fluids	4	8
Turbine drip oils	4	6
Water turbine bearing oils	4	5
Durable tableware	3	10
Expanded polystyrene foam recycling products	3	3
Fire starters	3	4
Fluid-filled transformers—Vegetable oil-based	3	4
Hair removal products	3	4
Wastewater systems coatings	3	3

Item Name	Number of Companies	Number of Products
Complex assemblies	2	5
Concrete curing agents	2	2
Lavatory flushing fluid	2	2
Lithographic offset inks (heatset)	2	2
Papers (nonwriting)	2	6
Plastic cards (wallet-sized)	2	2
Thermal shipping containers	2	3
Water tank coatings	2	2
Concrete repair patch	1	4
Industrial enamel coatings	1	5
Metalworking fluids—High-performance soluble, semisynthetic, and synthetic oils	1	5
Power-steering fluids	1	2
Rugs and floor mats	1	1

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