United States International Trade Commission

Industrial Biotechnology: Development and Adoption by the U.S. Chemical and Biofuel Industries

Investigation No. 332-481
USITC Publication 4020
July 2008

U.S. International Trade Commission

Address all communications to
Secretary to the Commission
United States International Trade Commission
Washington, DC 20436

U.S. International Trade Commission

Washington, DC 20436
www.usitc.gov

Industrial Biotechnology: Development and Adoption by the U.S. Chemical and Biofuel Industries

Investigation No. 332-481

Publication 4020 **July 2008**

This report was prepared principally by the Office of Industries

Project Leader
David Lundy

Deputy Project Leaders
Elizabeth Nesbitt and Laura Polly

Office of Industries
Laura Bloodgood, Jeffrey Clark, John Fry, Erland Herfindahl, Cathy Jabara, Katherine Linton, Douglas Newman, John Reeder, Philip Stone, Karl Tsuji, Jeremy Wise, and Isaac Wohl

Office of Economics
Robert Feinberg

Office of Investigations
Charles Yost

Primary Reviewers
Richard Brown and William Deese

Administrative Support
Brenda Carroll, Sharon Greenfield, and Monica Reed

Special Assistance
Wendy Cuesto, Brendan Lynch, Mark Paulson, Cynthia Payne, Joann Peterson, Wanda Tolson, and Stephen Wanser

Office of Publishing

Under the direction of
Karen Laney-Cummings, Director, Office of Industries
Dennis Rapkins, Chief, Chemicals and Textiles

Abstract

This report was prepared in response to a request from the Committee on Finance of the United States Senate regarding the competitive conditions affecting certain industries that are developing and adopting new biotechnology processes and products. As requested by the Committee, the report focused on firms in the U.S. chemical industry and U.S. producers of liquid biofuels. Much of the data for this report was gathered by questionnaire directly from the liquid fuel and chemical industries.

The development and adoption of industrial biotechnology (IB) in the United States by the chemical and liquid fuel industries expanded substantially during the 2004–07 period. These industries increasingly use enzymes, micro-organisms, and renewable resources in the production of fuels and chemicals. IB has the potential to lower production costs, create sustainable production processes, and reduce the environmental impact of producing and using fuels and chemicals.

IB adoption is reflected in a large increase in sales of U.S.-produced liquid biofuels and bio-based chemicals. Although a major portion of the increase is accounted for by the ethanol and biodiesel industries, which are supported by government tax incentives, mandatory use regulations, or both, pharmaceutical products still account for the majority of these sales. Sales of liquid biofuels and bio-based chemicals remain small in comparison to conventional chemicals and liquid fuels.

IB development may result in the creation of innovative products or processes. All measures of innovation increased during the 2004–07 period, including R&D expenditures, patent and trademark activity, strategic alliances, and government grants. However, operating income as a share of total net sales of bio-based products was relatively flat during the period, largely due to the substantial increase in agricultural feedstock prices. Feedstocks account for over 50 percent of production costs for liquid biofuels.

Industry participants consider a lack of capital to be a major impediment to both the development and adoption of IB. Many impediments identified by companies relate to the risk inherent in new technology, including the uncertainty of whether such technologies can be fully developed and adopted. This uncertainty makes it difficult to attract R&D and investment capital. Other major impediments identified by liquid fuel and chemical producers as affecting the adoption of IB include high feedstock and production costs and limits of technology.

IB activities in many foreign countries also increased during the 2004–07 period. Like the United States, foreign governments use tax incentives, mandatory use regulations, and R&D funding to support their IB industries. Brazil, China, and the EU are notable examples.

Abbreviations and Acronyms

ABARE	Australian Bureau of Agricultural and Resource Economics
ACC	American Chemistry Council
ADM	Archer Daniels Midland
AMS	Agricultural Marketing Service (USDA)
ANP	Agência Nacional de Petroleo, Gas, e Biocombustieis (Brazil)
APTA	Agência Paulista de Tecnologia dos Agronegócios (Brazil)
ARS	Agricultural Research Service (USDA)
ASTRA	Alliance for Science & Technology Research in America
BIO	Biotechnology Industry Organization
Bio-PDO	Bio-based 1,3 propanediol
BNDES	Banco Nacional de Desenvolvimento Econômico e Social (Brazil)
BRDA	Biomass Research and Development Act of 2000
BRDI	Biomass Research and Development Initiative
CAP	Common Agricultural Policy (EU)
CBERA	Caribbean Basin Economic Recovery Act
CBP	U.S. Customs and Border Protection
CCPA	Canada's Chemical Producers Association
CEBC	Center for Environmentally Beneficial Catalysis
cpg	Cents per gallon
CRAC	China Resources Alcohol Co.
CRADA	Cooperative Research and Development Agreement
CRFA	Canadian Renewable Fuels Association
CRI	Crown Research Institutions (New Zealand)
EC	European Commission
ecoABC	Agricultural Biofuels Capital Investment Program (Canada)
ECoAMu	Energy Cogeneration from Agricultural and Municipal Wastes (Canada)
EERE	Energy Efficiency and Renewable Energy (USDOE)
EESI	Environmental and Energy Study Institute
EIA	Energy Information Administration (USDOE)
EISA	Energy Independence and Security Act of 2007
EPA	U.S. Environmental Protection Agency
EPAct	Energy Policy Act (of 1992, 2005)
ESAB	European Federation of Biotechnology, Section on Applied Biocatalysts
ETBE	Ethyl tertiary butyl ether
EU	European Union
EuropaBio	European Association of Bioindustries
FAME	Fatty acid methyl ester
FAPRI	Food and Agricultural Policy Research Institute
FLC	Federal Laboratory Consortium
FSA	Farm Service Agency (USDA)
FTC	Federal Trade Commission
FTC	Federal Transfer Consortium
FTE	Full-time equivalent
FY	Fiscal year
GBEP	Global Bioenergy Partnership
GDP	Gross domestic product
GHG	Greenhouse gas
GLBSRP	Great Lakes Biomass State-Regional Partnership

GM	Genetically modified
HTS	Harmonized Tariff Schedule of the United States
IB	Industrial biotechnology
IP	Intellectual property
IPO	Initial public offering
LCA	Life-cycle assessment
MAPA	Ministério de Agricultura, Pecuaria, e Abastecimento (Brazil)
MDA	Ministério do Desenvolvimento Agrário (Brazil)
MF	Ministério de Fazenda (Brazil)
mgy	million gallons per year
MME	Ministério di Minas y Energia (Brazil)
MTBE	Methyl tertiary butyl ether
NAICS	North American Industry Classification System
NAS	National Academy of Sciences
NBB	National Biodiesel Board
NCGA	National Corn Growers Association
NREL	National Renewable Energy Laboratory
NSB	National Science Board
NTR	Normal trade relations
NVCA	National Venture Capital Association
ODC	Other duties and charges
OECD	Organization for Economic Cooperation and Development
ORNL	Oak Ridge National Laboratory
PCT	Patent Cooperation Treaty
PHA	Polyhydroxyalkanoate
PLA	Polylactic acid
PNPB	National Program for Production and Use of Biodiesel (Brazil)
PTC	Production-linked tax credits
PWC	PriceWaterhouseCoopers
R&D	Research and development
RD&C	Research, development, and commercialization
RFA	Renewable Fuels Association
RFS	Renewable Fuel Standard
RPS	Renewable Portfolio Standards
SBIR	Small Business Innovative Research Program
SG&A	Selling, general, and administrative
STDC	Sustainable Development Technology Canada
STTR	Small Business Technology Transfer Program
3-HPA	3-hydroxypropionic acid
UNCTAD	United Nations Conference on Trade and Development
USDA	U.S. Department of Agriculture
USDOE	U.S. Department of Energy
USITC	U.S. International Trade Commission
USPC	U.S. Patent Classification System
USPTO	U.S. Patent and Trademark Office
VAT	Value-added tax
VC	Venture capital
VEETC	Volumetric ethanol excise tax credit
WTO	World Trade Organization

Glossary

Biobutanol—Butanol is an alcohol that can be used as a replacement for gasoline. Biobutanol, like ethanol, is produced either from conventional crops, such as corn, or from cellulosic feedstocks. Some advantages that butanol has over ethanol as a transportation fuel are a higher energy density, which provides more miles traveled per gallon of fuel, and a lower tendency to absorb water, which provides more flexibility for transporting butanol and blending it with gasoline. A current disadvantage of butanol versus ethanol is that it is more expensive to produce using existing technology, making it less competitive with ethanol.

Biocatalysis—Biocatalysis is the use of isolated enzymes and/or micro-organisms as biocatalysts to conduct chemical reactions.

Biocatalyst—According to the American Heritage Dictionary, a biocatalyst is "A substance, especially an enzyme, that initiates or modifies the rate of a chemical reaction[, often] in a living body." Micro-organisms, including bacteria and fungi (e.g., yeasts), can also be used as biocatalysts.

Biodiesel—A liquid biofuel suitable as a diesel fuel substitute or diesel fuel additive or extender. Biodiesel is typically made from oils (e.g., soybean, rapeseed, or sunflower) or from animal fats. Biodiesel can also be made from hydrocarbons derived from agricultural products such as rice hulls.

Biofuels—Liquid fuels and blending components produced from biomass (plant) feedstocks, used primarily for transportation. (PCAST, *The Energy Imperative Technology and the Role of Emerging Companies*, November 2006, Glossary.)

Biomass—"Any organic matter that is available on a renewable or recurring basis, including agricultural crops and trees, wood and wood wastes and residues, plants (including aquatic plants), grasses, residues, fibers, and animal wastes, municipal wastes, and other waste materials." (Biomass Research and Development Act of 2000 7 USC 7624 Note.)

Biopolymers—A polymer comprised, at least in part, of building blocks called monomers, produced in a biorefinery from renewable feedstocks such as corn. An alternate definition for biopolymer, including all biologically produced polymers like DNA, RNA, and proteins, will not be used in this study.

Biorefineries—"A biorefinery is a facility that integrates biomass conversion processes and equipment to produce fuels, power, and chemicals. The biorefinery concept is analogous to today's petroleum refineries, which produce multiple fuels and products from petroleum." (National Renewable Energy Laboratory, Biomass Research. http://www.nrel.gov/biomass/biorefinery.html.)

Biotechnology—The use of enzymes and metabolic processes of living organisms (often micro-organisms) to produce chemicals that have medical, environmental, or economic value. "'Biotechnology is the integrated application of natural and engineering sciences for the technological use of living organisms, cells, parts thereof and molecular analogues for the production of goods and services.' Biotechnology thus consists of the use of living organisms or parts thereof, to make or modify products, improve plants and animals, or develop micro-organisms for specific purposes." (European Federation of Biotechnology (EFB) as noted in "Industrial Biotechnology and Sustainable Chemistry," January 2004, Royal Belgian Academy Council of Applied Science, 8.
http://www.europabio.org/documents/150104/bacas_report_en.pdf.)

Building block chemicals—Chemicals that are subsequently converted to other chemical products, either using methods of biotechnology or traditional chemical synthesis.

Chemical platforms—The term "chemical platforms" refers to the technological processes to convert biomass into biofuels (e.g., bioethanol), chemicals, and power. Also, defined as chemicals that are extracted from the agricultural feedstock as the first step in the biorefining processing. The biorefinery subsequently converts these chemicals to fuels and/or building block chemicals, so the term is also used to refer to biomass conversion technologies. The main platforms are the sugar platform and the thermochemical platform.

> ***Sugar platform***—Conversion technology to "biologically process sugars in biorefineries to fuel ethanol or other building block chemicals." In a sugar platform, sugars are often extracted from crops, such as sugarcane and corn, or from any cellulosic feedstock, and then converted to derivatives including bioethanol and biobutanol.
>
> ***Thermochemical platform***—"Converting the solid biomass to a gaseous or liquid fuel by heating it with limited oxygen prior to combustion," in turn allowing for the conversion of the biomass to chemicals and other products. In a thermochemical platform, bio-based synthesis gas produced from the partial combustion of biomass contains hydrogen gas and carbon monoxide, among other gases, which can be converted at high temperatures to a great variety of organic chemicals.

Enzymes—Biologically-derived, biodegradable proteins that speed up chemical reactions. For example, in a biorefinery producing cellulosic ethanol and other chemicals, a group of enzymes called cellulases is needed to breakdown cellulose into sugars that can be fermented to produce the desired products.

Ethanol (also called bioethanol)—A clear, colorless, flammable, oxygenated hydrocarbon (CH3-CH2OH). In addition to its uses as a chemical, ethanol is also a liquid biofuel that can be used as a substitute for or blended with gasoline. It is produced by fermenting sugars from carbohydrates found in agricultural crops and cellulosic residues. In the United States, the biofuel is produced mainly from corn. Cellulosic ethanol is produced from lignocellulose feedstocks (cellulosic residues), including agricultural residues (e.g., corn stover), forestry residues (e.g., wood chips), energy crops (e.g., switchgrass), and municipal waste. It is also used in the United States as a gasoline octane enhancer and oxygenate (blended up to 10 percent concentration; also called E10). Ethanol can also be used in high concentrations (E85; a blend of 85 percent ethanol with 15 percent gasoline) in vehicles designed for its use, which are usually called flex-fuel vehicles.

Fermentation—The use of micro-organisms to break down complex organic compounds into simpler ones.

Flex-fuel vehicle—A vehicle that can operate on:

(1) alternative fuels (such as E85),
(2) 100 percent petroleum-based fuels, or
(3) any mixture of an alternative fuel (or fuels) and a petroleum-based fuel.

Flex-fuel vehicles have a single fuel system to handle alternative and petroleum-based fuels. Flex-fuel vehicle and variable fuel vehicle are synonymous terms. (PCAST, *The Energy Imperative Technology and the Role of Emerging Companies*, November 2006, Glossary.)

Green chemistry—The design of chemical processes and products with the goal of reducing or eliminating the consumption or generation of hazardous or toxic substances. This commitment to developing alternative chemical syntheses reduces a company's environmental footprint and can improve a company's competitiveness. Among the 12 principles of green chemistry are several that can be met through the use of industrial biotechnology, including the prevention of waste, the design of safer and less toxic processes and chemicals, a focus on increased energy efficiency, and incorporation of renewable resources as inputs.

Greenhouse gas (GHG)—Those gases, such as water vapor, carbon dioxide, nitrous oxide, methane, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride, that are transparent to solar (short-wave) radiation but opaque to long-wave (infrared) radiation, thus preventing long-wave radiant energy from leaving Earth's atmosphere. The net effect is a trapping of absorbed radiation and a tendency to warm the planet's surface. (PCAST, *The Energy Imperative Technology and the Role of Emerging Companies*, November 2006, Glossary.)

Industrial biotechnology (or white biotechnology)—Distinct from medical (red biotechnology) and agricultural biotechnology (green biotechnology), industrial biotechnology "is the application of modern biotechnology for the industrial production of chemical substances and bioenergy, using living cells and their enzymes, resulting in inherently clean processes with minimum waste generation and energy use." (Royal Belgian Academy Council of Applied Science, "Industrial Biotechnology and Sustainable Chemistry," January 2004, 10.
http://www.europabio.org/documents/150104/bacas_report_en.pdf.)

The Commission's definition of industrial biotechnology is: the manufacture of liquid fuels and chemical products using enzymes, micro-organisms, fermentation, or biocatalysis at any stage of production, regardless of the type of raw materials used (e.g., biomass, fossil fuel-based, or inorganic substances), or the manufacture of liquid fuels and chemical products from renewable resources regardless of the type of processing technology used.

Patent—A set of exclusive rights granted by a government to an inventor or his assignee for a fixed period of time (usually 20 years) in exchange for the public disclosure of an invention.

Trademark—A word, name, symbol, or device that is used in trade with goods to indicate the source of the goods and to distinguish them from the goods of others.

Trade secrets—Information that derives economic value from not being generally known by others, and that is the subject of reasonable efforts to maintain its secrecy.

Transesterification—The reaction of an ester with an alcohol that results in the formation of a different ester. In the production of biodiesel, the transesterification reaction removes the fatty acid portions of the plant oils from their glycerin backbones to form fatty acid methyl esters and the glycerin byproduct.

Venture capital—Money provided by professional investment firms that invest alongside management in young, rapidly growing companies that have the potential to develop into significant economic contributors. Venture capital is an important source of equity for start-up companies.

Whole-cell systems—Micro-organisms that contain/generate multiple enzymes that perform a series, or a "cascade," of chemical conversions.

CONTENTS

Page

Abstract i

Abbreviations and Acronyms iii

Glossary v

Executive Summary xv

Chapter 1. Introduction 1-1

Purpose 1-2
Scope 1-3
Processes and products 1-4
Industry coverage 1-5
Approach 1-5
Information collection 1-5
Analysis 1-6
Respondent profile 1-6
Report organization 1-9

Chapter 2. Trends in Bio-based Business Activities 2-1

Industry characterization 2-2
Liquid biofuels 2-2
Bio-based chemicals 2-7
Trade 2-10
U.S. imports 2-11
U.S. exports 2-14
Financial performance 2-15
Feedstock costs 2-15
Results of operations 2-16
R&D expenditures and employment 2-20
Government funding 2-23
Investment 2-25

CONTENTS–*Continued*

Page

Chapter 3. Factors Affecting the Development and Adoption of Industrial Biotechnology 3-1

Cost and availability of feedstocks 3-3
Availability of capital 3-7
    Capital-related impediments 3-11
R&D and innovation 3-11
    Cellulosic ethanol 3-11
    Other technologies 3-12
    R&D impediments 3-17
Strategic alliances 3-18
    Domestic supply chain and technology transfer alliances 3-19
    Foreign supply chain and technology transfer alliances 3-24
Intellectual property 3-27
    Patenting 3-30
    Trademarks 3-34
    Licensing and purchases and sales 3-34
    IP-related impediments 3-35

Chapter 4. U.S. and Foreign Government Policies and Programs 4-1

Research, development, and commercialization support 4-16
    United States 4-16
    Foreign country comparison 4-21
Tax incentives 4-22
    United States 4-22
    Foreign country comparison 4-28
Mandatory use regulations 4-30
    United States 4-30
    Foreign country comparison 4-32
Loan guarantees 4-33
    United States 4-34
    Foreign country comparison 4-35
Agricultural feedstock programs 4-36
    United States 4-36
    Foreign country comparison 4-42

Bibliography Bibl-1

CONTENTS–*Continued*

Page

Appendices

A. Request letter from the Senate Finance Committee A-1
B. *Federal Register* notice B-1
C. Liquid biofuel and bio-based chemical industry activity in the United States and selected countries C-1
D. Process advantages of bio-based products versus their conventional counterparts D-1

Boxes

1-1. Current issues regarding industrial biotechnology 1-2
2-1. The globalization of supply chains 2-11
2-2. U.S. tariff treatment for ethanol 2-13
2-3. Examples of recent industrial biotechnology merger and acquisition activity 2-28
3-1. U.S. agricultural feedstocks 3-3
3-2. Examples of domestic supply chain strategic alliances 3-21
3-3. Examples of domestic technology transfer alliances 3-22
3-4. Example of U.S.-foreign technology transfer strategic alliance 3-25
3-5. Examples of U.S.-foreign supply chain strategic alliances 3-26

Tables

1-1. Liquid fuels and chemicals: Respondents’ production and research and development establishments, 2004–07 1-7
1-2. Industrial biotechnology: Respondent profile 1-8
1-3. Industrial biotechnology: Respondents’ indication of reasons for evaluating or pursuing industrial biotechnology development or adoption 1-9
2-1. Liquid biofuel and bio-based chemical industries: Respondents’ U.S. activity trends, 2004–07 2-1
2-2. Liquid fuels: Respondent U.S. producers’ structure, sales, and employment, 2004–07 2-3
2-3. Ethanol: Respondent U.S. producers’ structure and shipments, 2004–07 2-4
2-4. Biodiesel: Respondent U.S. producers’ structure and shipments, 2004–07 2-6
2-5. Chemicals: Respondent U.S. producers’ structure, 2004–07 2-8
2-6. Chemicals: Respondent U.S. producers’ sales, shipments, and employment, 2004–07 2-9
2-7. Trade: Respondent U.S. producers’ U.S. exports and imports, 2004–07 2-12
2-8. Ethanol: Production costs and related data, 2002 and estimate as of March 2008 2-15
2-9. Biodiesel (virgin): Production costs and related data, 2006–08 2-16
2-10. Liquid fuels: Selected financial data for respondents’ operations, 2004–07 2-17
2-11. Chemicals: Selected financial data for respondents’ operations, 2004–07 2-19
2-12. Research and development: Respondents’ U.S. expenditures and employment, 2004–07 . . 2-21
2-13. Research and development: Respondents’ U.S. expenditures and employment for their bio-based activities, by company groups, 2004–07 2-22
2-14. Government grants: Respondents’ receipts and matching funds, total and by selected company groups, 2004–07 2-24

CONTENTS–*Continued*

Page

Tables–*Continued*

2-15. Investment: Respondents' U.S. expenditures, 2004–07 2-26
2-16. Investment: Respondents' U.S. expenditures for bio-based activities, by company groups, 2004–07 2-26
3-1. Industrial biotechnology adoption: Respondents' indication of the significance of commercialization impediments 3-2
3-2. Liquid biofuel and bio-based chemical companies: Respondents' indication of most important competitive factors affecting ability to market products 3-2
3-3. Agricultural feedstocks: Respondents' ranking of issues affecting their operations 3-4
3-4. U.S. prices of agricultural feedstocks, biofuels, and petroleum products, 2004–07, and December 2007 3-5
3-5. Investment: Respondents' indication of funding importance 3-9
3-6. Selected cellulosic ethanol pilot and demonstration plants 3-13
3-7. Examples of innovative industrial biotechnology 3-14
3-8. Industrial biotechnology development: Research and development impediment significance, ranked by respondents 3-17
3-9. Research and development decisions by respondents: All companies and selected company groups 3-18
3-10. Strategic alliances: Respondents' reasons 3-19
3-11. Domestic strategic alliances: Number formed by respondents, 2004–07 3-20
3-12. National Renewable Energy Laboratory biomass program technology transfer activities, 2003–07 3-24
3-13. Foreign strategic alliances: Number formed by respondents, 2004–07 3-25
3-14. Intellectual property: Respondents' activity, 2004–07 3-28
3-15. Intellectual property: Respondents' patent applications and trademarks registered, by company groups, 2004–07 3-28
3-16. Intellectual property: Respondents' income and costs, by company groups, 2004–07 3-29
3-17. Patents: Number granted to respondents, 1997–2007 3-29
4-1. Government programs: Respondents' indication of importance in supporting development or adoption of industrial biotechnology 4-3
4-2. Government policies directly supporting development or adoption of industrial biotechnology by the liquid fuel and chemical industries in the United States and selected countries 4-5
4-3. U.S. Department of Energy expenditures for biomass and biorefinery systems research and development, 2003–07 4-17
4-4. U.S. Department of Agriculture and U.S. Department of Energy: Biomass research and development awards by type of project, and company matches, 2002–06 4-18
4-5. Small Business Innovative Research (SBIR) and Small Business Technology Transfer (STTR) program grants, by state, 2000–2007 4-19
4-6. Comparison of U.S. and foreign tax incentives for industrial biotechnology 4-22
4-7. Major U.S. federal government biofuel tax incentives 4-23
4-8. U.S. state tax incentives for industrial biotechnology 4-25

CONTENTS–*Continued*

Page

Tables–*Continued*

4-9. Comparison of U.S. and foreign mandatory use regulations for blended fuels 4-30
4-10. U.S. Department of Agriculture and U.S. Department of Energy: 2008 biomass research and development grants 4-40
C-1. Liquid biofuel and bio-based chemical industry activity, United States and selected countries C-3
D-1. Results of life-cycle assessments for certain bio-based products and their petroleum-based counterparts D-6

Figures

ES-1. Liquid biofuels and bio-based chemicals: Share of shipments, by industry, 2007 xvi
ES-2. Industrial biotechnology: U.S. business activity trends, 2004–07 xvi
ES-2. Industrial biotechnology: Innovation indicator trends, 2004–07 xvii
1-1. Industrial biotechnology: Location of establishments, 2007 1-7
2-1. Conventional and bio-based liquid fuels and chemicals: Relative sales of respondents' U.S. produced products, 2007 2-2
2-2. Research and development: Respondents' U.S. expenditures for their bio-based activities, by company groups, 2004–07 2-22
2-3. Research and development: Respondents' employment growth, 2004–07 2-23
2-4. Investment: Respondents' U.S. expenditures for bio-based production facilities, by company groups, 2004–07 2-27
2-5. Investment: Respondents' U.S. expenditures for bio-based research and development facilities, by company groups, 2004–07 2-27
3-1. Total venture capital investment in industrial biotechnology, 1995–2007 3-10
3-2. Venture capital investment in industrial biotechnology, 1995–2007 3-10
3-3. Industrial biotechnology-related patents granted, U.S. and foreign origin, cumulative, 1975–2006 3-32
3-4. Foreign-origin patents, by country, 2006 3-33
3-5. Domestic-origin patents, by state, 2006 3-33

Executive Summary

The Committee on Finance of the United States Senate requested the Commission to examine the competitive conditions affecting certain industries that are developing and adopting new industrial biotechnology (IB) processes and products. IB was defined for purposes of this study as the manufacture of liquid fuel and chemical products using enzymes, micro-organisms, or renewable resources. The report focuses on U.S. liquid biofuel producers and firms in the U.S. chemical industry. The application of IB can improve the efficiency of the industries and lead to the development of new products. The report provides an understanding of the current impact of IB on the U.S. economy.

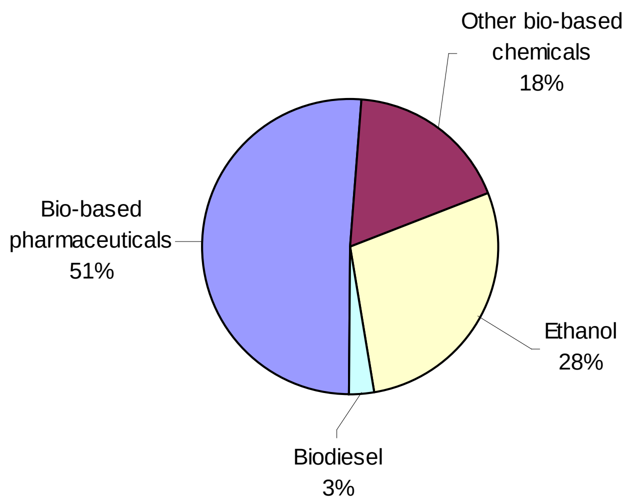
Overview and Principal Findings

The U.S. liquid biofuel and bio-based chemical industries expanded significantly from 2004 through 2007, although the current impact of this growth on the U.S. economy is relatively small. In terms of shipments, the liquid biofuel industry, composed of ethanol and biodiesel producers, grew at a faster rate, but the bio-based chemical industry, composed of pharmaceutical and other chemical producers, is larger (figure ES-1).

The liquid biofuel and chemical industries use IB in many products and processes, some of which are well established and already commercialized to a significant extent and others that are emerging. These products and processes, many of which are innovative, are subjects of significant R&D. The Commission's investigation, based on a detailed survey of these firms, found that business activities in IB—including the number of establishments, sales, shipments, production, employment, R&D expenditures, and investment—are growing at a rapid rate (figure ES-2). The magnitude of these activities, however, remains relatively small compared with that of the conventional chemical and liquid fuel industries. Government incentives and mandates are significant and have been vital to the growth and development of many of the companies that rely on IB, particularly for the liquid biofuel industry.

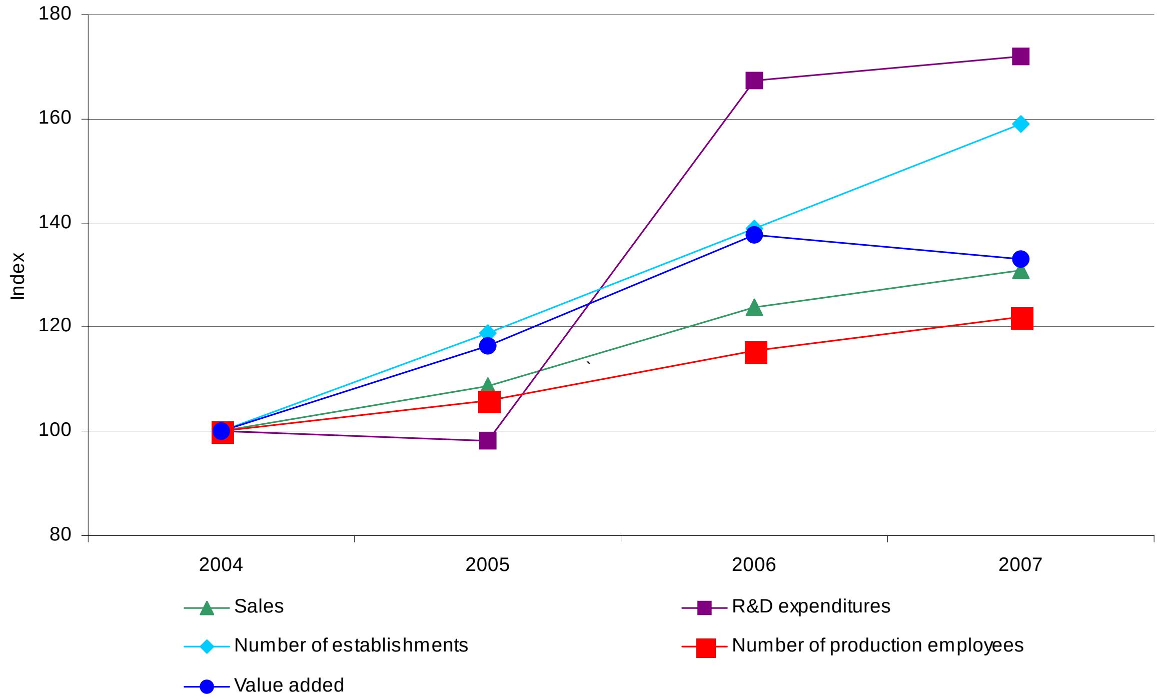
Innovation is important to the future competitiveness and productivity of U.S. firms. Innovation indicators—including R&D expenditures, strategic alliances, and intellectual property registrations—document substantial levels of activity focused on the development and adoption of new IB products and processes (figure ES-3). R&D expenditures for IB increased at three times the rate of conventional R&D spending. Large and increasing R&D expenditures have focused on the development of new drugs, advanced enzymes and micro-organisms, the use of nonfood feedstocks and the improvement of yields, and the development of higher-value co-products. New investments in pilot plants are moving the technology for cellulosic ethanol toward commercialization.

FIGURE ES-1
Liquid biofuels and bio-based chemicals: Share of shipments, by industry, 2007



Source: Compiled from data submitted in response to U.S. International Trade Commission questionnaire.

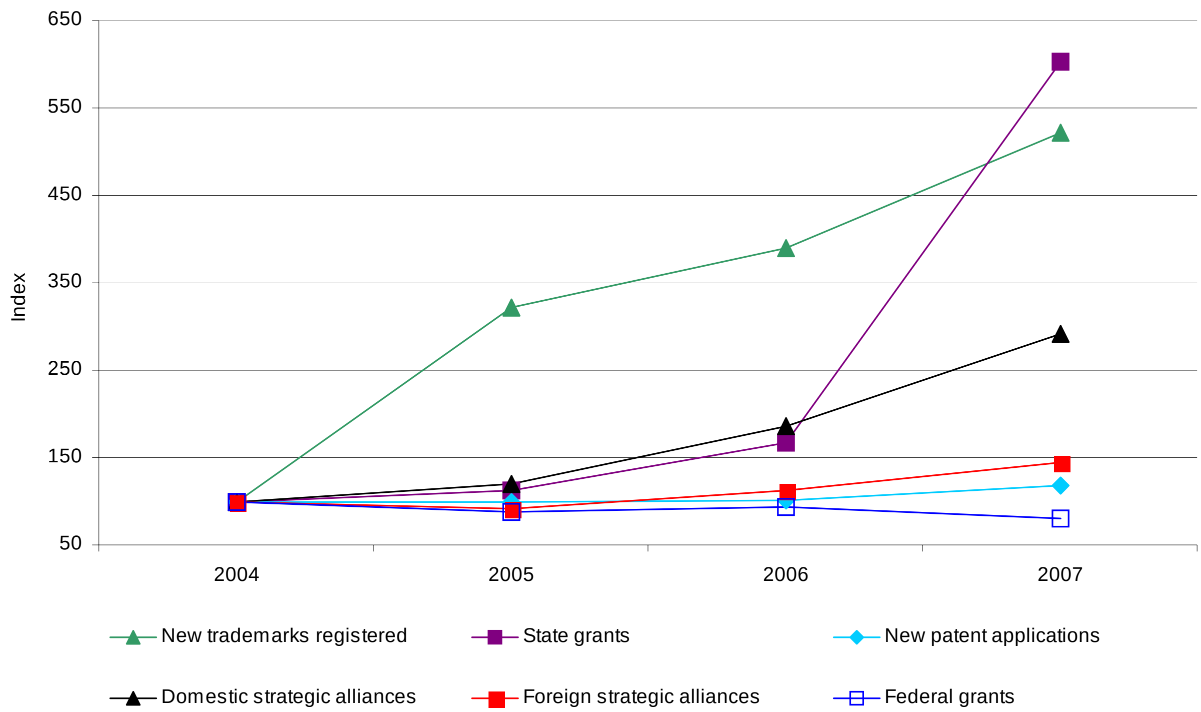
FIGURE ES-2
Industrial biotechnology: U.S. business activity trends, 2004–07



Note.—Index year 2004 = 100

Source: Compiled from data submitted in response to U.S. International Trade Commission questionnaire.

FIGURE ES-3
Industrial biotechnology: Innovation indicator trends, 2004–07



Note.—Index year 2004 = 100

Source: Compiled from data submitted in response to U.S. International Trade Commission questionnaire.

Strong growth in the number of domestic and foreign strategic alliances is enabling the transfer of technology and knowledge across universities, firms, and governments, and facilitating the globalization of supply chains. The formation of domestic and foreign strategic alliances has grown from 532 new IB alliances in 2004 to 1,367 new alliances in 2007. Patent and trademark activity has intensified as firms seek to protect, commercialize, and license their new discoveries and brands. Trademark registrations in particular have shown strong growth, increasing from 197 new registrations in 2004 to 1,027 in 2007, reflecting the increasing prominence of bio-based brands as the field moves from early discoveries to the commercialization of innovative technologies and products.

Among the most significant impediments to the successful development and adoption of IB by the U.S. liquid fuel and chemical industries are the rising cost of feedstocks and the inability to attract sufficient investment. More than one-half of the production costs for ethanol and 75 percent of the production costs for biodiesel are attributable to feedstocks; consequently, feedstock cost and availability significantly impact firm operating income as a share of total net sales. Retained earnings and debt are the most significant sources of capital for IB firms; however, many small firms, including those focused exclusively on R&D, have limited access to these sources. For these firms, and for others developing new technologies, attracting funds or capital is a leading impediment. Funding from alternative sources such as venture capital companies, strategic alliance partners, and federal government programs is critical, but often difficult to obtain. Impediments to the development and adoption of IB reportedly have resulted in a number of firms deciding not to pursue IB activities or to abandon a specific IB project.

Government programs assist in overcoming some impediments, particularly with respect to liquid biofuels. Policies that contribute to the development and adoption of IB include tax incentives; mandatory use regulations; research, development, and commercialization support; loan guarantees; and agricultural feedstock support programs. The liquid biofuel and bio-based chemical industries rank federal tax incentives, mandatory use regulations for final products, and state or local tax incentives as the most important U.S. government policies.

IB has the potential to benefit the U.S. economy by allowing for the substitution of liquid biofuels for conventional liquid fuels, potentially reducing crude petroleum imports, and stimulating the development of rural economies as a result of increased agricultural feedstock consumption. At the industry level, IB can improve production efficiency in the liquid biofuel and chemical industries, resulting in potential reductions in manufacturing costs and capital expenditures. The impact of IB on the productivity and competitiveness of U.S. chemical and liquid biofuel firms is primarily related to the development of innovative products and technologies. Life-cycle assessments conducted by firms to compare production factors for bio-based products with their conventionally produced counterparts indicate that IB can streamline production processes, lower energy consumption, and decrease waste generation. IB can also create new products such as biodegradable plastics that can compete with conventional products. IB may also provide a range of environmental benefits, including sustainable production, reduced greenhouse gas (GHG) emissions, and less waste generation.

Certain benefits of IB are controversial, especially concerning liquid biofuels. Questions raised in this context include, but are not limited to, how corn used for ethanol affects food supplies and prices, whether the increased production of corn is environmentally sustainable, the magnitude of the impact of biofuels on GHG emissions, and the net energy content of ethanol. An assessment of these factors is beyond the scope of this report. Whether the promise of liquid biofuels and bio-based chemicals ultimately outweighs the potential drawbacks will depend in large part on whether technological advances, such as cellulosic ethanol, effectively mitigate some of the costs and other concerns, and on the impact of government policy and market forces on the development of IB industries.

Liquid Biofuels

Because growth in the U.S. liquid biofuel industry during the 2004–07 period is primarily the result of mandatory use regulations and tax incentives, it is difficult to assess the impact of IB on the competitiveness and productivity of liquid biofuel firms. However, current R&D efforts by U.S. firms on innovative technologies may enhance competitiveness and productivity in the future. These technologies include, for example, the development of cellulosic ethanol, which uses nonfood, and potentially less costly, feedstocks; and an alternate liquid biofuel, biobutanol, which may offer increased energy content and greater compatibility with existing liquid fuel distribution infrastructure and vehicle engines as compared with ethanol.

The number of liquid biofuel producers, production establishments, and the value of corn ethanol shipments each more than doubled from 2004 through 2007. The value of biodiesel shipments increased by almost 2,500 percent. U.S. imports and exports of liquid biofuels increased significantly, with ethanol accounting for most activity. Operating income as a share of total net sales remained relatively flat for liquid biofuel producers, largely due to rising feedstock costs.

The levels of R&D activity and investment in IB increased strongly from 2004 through 2007, both in absolute terms and compared with total liquid fuel industry R&D activity and investment. Liquid biofuel R&D expenditures increased by more than 400 percent from 2004 through 2007, reaching $152.5 million. These expenditures increasingly focused on the commercialization of cellulosic ethanol. Cellulosic ethanol technologies have been an important focus of R&D and investment as firms seek to broaden the base of feedstocks. Several companies are expected to bring pilot or demonstration plants onstream in the United States in 2008, with one firm expected to begin commercial scale cellulosic ethanol production. Liquid biofuel producers, as compared with bio-based chemical producers, accounted for the majority of investment in production facilities.

The prices of the primary feedstocks used in U.S. liquid biofuels (corn for ethanol and soybeans for biodiesel) increased during the past several years. Other feedstock-related issues such as poor crop yields, storage capacity, supply disruptions, transportation bottlenecks, feedstock quality, and the unavailability of new feedstock varieties were also reported by liquid biofuel producers as impediments to the successful development and adoption of IB. Government programs that support the supply and utilization of feedstocks are particularly important to liquid biofuel producers. Federal programs affecting agricultural feedstocks involve a wide range of activities, including direct support for farmers, R&D projects at universities and in the private sector, and research at government laboratories.

Targeted U.S. and foreign government support for the development and adoption of IB is much more extensive for the liquid fuel industry than for the chemical industry and is largely driven by concerns about energy costs and security. Tax incentives are the most important form of support for U.S. liquid biofuel producers, and are available at the federal and state level. However, some firms report that current policies support a select few traditional technologies for producing biofuels from traditional feedstocks, claiming that such policies discourage innovation and the introduction of new biofuels to the marketplace.

Mandatory use regulations in the United States, ranked by liquid biofuel producers as the second most important type of program, are comprehensive, with annually rising minimum requirements for renewable fuels in the nation's fuel supply. The strong growth of the U.S. ethanol industry is largely attributable to U.S. mandatory use regulations.

The foreign countries examined in this report use tax incentives and have adopted or are moving toward adoption of mandatory use regulations for liquid biofuels. All governments also provide research, development, and sometimes commercialization support to the private sector and fund government research entities that share findings with the private sector to some degree. As in the United States, foreign government funding for liquid biofuels is typically explicitly earmarked.

Bio-based Chemicals

The bio-based chemical industry also expanded during the 2004–07 period, reflecting its continued utilization of IB and its increasing commitment to green chemistry. Government support policies do not target this industry to the extent they do the liquid biofuel industry. The industry is also much less reliant on agricultural feedstocks. The pharmaceutical sector dominates this industry. This sector is increasing its production of bio-based drugs, reflecting the biological nature of producing consumer drugs such as vaccines and antibiotics, and its increasing use of evolving bioprocesses. This industry also produces a wide variety of other bio-based chemicals, such as commodity chemicals, food ingredients, and biodegradable plastics.

The impact of IB on the competitiveness and productivity of bio-based chemical firms is evident at the production and market levels through enhanced performance characteristics, reductions in the environmental impact of production processes, reduction in production costs and capital expenditures, the creation of innovative products, and novel market positioning. Biopolymers, for example, produced sustainably from renewable resources such as corn, are becoming increasingly competitive with their petrochemical counterparts in terms of performance, cost, and product characteristics such as biodegradability. Pharmaceutical companies are increasingly using IB to improve product purity and yield, generate products that might otherwise not be technically feasible, incorporate sustainable chemical processes, and realize related cost benefits. For example, the use of IB in the production of certain antibiotics—a product category described as being highly competitive with low margins—resulted in lower production costs and improved competitiveness.

The rate at which the bio-based chemical industry expanded, as expressed in the number of producers, establishments, shipments, and employment, was less pronounced than that of the liquid biofuel industry. Imports of bio-based chemicals declined slightly, while exports increased by 17 percent during the period. Operating income as a share of total net sales remained relatively flat for bio-based chemical producers.

The levels of R&D activity and investment in IB increased strongly from 2004 through 2007, both in absolute terms and compared with total chemical industry R&D activity and investment. R&D expenditures related to bio-based chemicals were much larger than those related to liquid biofuels, reaching $3.4 billion in 2007. A small number of large pharmaceutical companies accounted for a large share of bio-based chemical R&D expenditures. Of the bio-based investment, pharmaceutical companies accounted for the majority of investment in R&D facilities. The research focus is diverse in bio-based chemicals, but largely targets the development of newer and more effective enzymes, bio-based products, and production processes. Bio-based chemical producers and dedicated R&D companies have been the largest contributors to the growth in technology transfer alliances, entering into technology development alliances with foreign R&D firms and universities.

Less government funding went to bio-based chemical producers than to liquid biofuel producers, although bio-based chemical funding rose slightly during the period. As in the United States, foreign government funding available to bio-based chemical producers is usually part of more general authorizations.

CHAPTER 1
Introduction

Industrial biotechnology (IB) activities in the United States by the chemical and liquid fuel industries increased substantially during the 2004–07 period. Sales of U.S.-produced bio-based products, for example, increased by over 30 percent during the period. Much of this growth is accounted for by the ethanol and biodiesel industries, which are strongly supported by government tax incentives or mandatory use regulations, or both. Pharmaceuticals accounted for the majority of IB sales. Sales of bio-based products remain small in comparison to conventional chemicals and liquid fuels.

IB R&D activity in the United States also increased substantially during the 2004–07 period. R&D expenditures rose by almost 72 percent; most of these expenditures were made by the research-intensive pharmaceutical industry. Both intellectual property activity and strategic alliances, which are focused on many innovative aspects of IB including noncrop feedstocks, enzymes and micro-organisms, and production processes, grew during the period as well. Government grants support many IB R&D activities.

Despite strong growth in some parts of these industries, U.S. firms identified several major impediments to the development and adoption of IB. Most of these impediments relate to the risk inherent with new technology, including the uncertainty as to whether such technologies can be fully developed and adopted. This uncertainty makes it difficult to attract R&D and investment funds. Other impediments affecting the adoption of IB include high production costs, especially feedstock costs, and perceived high market risk in comparison to profit potential.

IB activities in countries such as Brazil, China, and the EU also expanded during the 2004–07 period. As in the United States, governments of these countries use tax incentives, mandatory use regulations, and R&D funding to support their IB industries.

The development and adoption of IB can benefit the U.S. economy in a number of ways, such as allowing for the substitution of liquid biofuels for conventional liquid fuels, thereby potentially reducing crude petroleum imports, and enhancing rural economies as a result of increased agricultural feedstock consumption. At the industry level, IB can improve process efficiency as compared with conventional processes, resulting in potential reductions in manufacturing costs and capital expenditures. IB can also create new products such as biodegradable plastics that compete with conventional products.

IB may have environmental benefits, including sustainable production, reduced greenhouse gas (GHG) emissions, and less waste generation, particularly in regard to the production of bio-based chemicals. However, certain apparent advantages of IB are currently subject to conflicting points of view (box 1-1).

BOX 1-1 Current issues regarding industrial biotechnology

Industrial biotechnology is increasingly being adopted by the chemical and liquid biofuel industries because of its many potential technical, economic, and environmental advantages. Such advantages include process simplification, process cost savings, reduced consumption of fossil fuel inputs and energy, potential reductions in U.S. imports of crude petroleum, development of rural economies, and beneficial environmental effects, the magnitude of which vary by sector. However, certain aspects of producing and consuming liquid biofuels and bio-based chemicals are subject to ongoing debate. Perhaps one of the most contested issues is the "food-versus-fuel" debate. Questions raised in this context include, but are not limited to:[1]

- whether the use of corn to produce ethanol has diverted supply from the food chain;
- whether the escalating use of corn and associated price increases have been responsible for the recent increase in food prices;
- whether farmers are now devoting increased acreage to corn at the expense of soybeans (the main feedstock in the United States for biodiesel) or other crops; and
- whether increased production of corn is environmentally sustainable.

Questions have also arisen regarding two aspects of corn-based ethanol: (1) the magnitude of the biofuel's impact on greenhouse gas (GHG) emissions, and (2) the net energy balance of the biofuel.[2] For example, two analyses found that the use of corn-based ethanol can reduce GHG emissions by as much as 12–13 percent.[3] Farrell, et al. indicate, however, that a comparison of numerous studies evaluating corn-based ethanol versus gasoline showed divergent values regarding GHG emissions, ranging from a 20 percent increase to a 32 percent decrease, as well as divergent net energy values. The differences are attributed to numerous factors, including variations in the values and parameters utilized in the studies and whether the corn is grown on existing farmland or on land that has been recently converted for farm use.[4] Analyses by both Farrell, et al. and Hill, et al. indicate that cellulosic ethanol has the potential to significantly reduce GHG emissions. Moreover, Hill, et al. noted that biodiesel reduces GHG emissions by 41 percent compared with diesel, and found net energy balances of about 25 percent for corn-based ethanol and 93 percent for biodiesel.

[1] These questions are posed by various sources. Responses to many have been provided by numerous sources including: BIO, "Achieving Sustainable Production of Agricultural Biomass for Biorefinery Feedstock," November 21, 2006; NCGA, "U.S. Corn Growers: Producing Food and Fuel," November 2006; and RFA, "Ethanol Facts: Food Vs. Fuel," undated (accessed May 5, 2008).
[2] Hill, et al., "Environmental, Economic, and Energetic Costs and Benefits," July 25, 2006. The net energy balance is the amount of energy provided by the liquid biofuel compared with the energy used to produce it. Corn ethanol is said to have a low net energy balance because of the high energy input used in both the production of corn and the resulting ethanol.
[3] Farrell, et al., "Ethanol Can Contribute to Energy and Environmental Goals," January 27, 2006; and Hill, et al., "Environmental, Economic, and Energetic Costs and Benefits," July 25, 2006.
[4] Farrell, et al., "Ethanol Can Contribute to Energy and Environmental Goals," January 27, 2006.

Sources: Compiled from various sources.

Purpose

This report was prepared in response to a request from the Committee on Finance of the United States Senate regarding the competitive conditions affecting certain industries that are developing and adopting new IB processes and products.[1] As requested by the Committee, the Commission's report focused on firms in the U.S. chemical industry that are developing bio-based products and renewable chemical platforms, and U.S. producers of liquid biofuels. The Committee asked that the Commission's report:

[1] This request was received by the Commission on November 2, 2006, pursuant to the provisions of section 332(g) of the Tariff Act of 1930 (19 U.S.C. 1332(g)). A copy of the request letter is included in app. A. The Commission's notice of institution of this investigation was published in the *Federal Register* of December 1, 2006 (71 Fed Reg 69588–89) and is included in app. B.

- Describe and compare government policies in the United States and key competitor countries throughout the world relating to the development of products by these industries;

- Analyze the extent of business activity in these industries, including, but not limited to, trends in production, financial performance, investment, research and development, and impediments to development and trade;

- Examine factors affecting the development of bio-based products, including liquid biofuels, and renewable chemical platforms being developed by the U.S. chemical industry, including, but not limited to, globalization of supply chains, capital investment sources, strategic alliances, intellectual property rights, and technology transfer mechanisms;

- Determine, to the extent feasible, how the adoption of industrial biotechnology processing and products impacts the productivity and competitiveness of firms in these industries; and

- Assess how existing U.S. government programs may affect the production and utilization of agricultural feedstocks for liquid biofuels as well as bio-based products and renewable chemical platforms being developed by the U.S. chemical industry.

Scope

Industrial biotechnology is the application of biotechnology (i.e., the use of living organisms, or substances derived from living organisms) to manufacture various intermediate and consumer products. Also called white biotechnology, IB is often referred to as the "third wave" of biotechnology, following the relatively longer-term use of biotechnology in the healthcare sector (red biotechnology) and the agricultural sector (green biotechnology).[2] The distinction between red and white biotechnology with regard to pharmaceuticals is important in defining the scope of this investigation. The development of pharmaceuticals using genetic engineering or cell culturing is red biotechnology and is outside the scope of this investigation. The downstream synthesis of pharmaceuticals using living organisms or derivatives thereof is white biotechnology and is included in this investigation.

According to industry trade associations such as BIO and EuropaBio[3] and other industry sources, IB processes are defined as specifically incorporating the use of enzymes or micro-organisms to convert raw materials into finished products. This investigation focused on two types of products made this way—bio-based chemicals including pharmaceuticals and nonpharmaceuticals such as plastics, food ingredients, flavors, and fragrances; and liquid biofuels such as ethanol. Other industry sources contacted by the Commission expand the definition of IB to include any chemical or fuel made from renewable resources, regardless

---

[2] Red and green biotechnology focus on genetic engineering or cell culturing involving plants or micro-organisms to create new or improved pharmaceuticals or crops, respectively.

[3] Biotechnology Industry Organization (BIO) is a major U.S. trade association representing hundreds of biotechnology companies. The European Association of Bioindustries (EuropaBio) represents hundreds of European biotechnology companies.

of the production process. This expanded definition encompasses the production of biodiesel, a major liquid biofuel that is not currently manufactured with enzymes or micro-organisms.

For the purpose of this investigation, based on information derived from industry sources, the Commission defined industrial biotechnology as follows:

> *The manufacture of liquid fuels and chemical products using (1) enzymes or micro-organisms at any stage of the production process, regardless of the type of raw materials used (e.g., renewable, fossil fuel-based, or inorganic); or (2) renewable resources and conventional chemical processing.*

Processes and Products

Fermentation and biocatalysis are common terms for chemical reactions that occur as a result of using enzymes or micro-organisms.[4] Industry sources are inconsistent regarding the distinction between these terms, but in general, fermentation is considered to be a type of biocatalytic process.[5] For the purposes of this investigation, biocatalysis is used to indicate fermentation, enzymatic, and microbial processes.[6] Biocatalysis can be applied to renewable and nonrenewable raw materials.

Using the Commission's definition of IB, "conventional chemical processing" applied to renewable resources results in the production of chemicals without using enzymes or micro-organisms. Typically, this processing involves high temperatures or pressures and metal catalysts to initiate chemical reactions.

These processes create bio-based products, or more specifically for this investigation, liquid biofuels and bio-based chemicals. The most common liquid biofuel produced in the United States is ethyl alcohol, or ethanol, which is primarily manufactured from the starch portion of corn kernels. Brazil, a major producer of ethanol, uses sugarcane as its primary raw material. Biodiesel is the second most common liquid biofuel. In the United States, soybean oil is the primary raw material for biodiesel. The EU, a major producer of biodiesel, uses mostly rapeseed as its feedstock. In terms of sales, pharmaceuticals are the most common bio-based chemicals produced in the United States.

Liquid biofuels and bio-based chemicals include a wide variety of products, some of which are well established and already commercialized to a significant extent and others that are emerging. Many products are innovative in terms of manufacturing process or raw material, particularly those that are produced using biocatalysis. A significant amount of U.S. R&D is focused on developing and adopting innovative products and processes.

Conventional liquid fuels and chemicals are produced using nonrenewable resources, usually fossil fuel-based substances, and conventional chemical processing. Over 95 percent of

---

[4] Enzymes are organic compounds that initiate or accelerate chemical reactions. Micro-organisms, or microbes, are simple life forms that consume raw materials using enzymes that are a natural part of their metabolism.

[5] See definitions in the glossary for more information.

[6] A biocatalytic process breaks down chemically complex raw materials into simpler substances, causes reactions to initiate, or shortens reaction time. This occurs in a vessel, or series of vessels, containing enzymes or micro-organisms. Heat, water, or nutrients may be used to induce or optimize the chemical reactions.

chemicals and liquid fuels are currently produced using nonrenewable resources and conventional chemical processing.[7]

Industry Coverage

This report addresses the development and adoption of IB by the U.S. chemical industry and liquid biofuel producers and the factors affecting the development and adoption of IB by these industries. Commission staff defined the chemical industry to include companies that have establishments classified in North American Industrial Classification System (NAICS) code 325.[8] The liquid biofuel industry was defined to include all companies that produce liquid biofuels, regardless of NAICS code. This report refers to both sets of companies as industries.

For the purposes of this report, these industries were further divided into several product categories. For the chemical industry, these included commodity and specialty chemicals; chemical intermediates; polymers; pharmaceuticals; food ingredients; and flavors and fragrances. For the liquid biofuel industry, these included biodiesel from virgin feedstocks; biodiesel from recycled raw materials; starch-based ethanol from corn; other grain-based ethanol; cellulosic ethanol; and biobutanol (another liquid biofuel).

Approach

Information Collection

Most information gathered for this investigation was collected through interviews with industry representatives and by means of a questionnaire developed by Commission staff.[9] The questionnaire addressed the elements of the request letter and was designed to both identify companies with IB production or R&D activities, and to gather quantitative and qualitative information about these activities. All liquid fuel and chemical companies were requested to complete the questionnaire, regardless of whether they were involved in IB activities, in order to place their IB activities in perspective relative to the entire liquid fuel and chemical industries.

Over 1,800 questionnaires were mailed to liquid fuel and chemical companies, both producers and R&D firms, in September 2007. About 67 percent of companies returned responses, of which almost one-half reported business activities related to liquid fuels or chemicals. The remaining respondents reported that they did not engage in these activities. Several chemical companies did not provide responses.[10] The majority of nonrespondents were R&D companies whose activities were most likely not within the scope of this investigation.

[7] Based on Commission questionnaire responses.
[8] Code 325 is defined in the NAICS as *Chemical Manufacturing*. A list of all NAICS codes can be found at http://www.census.gov/epcd/naics02/.
[9] A copy of this questionnaire can be found at http://www.usitc.gov/ind_econ_ana/research_ana/usitc_questionnaire_biotechnology_final.pdf.
[10] Because no other data sources specifically address IB sales by the chemical industry, it is not known whether these companies' IB sales are significant.

The information in questionnaire responses was supplemented by written submissions provided to the Commission by interested parties; trade literature, including reports from numerous government and nongovernment organizations;[11] and interviews of industry representatives in Illinois, Iowa, Nebraska, and Washington, DC.

Analysis

The Commission's analysis draws on questionnaire responses to analyze trends that occurred during the 2004–07 period.[12] Cross-sectional analysis was used to evaluate trends for groups of companies that produce similar products or perform similar activities. These groups, listed below, were chosen to minimize overlap of activities; e.g., certain biofuel companies make both ethanol and biodiesel and were grouped together as liquid biofuel producers to avoid double counting. Nevertheless, a small amount of overlap was unavoidable. The groups used were:

- IB producer groups:
    - Liquid biofuel producers
    - Bio-based chemical producers:
        - Pharmaceutical producers
        - All other bio-based chemical producers

- IB dedicated R&D companies:
    - Pharmaceutical companies
    - All other R&D companies

The analysis includes an evaluation of the impact of IB on the U.S. economy. Economists generally estimate the economic impact of a particular sector or industry on the aggregate economy through the sector's contribution to gross domestic product, or GDP. The total contribution of the IB sector to GDP includes the value added in producing IB products; purchases of labor, agricultural feedstocks, equipment, and other production inputs; and taxes paid. Indicators of this contribution include production or output of goods generated in the local economy, sales, wages and salaries, employment and job creation, and the income, sales, and property taxes paid to federal, state, and local governments.[13] Companies that have not yet brought products to market still make current contributions to the U.S. economy through R&D expenditures and by purchasing inputs from other companies.

Respondent Profile

There was a substantial increase in IB activities during the 2004–07 period. The number of IB establishments increased by over 50 percent, compared with an increase of less than 10 percent for conventional liquid fuel and chemical establishments (table 1-1). Most IB establishments are located in California, Massachusetts, Texas, Iowa, and Illinois (figure 1-1).

[11] An extensive bibliography is provided in this report.
[12] The questionnaire was mailed to respondents in September 2007 and responses were typically prepared before complete 2007 data were available. Respondents were requested to make reasonable estimates for full-year data based on year-to-date 2007 information. Data are aggregated in this report so as not to reveal the operations of any one company.
[13] See, for example, Ernst and Young LLP, *The Economic Contributions of the Biotechnology Industry to the U.S. Economy*, May 2000.

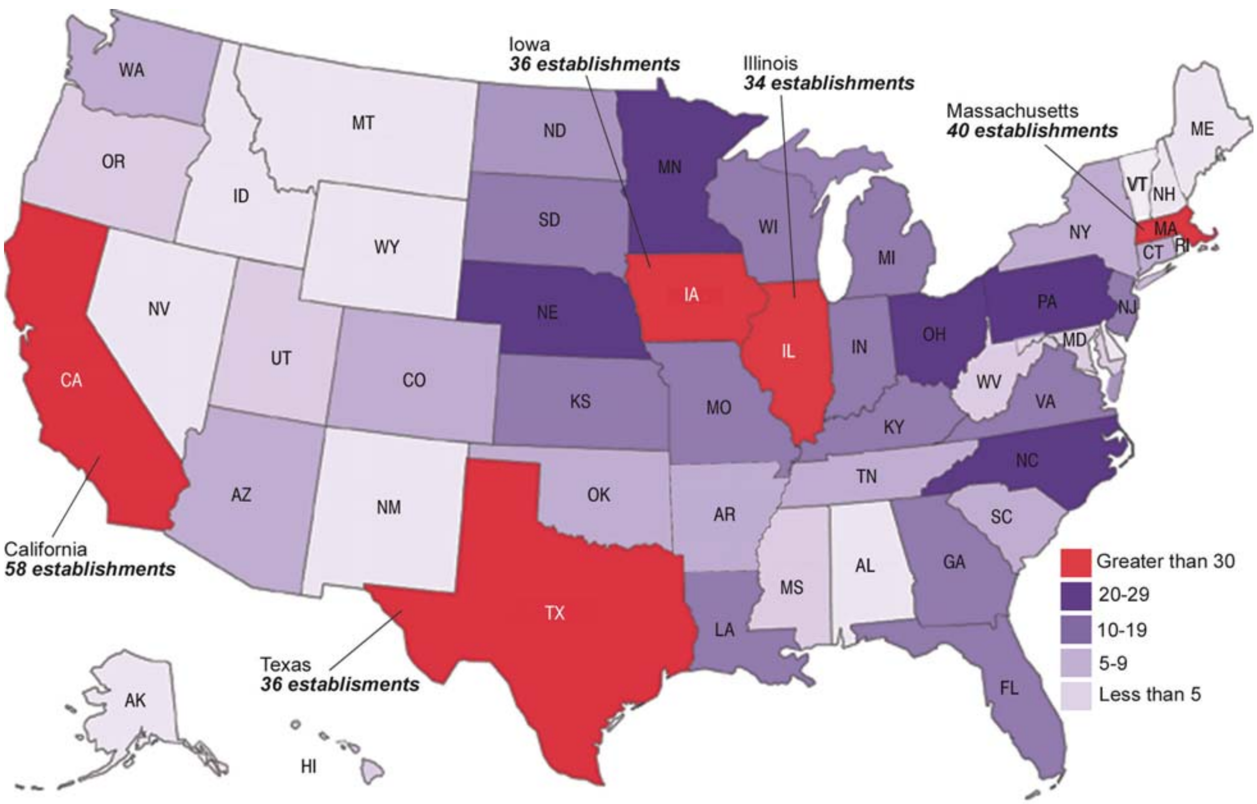
TABLE 1-1
Liquid fuels and chemicals: Respondents' production and research and development establishments, 2004–07

(*Number*)

Establishment type	2004	2005	2006	2007	2004/07 percent change
Conventional liquid fuels and chemicals . . .	933	942	990	990	6.1
Liquid biofuels and bio-based chemicals . .	389	463	541	618	58.9
Total	1,322	1,405	1,531	1,608	21.6

Source: Compiled from data submitted in response to U.S. International Trade Commission questionnaire.

FIGURE 1-1
Industrial biotechnology: Location of establishments, 2007



Source: Compiled from data submitted in response to U.S. International Trade Commission questionnaire.

Responding companies were diverse, and included large petroleum refiners, chemical companies, pharmaceutical companies, and agribusiness companies, as well as more narrowly focused companies that produce only liquid biofuels or bio-based chemicals, or are focused solely on R&D activities.

Table 1-2 presents certain information regarding respondents. Almost 60 percent of respondents rated IB as a crucial or important part of their business, and almost 70 percent of respondents claimed to be performing one or more IB activities. For many companies, biotechnology, IB, or renewable resources are specifically part of their written goals and strategies.

Respondents cited a wide variety of reasons for evaluating or pursuing IB activities (table 1-3). Principal reasons include improved profitability and sales growth potential.

TABLE 1-2
Industrial biotechnology: Respondent profile

Item	Number of responses
Total respondents reporting liquid fuel or chemical production or research and development activities	559
Respondent organization type:	
Farmers' cooperative	19
Joint venture:	
Farmers' cooperative and private company	8
Private company	8
Publically traded company	165
Privately held company	324
Other	33
Importance of industrial biotechnology to organization's business:	
Crucial	198
Important	126
Minor importance	73
Not important	152
Status of industrial biotechnology activities:[1]	
None	177
Evaluation of whether to initiate activities	29
Research and/or development of enzymes or micro-organisms	75
Research and/or development of agricultural feedstocks	63
Other process or product research and/or development	104
Liquid biofuel production	181
Bio-based chemical production	79
Downstream production activities	21
Respondent companies' goals and strategies:	
Specifically reference biotechnology, industrial biotechnology, or renewable resources	243
Year first referenced:	
Before 2004	131
2004	19
2005	31
2006	43
2007	23

[1] If "none" or "evaluation of activities" was indicated, respondents were not permitted to check any other category. Multiple selections were permitted for remaining activities.

Source: Compiled from data submitted in response to U.S. International Trade Commission questionnaire.

TABLE 1-3
Industrial biotechnology: Respondents' indication of reasons for evaluating or pursuing industrial biotechnology development or adoption

Reason	Total responses	Percentage indicating: Very significant	Least significant
Improve profitability	367	75	16
Sales growth potential	362	71	18
Improve competitiveness	362	59	24
Related to current competencies	367	55	25
Market share potential	361	54	24
Potential to develop novel products	369	53	29
Improve productivity	363	51	35
Implement sustainable production	365	50	30
Product diversification	366	44	36
Reduce emissions of greenhouse gases	363	40	40
Take advantage of government mandatory use requirements	360	33	47
Lessen other environmental effects	361	25	53

Note.—Respondents indicated multiple reasons in most cases.

Source: Compiled from data submitted in response to U.S. International Trade Commission questionnaire.

Report Organization

This report addresses IB development and adoption by the U.S. chemical and liquid biofuel industries and is divided into this and three other chapters that together address the elements of the request letter. Chapter 2 provides extensive quantitative information on the level of IB business activity in the United States, based primarily on the responses to the Commission's questionnaire. Chapter 2 also includes an analysis of important business activity trends. Chapter 3 examines the factors affecting the development and adoption of IB with a focus on impediments reported by the respondents and business strategies employed to address these impediments, including the globalization of supply chains, diversification of capital investment sources, strategic alliances and technology transfer, and intellectual property rights. It includes a discussion of agricultural feedstocks and IB R&D and innovation in the United States, with particular examples of important technologies in use or under development and their potential advantages over conventional products or processes. Chapter 4 compares U.S. government and major foreign government policies that support the development and adoption of IB. The chapter is arranged by policy, addressing R&D support, tax incentives, regulations concerning the mandatory use of IB products, loan guarantees for producers, and agricultural feedstock support programs.

The impact of IB on the productivity and competitiveness of U.S. chemical and liquid biofuel firms is a cross-cutting issue addressed in chapters 2–4, particularly in the discussion of financial performance in chapter 2; the description of new technologies and their potential advantage in chapter 3; the description of the impact of governmental programs on the liquid biofuel industry in the United States and selected competitor countries in chapter 4; and in appendix D, which describes life-cycle assessments conducted by firms to compare production and environmental factors for bio-based products with their conventionally produced counterparts.

CHAPTER 2
Trends in Bio-based Business Activities[1]

Activity in the liquid biofuel and bio-based chemical industries expanded significantly during the 2004–07 period according to indicators of industry size for which data were collected in this investigation (table 2-1). However, if ethanol and biodiesel activity, both of which receive substantial government support, are excluded, the activity growth trend is much less robust. Although ethanol and biodiesel accounted for almost 70 percent of the increase in IB sales from 2004 through 2007, pharmaceutical sales accounted for 57 percent of total IB sales in 2007.

Despite this expansion, the size of the liquid biofuel and bio-based chemical industries is small compared with the conventional liquid fuel and chemical industries. In terms of sales, bio-based products account for less than 5 percent of total sales of liquid fuels and chemicals (figure 2-1).

TABLE 2-1
Liquid biofuel and bio-based chemical industries: Respondents' U.S. activity trends, 2004–07

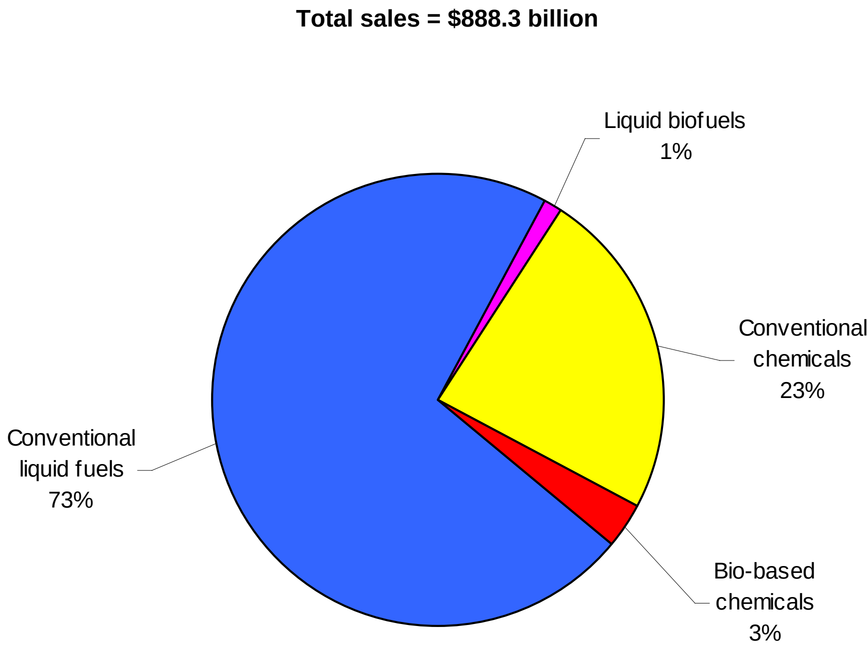
Item	2004	2005	2006	2007	2004/07 percent change
Number of establishments	389	463	541	618	58.9
Sales of U.S.-produced products (*1,000 dollars*):					
Liquid biofuels	4,712,944	5,543,593	8,748,272	11,299,279	139.7
Bio-based chemicals	26,881,186	28,809,554	30,371,984	29,944,393	11.4
Total	31,594,130	34,353,147	39,120,256	41,243,672	30.5
Value-added (*1,000 dollars*)	14,882,499	17,311,706	20,498,414	19,794,236	33.0
Production employees:					
Number	20,718	21,919	23,926	25,262	21.9
Wages and salaries (*1,000 dollars*)	1,767,593	1,901,092	2,084,338	2,166,672	22.6
Research and development:					
Expenditures (*1,000 dollars*)	2,203,520	2,160,779	3,689,117	3,789,052	72.0
Number of employees	7,048	7,631	8,940	9,509	34.9
Investment (*1,000 dollars*)	2,525,940	2,730,663	5,046,363	8,061,796	219.2
Federal and state grants (*1,000 dollars*)	104,279	([1])	98,734	151,044	44.8

[1] Data withheld to avoid disclosure of confidential business information.

Source: Compiled from data submitted in response to U.S. International Trade Commission questionnaire.

[1] Unless otherwise indicated, data in this chapter are based on Commission questionnaire responses.

FIGURE 2-1
Conventional and bio-based liquid fuels and chemicals: Relative sales of respondents' U.S.-produced products, 2007



Source: Compiled from data submitted in response to U.S. International Trade Commission questionnaire.

Industry Characterization

Liquid Biofuels

The liquid biofuel industry expanded significantly from 2004 through 2007, largely because of mandatory use regulations, tax incentives, and MTBE bans[2] implemented by federal and state legislation. The Energy Policy Act of 2005 (EPAct 2005, P.L. 110-58), established the first-ever Renewable Fuels Standard (RFS) in federal law, requiring increasing volumes of ethanol and biodiesel to be blended with the U.S. fuel supply between 2006 and 2012. The Energy Independence and Security Act of 2007 (P.L. 110-140, H.R. 6) amended and increased the RFS, requiring 9 billion gallons of renewable fuel use in 2008, stepping up to 36 billion gallons by 2022. Virtually all of the expansion is the result of increased activity related to the production of corn ethanol and biodiesel.

---

[2] MTBE is a fuel additive that was used as an octane enhancer and as an oxygenate to lower harmful emissions and enable compliance with U.S. clean air standards. Health concerns resulted in numerous state bans on the use of MTBE. Ethanol is a substitute for MTBE. The Renewable Fuel Standard led to the lifting of most requirements for oxygenates, as the required ethanol content in gasoline generally meets these requirements. EPA, "Methyl Tertiary Butyl Ether (MTBE): Gasoline," September 13, 2007; EPA, "Contaminant Focus," November 30, 2007; and EPA, "State Actions Banning MTBE (Statewide)," August 2007.

The numbers of liquid biofuel producers and establishments[3] both more than doubled during the 2004–07 period (table 2-2). Sales and employment had similar increases. Liquid biofuel sales remain a small portion of total sales of liquid fuels in the United States, but their annual growth rate was significantly higher.[4] These sales accounted for 1.8 percent of the value of total liquid fuel sales in 2007, up from 1.2 percent in 2004. Similarly, liquid biofuel employment accounted for 11 percent of total liquid fuel employment in 2007, compared with 6 percent in 2004.

TABLE 2-2
Liquid fuels: Respondent U.S. producers' structure, sales, and employment, 2004–07

Item	2004	2005	2006	2007	2004/07 percent change
Number of producers:[1]					
All liquid fuels[2]	103	113	153	205	99.0
Liquid biofuels	60	73	109	164	173.3
Number of liquid biofuel production establishments[3]	91	112	157	218	139.6
	Value (*1,000 dollars*)				
Sales of U.S.-produced products:					
Conventional liquid fuels	396,868,019	537,530,014	602,529,682	634,693,800	59.9
Liquid biofuels:					
Fuel products	4,712,944	5,543,593	8,748,272	11,299,279	139.7
Byproducts	731,402	709,839	916,977	1,606,127	119.6
Employment:					
Conventional liquid fuels:					
Number of employees (*FTE*)	55,075	57,928	59,586	61,014	10.8
Wages and salaries (*1,000 dollars*)	5,666,062	6,178,186	6,751,758	7,130,205	25.8
Liquid biofuels:					
Number of employees (*FTE*)	3,797	4,434	5,633	7,292	92.0
Wages and salaries (*1,000 dollars*)	216,179	255,678	327,424	425,616	96.9

[1] The number of producers includes only companies that reported sales or shipments during the year. Companies that sold or shipped more than one type of bio-based product are included in each category, except for totals.
[2] Includes both conventional fuel and liquid biofuel producers. Conventional fuels, including, for example, gasoline, diesel fuel, and jet fuel, are produced at crude petroleum refineries.
[3] Includes establishments that produced both liquid biofuels and bio-based chemicals.

Source: Compiled from data submitted in response to U.S. International Trade Commission questionnaire.

[3] An establishment is a single physical production or R&D location.
[4] Much of the growth in sales of conventional liquid fuels is attributable to crude petroleum price increases.

Ethanol

The number of U.S. ethanol producers increased by 70 percent during 2004–07 in response to rising demand (table 2-3).[5] According to the Renewable Fuels Association, the U.S. ethanol industry expanded from 72 plants with an annual capacity of 3.1 billion gallons in January 2004 to 139 plants with an annual capacity of 7.9 billion gallons as of January 2008.[6] Although U.S. ethanol production capacity has become somewhat more dispersed geographically, production and capacity remain concentrated in the Midwest.

TABLE 2-3
Ethanol: Respondent U.S. producers' structure and shipments, 2004–07

Item	2004	2005	2006	2007	2004/07 percent change
Number of producers:					
Starch-based corn ethanol	32	38	45	58	81.3
Other starch-based ethanol	8	8	9	10	25.0
Shipments:					
Starch-based corn ethanol:					
Quantity (*1,000 gallons*)[1]	2,884,522	3,187,356	3,894,383	5,182,100	79.7
Value (*1,000 dollars*)	4,248,990	4,819,868	7,736,402	10,189,843	139.8
Unit value (*dollars per gallon*)[2]	1.47	1.51	1.99	1.97	33.5
Other starch-based ethanol:					
Quantity (*1,000 gallons*)[1]	230,471	237,914	288,959	298,849	29.7
Value (*1,000 dollars*)	289,976	337,800	408,970	413,083	42.5
Unit value (*dollars per gallon*)[2]	1.26	1.42	1.42	1.38	9.9
Total:					
Quantity (*1,000 gallons*)	3,114,993	3,425,270	4,183,342	5,480,949	76.0
Value (*1,000 dollars*)	4,538,966	5,157,668	8,145,372	10,602,926	133.6

[1] Data understated because not all producers were able to provide shipment quantities.
[2] Unit values based only on responses that provided both value and quantities in the indicated year.

Source: Compiled from data submitted in response to U.S. International Trade Commission questionnaire.

The average size of a U.S. ethanol plant has been increasing; however, plant size varies by type of ownership. The average capacity of farmer-owned plants was 40 million gallons per year in 2008, as compared with 66 million gallons per year for other plants.[7] Single-plant operations accounted for 82 percent of ethanol production capacity in 2007,[8] and new entrants tend to be single-plant firms.[9] About two-thirds of U.S. ethanol production capacity was accounted for by nonfarmer companies as of January 2008; the remainder was held by farmer-owned cooperatives. Prior to 2007, farmer-owned cooperatives' share of total capacity had been increasing. The increase in nonfarmer companies' capacity share in 2007 and 2008 largely reflects a broadening of participant types and capital sources.

[5] FTC, *2007 Report on Ethanol Market Concentration*, undated (accessed March 21, 2008), 14 and 17. The Herfindahl-Hirschman Index, based on individual producers' capacity, declined from 0.499 in 2005 to 0.292 in 2007. FTC, *2005 Report on Ethanol Market Concentration*, December 1, 2005, 13; FTC, *2006 Report on Ethanol Market Concentration*, December 1, 2006, 11; and FTC, *2007 Report on Ethanol Market Concentration*, undated, 16.
[6] RFA, *Changing the Climate*, February 2008, 4.
[7] Calculated by Commission staff using data from RFA, *Industry Statistics, 2005*, undated (accessed March 27, 2008).
[8] Lauritzen, "Consolidation & Strategic Alternatives for Ethanol Producers," May 10, 2007, 14.
[9] Ibid., 15.

Ethanol shipments expanded from 2004 through 2007, largely owing to state MTBE bans,[10] the initial imposition of the RFS in 2005,[11] and the expansion of the RFS in 2007.[12] Shipments of ethanol, the bulk of which were corn ethanol, increased by 76 percent in quantity and 134 percent in value from 2004 through 2007.[13] According to the USDOE, the quantity of ethanol produced in the United States increased from 3.4 billion gallons in 2004 to 6.5 billion gallons in 2007, or by 91 percent.[14] The average unit value for corn ethanol increased from 2004 though 2006 because demand increased more rapidly than production capacity and import supplies; the average unit value declined in 2007, when additional production capacity came onstream.

The U.S. industry reported capacity expansion plans for the 2007–09[15] period totaling 3.7 billion gallons per year in 50 new plants, and published sources report U.S. ethanol industry capacity expansion plans of 5.5 billion gallons per year as of February 2008.[16] However, a number of firms have recently announced that they will delay or cancel plans to expand capacity or build new capacity, mainly in response to the rapid expansion in recent years that has resulted in an excess of ethanol production and falling prices, and escalating corn costs. A recent estimate puts the amount of expanded capacity that is currently being delayed or cancelled at approximately 1.3 billion gallons per year.[17]

Biodiesel

The number of U.S. biodiesel producers increased by more than 400 percent from 2004 to 2007 (table 2-4). Firms also increased their production considerably; average biodiesel production from virgin feedstocks (the most common feedstock in the United States is soy) per firm increased from a mean of 1.9 million gallons in 2004 to 5.8 million gallons in 2007. The increase in average production per firm was lower for firms making biodiesel from recycled oils (mostly used cooking oil). The National Biodiesel Board estimated that the total biodiesel production capacity in the United States, as of January 2008, was 2.2 billion gallons from 171 plants.[18] Although biodiesel production is spread throughout the United States, with production facilities in 41 of 50 states,[19] most production occurs in the Midwest, Southeast, and the state of Texas. Texas has the largest number of production facilities at 22.[20]

---

[10] The largest impact was caused by the MTBE bans in California, New York, and Connecticut, which became effective January 1, 2004. USDOE, EIA, "Status and Impact of State MTBE Bans," March 27, 2003.

[11] Energy Policy Act of 2005, Pub. L. No. 109-058, § 1501.

[12] Energy Security and Independence Act of 2007, Pub. L. No. 110-140, § 202.

[13] The quantity of shipments reported in 2007 represented 82 percent of U.S. production that year.

[14] USDOE, EIA, "U.S. Fuel Ethanol Oxygenate Production at Oxy Plant," February 29, 2008.

[15] Commission questionnaires were submitted by respondents in October 2007, so the expansion plan period began in late 2007.

[16] RFA, *Changing the Climate*, February 2008.

[17] *Ethanol & Biodiesel News*, "Special Report: Capacity Glut Crimps New Ethanol Plants," February 19, 2008.

[18] NBB, "Commercial Biodiesel Production Plants," January 25, 2008.

[19] Ibid.

[20] Ibid.

TABLE 2-4
Biodiesel: Respondent U.S. producers' structure and shipments, 2004–07

Item	2004	2005	2006	2007	2004/07 percent change
Number of biodiesel producers:[1]					
Using recycled raw material	7	10	14	25	257.1
Using virgin raw material	12	18	43	82	583.3
Shipments:					
From recycled raw material:					
Quantity (*1,000 gallons*)[2]	9,598	12,094	10,466	15,710	63.7
Value (*1,000 dollars*)	8,456	12,786	18,205	33,698	298.5
Unit value (*dollars per gallon*)[3]	.98	1.41	1.74	2.14	118.1
From virgin raw material:					
Quantity (*1,000 gallons*)[2]	22,381	94,266	247,693	479,684	2,043.3
Value (*1,000 dollars*)	32,652	190,803	422,998	1,034,628	3,068.7
Unit value (*dollars per gallon*)[3]	2.15	2.63	2.39	2.49	16.0
Total:					
Quantity (*1,000 gallons*)[2]	31,979	106,360	258,159	495,394	1,449.1
Value (*1,000 dollars*)	41,108	203,589	441,203	1,068,326	2,498.8

[1] The number of producers includes only companies that reported sales or shipments during the year. Companies that sold or shipped more than one type of bio-based product are included in each category, except for totals.
[2] Data understated because not all producers were able to provide shipment quantities.
[3] Unit values based only on responses that provided both value and quantities in the indicated year.

Source: Compiled from data submitted in response to U.S. International Trade Commission questionnaire.

The RFS and blenders' tax credit[21] contributed to the increase of well over 1,000 percent in biodiesel shipments during the 2004–07 period to 495.4 million gallons. Most of the increase in biodiesel shipments came from firms making biodiesel from virgin feedstocks as opposed to recycled feedstocks, possibly because of the larger value of the excise tax credit for biodiesel from virgin feedstocks versus recycled feedstocks.[22] The weighted average unit value for all biodiesel shipments increased from $1.29 per gallon in 2004 to $2.16 per gallon in 2007;[23] reported spot prices were higher still.[24]

Over 40 biodiesel plants with a combined capacity of 884 million gallons are expected to come onstream by 2009, according to Commission questionnaire responses. Twenty-five of these plants will use virgin feedstocks and have a combined capacity of 802.5 million gallons. Seventeen plants currently under construction will produce biodiesel from recycled raw materials and will have a combined capacity of 81.7 million gallons.

[21] A federal tax credit for biodiesel was included in the American Jobs Creation Act of 2004. This act allowed fuel blenders to claim a tax credit for each gallon of biodiesel blended with petroleum diesel; the credit is $1 per gallon for biodiesel from agricultural commodities such as soybean oil and $0.50 per gallon for biodiesel from recycled oils. EPAct 2005 extended this excise tax credit and introduced a producers' credit for small biodiesel producers using virgin feedstocks. USDOE, EIA, "American Jobs Creation Act of 2004," 2005; and USDOE, EERE, "Energy Policy Act of 2005," January 24, 2008.
[22] NBB, "Commercial Biodiesel Production Plants," January 25, 2008.
[23] Average unit values were calculated only from data of respondents that reported both value and quantity of biodiesel shipments for a given year.
[24] FAPRI, *2008 US Baseline Briefing Book*, March 2008; and Carriquiry and Babcock, "A Billion Gallons of Biodiesel," Winter 2008. FAPRI reported a projected rack price for biodiesel of $3.84 per gallon for the period October 2007 through September 2008; Carriquiry and Babcock reported an average biodiesel price in Iowa for the week ending on January 11, 2008, of $4.20 per gallon.

Bio-based Chemicals

The bio-based chemical industry also expanded during the 2004–07 period, reflecting the sector's continued utilization of IB and its increasing commitment to green chemistry.[25] But its rate of expansion as expressed in the number of producers, establishments, sales, and employment was much less pronounced than that of the liquid biofuel industry (tables 2-5 and 2-6). Bio-based chemical sales as a share of total chemical sales decreased slightly, from 14 percent to 13 percent during the 2004–07 period.

This comparatively slower growth is likely the result of the industry receiving substantially less government support. There are few, if any, tax incentives and mandatory use regulations that target the industry.[26] In addition, the industry is more mature than the liquid biofuels industry; biocatalysis and renewable resources have been used by chemical producers for decades.

Pharmaceuticals

The bio-based chemical industry is dominated by the pharmaceutical sector, even though the number of producers and establishments in this sector is substantially less than the number producing other bio-based chemicals. Pharmaceutical companies accounted for almost 79 percent of total bio-based chemical sales in 2007. Pharmaceutical companies' bio-based sales as a share of total pharmaceutical sales are approximately 33 percent, which is significantly higher than for any other chemical sector, reflecting the biological nature of producing many drugs such as vaccines and antibiotics, and the sector's increasing use of evolving bioprocesses.

The majority of the sector's bio-based chemical shipments during the period were accounted for by products derived using biocatalysis, and the value of such shipments increased steadily from 2004 through 2007. Biocatalysis has been part of the pharmaceutical production process for decades. For example, most vitamin B_2 production was converted to a biocatalytic process in the 1980s. Furthermore, many bio-based pharmaceuticals are the result of chemical processes that are now being redesigned to integrate biocatalysis. The production capacity of bio-based pharmaceuticals is expected to expand during the 2008–11 period as six new plants come onstream.

---

[25] Green chemistry is the design of chemical processes and products to decrease or eliminate the consumption or generation of toxic and hazardous substances.

[26] Several U.S. cities have adopted mandatory use of bio-based plastics for certain limited applications.

TABLE 2-5
Chemicals: Respondent U.S. producers' structure, 2004–07

Item	2004	2005	2006	2007	2004/07 percent change
Number of producers:					
All chemicals:					
Pharmaceuticals	35	35	35	34	-2.9
All other	129	131	135	138	7.0
Total	164	166	170	172	4.9
Bio-based chemicals:[1]					
Enzymes and micro-organisms	6	6	8	6	0.0
Biocatalysis chemicals:[2]					
Commodity chemicals	4	5	4	5	25.0
Specialty chemicals	6	6	6	7	16.7
Chemical intermediates	4	4	5	6	50.0
Polymers	3	3	3	3	0.0
Pharmaceuticals	12	12	15	14	16.7
Food additives and ingredients	5	5	5	5	0.0
Flavors and fragrances	3	5	5	5	66.7
Other chemicals	4	4	5	6	50.0
Other chemicals produced using renewable resources:					
Commodity chemicals	14	14	15	16	14.3
Specialty chemicals	20	23	23	23	15.0
Chemical intermediates	6	7	8	8	33.3
Polymers	8	9	9	9	12.5
Pharmaceuticals	3	3	3	3	0.0
Food additives and ingredients	7	7	7	6	-14.3
Flavors and fragrances	7	7	7	7	0.0
Other chemicals	4	4	4	5	25.0
Total[3]	72	78	83	82	13.9
Number of bio-based chemical production establishments:[4]					
Pharmaceuticals	29	29	29	30	3.4
All other	127	155	158	159	25.2

[1] The number of producers includes only companies that reported sales or shipments during the year. Companies that sold or shipped more than one type of bio-based product are included in each category, except for totals.
[2] Includes products made using fermentation or micro-organisms.
[3] Total does not equal sum of above because some producers produce more than one type of bio-based product.
[4] Includes establishments that produced both liquid biofuels and bio-based chemicals.

Source: Compiled from data submitted in response to U.S. International Trade Commission questionnaire.

TABLE 2-6
Chemicals: Respondent U.S. producers' sales, shipments, and employment, 2004–07

Item	2004	2005	2006	2007	2004/07 percent change
	Value (*1,000 dollars*)				
Sales of U.S.-produced products:					
Conventional chemicals:					
Pharmaceutical companies	45,904,647	46,362,734	47,371,362	48,252,490	5.1
All other companies	117,632,858	135,450,482	153,868,877	158,163,226	34.5
Total	163,537,505	181,813,216	201,240,239	206,415,716	26.2
Bio-based chemicals:					
Pharmaceutical companies	21,234,419	23,208,103	24,457,206	23,622,484	11.2
All other companies	5,646,767	5,601,451	5,914,778	6,321,909	12.0
Total	26,881,186	28,809,554	30,371,984	29,944,393	11.4
Byproducts	([1])	([1])	([1])	([1])	146.0
Bio-based chemical shipments:					
Pharmaceutical companies	16,805,664	18,704,161	19,829,563	19,495,629	16.0
All other companies:					
Biocatalysis chemicals and enzymes/micro-organisms	2,389,302	2,314,535	2,412,542	2,544,755	6.5
Other chemicals produced using renewable resources:					
Commodity chemicals	1,128,325	1,199,290	1,281,978	1,290,039	14.3
Specialty chemicals	1,114,452	1,404,678	1,463,152	1,573,777	41.2
Food additives and ingredients	132,435	158,936	145,231	117,681	-11.1
All other	934,423	933,011	1,108,640	1,265,094	35.4
Total	3,309,635	3,695,915	3,999,001	4,246,591	28.3
Total, all other companies	5,698,937	6,010,450	6,411,543	6,791,346	19.2
	Number of employees (*FTE*)				
Employment:					
Conventional chemicals:					
Pharmaceutical companies	22,872	21,573	18,018	16,649	-27.2
All other companies	101,829	104,044	103,906	101,840	([2])
Bio-based chemicals:					
Pharmaceutical companies	11,288	11,826	12,639	12,253	8.5
All other companies	5,633	5,659	5,654	5,717	1.5

[1] Data withheld to avoid disclosure of confidential business information.
[2] Less than 0.5 percent.

Source: Compiled from data submitted in response to U.S. International Trade Commission questionnaire.

Other Bio-based Chemicals

The number of U.S. producers in the nonpharmaceutical bio-based chemical sector (herein referred to as the bio-based chemical sector) increased by a small amount from 2004 through 2007, although the number of establishments increased by over 25 percent.[27] The increased number of establishments likely indicates increased use of IB stemming from efforts by companies within the sector to expand sustainable production practices and to boost traditionally narrow margins for some product groupings.

Shipments of nonpharmaceutical bio-based chemicals rose steadily during the period, increasing by over 19 percent by value. Most bio-based chemicals were manufactured using renewable resources without biocatalytic processing. Commodity chemicals and specialty chemicals combined accounted for about two-thirds of the annual output derived from renewable resources. Bio-based polymers accounted for most of the remainder. Questionnaire responses indicate the quantity of shipments increased only marginally, which is consistent with the sector's relatively small increase in employment. The sector's overall bio-based production capacity will expand by 184 million pounds by the end of 2008, as eight production facilities come onstream.

However, despite the increase in bio-based chemical sales, these products' share of total chemical sales declined from 5 percent to 4 percent from 2004 to 2007. This likely reflects increasing prices for conventional chemicals as a result of the increased cost of crude petroleum, the main raw material for many of these chemicals.

Trade[28]

Total trade in liquid biofuels and bio-based chemicals reported by questionnaire respondents increased during the 2004–07 period; U.S. imports including agricultural feedstocks increased by 35 percent, and U.S. exports increased by 17 percent.[29] Higher trade volumes largely reflect the increasing globalization of supply chains (box 2-1). Strong U.S. demand for ethanol and increased related-party trade in bio-based chemicals accounted for a large share of the increase in trade. Relatively few respondents cited trade issues such as foreign market tariffs and other foreign market barriers as significant commercialization impediments.

[27] An establishment is a single physical production or R&D location.

[28] Trade values based on Commission questionnaire responses shown in this section are likely understated as compared with actual trade because they do not include imports and exports by other types of organizations such as wholesalers and distributors.

[29] This percentage change is understated, as liquid biofuel export data were withheld in 2004 to avoid disclosure of confidential business information.

BOX 2-1 The globalization of supply chains

Global supply chains allow liquid biofuels and bio-based chemicals firms to reduce costs and diversify risks by sourcing their inputs in countries with different research capacities, technologies, regulatory structures, or factor costs. The availability of global alliances provides firms with a larger and more diverse pool of partners that share their interests and complement or augment their technical skills, and also provides access to new markets. IB firms can form strategic alliances with foreign partners to customize and coordinate approaches to consumers in different countries and respond to demands for faster innovation and more specialized niche products.

However, globalization requires the ability to manage the added complexity of cross-border relationships. Alliances with foreign organizations involve additional challenges of managing language and cultural barriers, intellectual property laws, exchange rates, host country foreign policies, and 24-hour schedules. In addition, the involvement of multiple intermediaries in multiple countries can lengthen supply chains and make them more complex. Pressured to minimize delivery lead times, firms try to increase the speed of their supply chains even as they are spread across an increasing number of countries. Successful IB firms can overcome these challenges by effectively coordinating information flows among their global partners and ensuring that the incentives of supply chain intermediaries are coordinated.

Sources: OECD, Directorate for Science, Technology and Industry, Committee for Scientific and Technological Policy, Working Party on Biotechnology, Task Force on Biotechnology for Sustainable Industrial Development, *Globalisation of Industrial Biotechnology R&D*, February 14, 2008, 10–20; and Krivda, "The Global Supply Chain," 2005.

U.S. Imports

U.S. imports of liquid biofuels increased significantly during the 2004–07 period, by more than 375 percent, to surpass $470 million (table 2-7). Ethanol accounts for most liquid biofuel imports; state MTBE bans and the RFS standard contributed to increased overall demand for ethanol and hence increased U.S. imports. The United States is the world's leading importer of ethanol, accounting for 30 percent of the quantity of total global imports in 2007;[30] however, imports accounted for a small share of the U.S. market, approximately 7 percent in 2007.[31] U.S. imports of fuel ethanol grew from 164 million gallons, valued at $621 million, in 2004 to 441 million gallons, valued at $1.7 billion, in 2007.[32]

[30] LMC International, *Ethanol Quarterly*, December 2007, 19. Data are for nonbeverage ethanol.
[31] Ibid., 23.
[32] Compiled from official statistics of the U.S. Department of Commerce.

TABLE 2-7
Trade: Respondent U.S. producers' U.S. exports and imports, 2004–07
(*1,000 dollars*)

Item	2004	2005	2006	2007	2004/07 percent change
Exports:					
Liquid biofuels	([1])	([1])	22,577	218,463	([1])
Bio-based chemicals:					
Pharmaceutical companies	3,857,839	4,433,970	4,863,583	4,609,396	19.5
All other companies	1,061,846	1,071,997	1,116,006	1,150,920	8.4
Total, bio-based chemicals	4,919,685	5,505,967	5,979,589	5,760,316	17.1
Imports:					
Agricultural feedstocks:					
For use in liquid biofuel production	0	([1])	0	([1])	([2])
For use in bio-based chemical production	175,883	141,849	162,145	242,890	38.1
Liquid fuels:					
Ethanol	98,805	126,122	1,134,925	470,101	375.8
Biodiesel	0	0	0	([1])	([2])
Bio-based chemicals:					
Pharmaceutical companies	275,753	246,881	239,037	279,952	1.5
All other companies:					
Enzymes and micro-organisms	137,043	139,574	155,353	151,752	10.7
Commodity chemicals	34,138	43,142	35,602	49,441	44.8
Specialty chemicals	64,398	61,249	70,543	75,131	16.7
Flavors and fragrances	9,855	10,861	11,507	12,622	28.1
All other bio-based chemicals	438,111	450,790	393,683	385,146	-12.1
Total, bio-based chemicals	959,298	952,497	905,725	954,044	-0.5

[1] Data withheld to avoid disclosure of confidential business information.
[2] Not applicable.

Source: Compiled from data submitted in response to U.S. International Trade Commission questionnaire.

Although the U.S. tariff treatment of ethanol affects the level and sources of fuel ethanol imports (box 2-2), recent domestic and global market developments and the use of duty drawbacks[33] are moderating these effects, particularly for fuel ethanol. The bulk of U.S.

[33] U.S. importers of fuel ethanol have been eligible to receive duty drawbacks in the following manner. Duty drawback regulations specify that supplies used by vessels traveling overseas are considered to be "deemed exports." Thus, jet fuel sold by firms to private airlines and the military and subsequently used on overseas flights can be claimed as exports to be used in duty drawback claims. The link between deemed exports of jet fuel and imports of pure fuel ethanol has been established through a combination of explicit duty drawback provisions and administrative rulings by U.S. Customs and Border Protection (CBP). First, the substitution drawback provisions generally allow for duty drawbacks if the imported merchandise is of the "same kind and quality" as the final manufactured exported product. More specifically, the petroleum derivatives provisions of the drawback regulations establish a specific link between HTS subheadings at the 8-digit level. Under these provisions, "qualified articles," which are specified, and other articles sharing an 8-digit HTS subheading, are eligible for duty drawbacks. Certain jet fuel and gasoline blends (including those containing ethanol) are both classified in HTS subheading 2710.11.15. A series of CBP rulings established the commercial interchangeability between gasoline/ethanol blends and pure fuel ethanol. Data are not available on the amount of fuel ethanol imports that have benefitted from duty drawbacks. Recent legislation has amended the drawback regulations and essentially eliminated this practice (Food, Conservation, and Energy Act of 2008, Pub. L. No. 110-246, § 15334, 122 Stat. 1651). Exported products claiming a drawback based on ethanol imports must now contain ethanol.

imports traditionally have been from beneficiary countries under the Caribbean Basin Economic Recovery Act (CBERA). However, increased U.S. demand for ethanol led to increased imports from non-CBERA sources, principally Brazil, despite the substantial additional duty applicable to imports of ethanol for fuel use.

BOX 2-2 U.S. tariff treatment for ethanol

Tariff rates for fuel ethanol.–U.S. duties on imports of fuel ethanol vary by product form. U.S. imports of undenatured fuel ethanol are classifiable under Harmonized Tariff Schedule of the United States (HTS) subheading 2207.10.60, at a column 1 (NTR) duty rate of 2.5 percent ad valorem.[1] U.S. imports of denatured fuel ethanol are classifiable under HTS subheading 2207.20.00 at an NTR duty rate of 1.9 percent ad valorem. Duty-free treatment is provided under both HTS subheadings to U.S. imports under various preferential trading arrangements and free trade agreements. These duty rates apply to imports of fuel ethanol wholly produced in the source country, using indigenous feedstocks.

Additional duty specified in HTS 9901.00.50.–In addition to the above duties, imports of fuel ethanol are subject to a duty specified in HTS subheading 9901.00.50, which is temporary and is due to expire on January 1, 2009. The duty, $0.1427 per liter ($0.54 per gallon), applies not only to fuel ethanol but to fuel mixtures containing ethanol. The duty is not applicable to imports under certain preferential trade arrangements and free trade agreements. As is the case with the tariff treatment in chapter 22, this tariff treatment applies to imports of fuel ethanol wholly produced in the source country, using indigenous feedstocks. This duty is in a category referred to as “other duties or charges” (ODCs) and as such there is no obligation to reduce it pursuant to any World Trade Organization (WTO) agreement. However, ODCs are bound under the WTO Uruguay Agreement. The purpose of this additional duty on U.S. imports of fuel ethanol is to counter the domestic volumetric ethanol excise tax credit (VEETC). The VEETC is provided to U.S. ethanol blenders, not producers. As blenders may use ethanol from domestic and imported sources, the additional duty was designed to deny the benefit of the VEETC to foreign ethanol producers exporting to the U.S. market.

Preferential duty treatment for insular possessions and CBERA beneficiaries.–Section 423 of the Tax Reform Act of 1986, as amended (19 U.S.C. 2703 note), provides for duty-free U.S. imports of ethyl alcohol (ethanol) from U.S. insular possessions and CBERA-beneficiary countries under a special provision pertaining to local feedstock requirements. Under this provision, hydrous ethanol is imported by beneficiary countries, dehydrated, and exported as anhydrous ethanol to the United States. An amount equal to 7 percent of U.S. consumption may be imported free of duty without the requirement of using local feedstocks. An additional 35 million gallons may be imported free of duty subject to a local feedstock requirement of at least 30 percent, and an unlimited amount may be imported free of duty subject to a requirement of at least 50 percent local feedstocks. The quota is first come first served, except that El Salvador is provided a guaranteed amount under the Dominican Republic-Central America-United States Free Trade Agreement. In 2008, the quota is 452.5 million gallons. Although U.S. imports under the provision have increased substantially, particularly from 2001 to 2007, the quota has never been filled. In 2007, the quantity of U.S. ethanol imports entering duty free under the quota was 247.9 million gallons, or 71 percent of total U.S. ethanol imports.

---

[1] Chemicals, usually toxic substances, are used to denature ethanol and make it unfit for human consumption.

Sources: USITC, Harmonized Tariff Schedule of the United States (2008) Revision 1, 2008, 22–9 and 99–I–3; WTO, “Understanding on the Interpretation of Article II:1(b),” undated (accessed March 21, 2008); Yacobucci and Womach, *Fuel Ethanol*, 2004, 17; Energy Policy Act of 2005, Pub. L. No. 109-58, § 1501, 119 Stat. 1069 (2005); and Energy Independence and Security Act of 2007, Pub. L. No. 110-140, § 202.

With respect to biodiesel, industry sources stated that there were imports during the 2004–07 period, and such imports were reportedly "minimal in value" in 2004 and 2005.[34] Respondents reported biodiesel imports for 2007 only.[35] Argentina, Brazil, and Singapore were the leading sources of biodiesel imports.

In contrast with liquid biofuels, U.S. imports of bio-based chemicals did not vary to a great extent, declining by less than 1 percent, during the 2004–07 period. Bio-based pharmaceuticals accounted for the majority of the total; U.S. imports of bio-based products by the pharmaceutical sector fell from 2004 through 2006 before rebounding in 2007 for a gain of 2 percent for the period. This trend is likely attributable to related-party trade, as many pharmaceutical companies have globalized production facilities.

Bio-based chemical producers increased their imports of agricultural feedstocks by 38 percent during the 2004–07 period. Industry sources indicate that palm oil and related oil imports from indigenous producers such as Malaysia and Indonesia contributed to the total. These and other imports in this category were used to produce chemicals generally intended for use in personal care products, detergents, and cleaners.[36] In contrast, most U.S. liquid biofuel firms currently use domestically produced corn and soybeans as their main input.

U.S. Exports

U.S. exports of liquid biofuels increased significantly from 2004 through 2007, largely due to ethanol exports. U.S. exports of nonbeverage ethanol, most of which is nonfuel ethanol,[37] increased from 47.2 million gallons, valued at $80.7 million, in 2004 to 149.5 million gallons, valued at $356.8 million, in 2007.[38] Canada was the leading export market, accounting for 79 percent of the quantity and 70 percent of the value in 2007. The EU-27 was a distant second. Industry sources state that there were biodiesel exports during the 2004–07 period, but such exports in 2004 and 2005 were described as "minimal in value."[39]

U.S. exports of bio-based chemicals increased by 17 percent during the 2004–07 period, largely attributable to increased demand spurred by related-party trade and lower prices due to the decline in the value of the dollar.[40] Exports of bio-based products by pharmaceutical companies, which accounted for 80 percent of total exports of bio-based chemicals, rose by nearly 20 percent in the period.

---

[34] Industry official, telephone interview by Commission staff, May 5, 2008.
[35] The amount is withheld to avoid disclosure of confidential business information.
[36] Industry officials, telephone interviews by Commission staff and e-mail messages to Commission staff, May 14, 2008.
[37] Port Import Export Reporting Service, PIERS Database; and industry representatives, telephone interview by Commission staff, May 5, 2008. Nonfuel ethanol is used in the manufacture of products such as beverages, solvents, personal care products, pharmaceuticals, and inks.
[38] Compiled from official statistics of the U.S. Department of Commerce.
[39] Industry official, telephone interview by Commission staff, May 5, 2008.
[40] The dollar continued to decline significantly in value versus most major currencies in 2008.

Financial Performance

The financial performance of liquid biofuel and bio-based chemical producers was relatively flat during the 2004–07 period. Operating income as a share of total net sales was overwhelmingly influenced by rising agricultural feedstock costs, although less so for bio-based chemical companies, as such feedstocks account for a smaller portion of their raw materials.[41]

Feedstock Costs

Questionnaire respondents indicated that the price of feedstocks is the most important competitive factor or most significant impediment affecting their operations. Feedstock prices increased substantially during the 2006–07 period as a result of factors such as the increasing global consumption of food, especially in Asia; poor weather patterns in crop growing regions of the world; and increased feedstock consumption by liquid biofuel producers.[42] For ethanol producers, net feedstock costs and total variable operating costs more than doubled since 2002 (table 2-8); for biodiesel producers, net feedstock costs rose by 85 percent and total variable operating costs rose by over 70 percent from 2006 to January 2008 (table 2-9). Although similar cost data are not available for bio-based chemical products, some of these products are made using agricultural feedstocks. For more information on agricultural feedstock costs and liquid biofuel prices, see chapter 3.

TABLE 2-8
Ethanol: Production costs and related data, 2002 and estimate as of March 2008

Item	USDA 2002 survey[1]	Estimate as of March 2008[2]
Corn cost (*dollars per bushel*)	2.20–2.25	4.90–5.00
Ethanol yield (*gallons per bushel*)	2.66	2.75–2.80
Production costs (*dollars per gallon of ethanol*):		
Average feedstock cost	0.80	1.78
Byproduct cost recovery	-0.26	-0.40
Net feedstock costs	0.54	1.38
Other cash operating expenses[3]	0.41	0.65
Total variable operating costs	0.95	2.03

[1] Shapouri and Gallagher, *USDA's 2002 Ethanol Cost-of-Production Survey*, July 2005, 4–6.
[2] H. Shapouri, USDA Office of Energy Policy and New Uses, interview by Commission staff, March 26, 2008.
[3] Includes fuels (electricity and natural gas), enzymes, chemicals, denaturant gasoline, maintenance, labor, and administrative costs.

Source: See table footnotes.

[41] Operating income is total net sales minus the costs of goods sold and selling, general, and administrative costs.
[42] Walt, "The World's Growing Food-Price Crisis," February 28, 2007; and Rosenwald, "The Rising Tide of Corn," June 15, 2007.

TABLE 2-9
Biodiesel (virgin): Production costs and related data, 2006–08

Item	2006[1]	2007[2]	January 2008[3]
Soybean oil cost (*dollars per pound*)	0.26	0.33	0.49
Conversion ratio (*pounds of soybean oil to one gallon of virgin biodiesel*)	7.48	7.50	7.60
Production costs (*dollars per gallon of virgin biodiesel*):			
Average feedstock cost	1.95	2.48	3.69
Byproduct cost recovery	([4])	-0.08	-0.08
Net feedstock costs	1.95	2.40	3.61
Other variable operating expenses[5]	0.50	0.42	0.59
Total variable operating costs	2.45	2.82	4.20

[1] Collins, Office of the Chief Economist, USDA, statement before the U.S. Senate Committee on Environment and Public Works, September 6, 2006, 11.
[2] Paulson and Ginder, "The Growth and Direction of the Biodiesel Industry in the United States," May 2007, 11 and 22.
[3] Carriquiry and Babcock, *A Billion Gallons of Biodiesel,* Winter 2008, 6–7.
[4] Not specified. No byproduct cost recovery used in the report.
[5] Includes catalyst, alcohol, electricity, fuel, labor, plant administration, supplies, maintenance, selling, general and administrative expenses, etc.

Source: See table footnotes.

Results of Operations

Liquid Fuel Industry

The ratio of operating income to total net sales for corn ethanol producers was substantially higher than for conventional liquid fuel producers during the 2004–07 period, but decreased in 2007, likely as a result of higher corn costs (table 2-10). Byproduct sales, such as animal feeds, significantly improved corn ethanol producers' results of operations. The ratio of operating income to total net sales for virgin biodiesel producers was very low for most years during the 2004–07 period, likely a result of increasing soybean oil costs. In addition, byproduct sales in value terms declined because prices for glycerin (the primary biodiesel byproduct) fell during the period. For biofuel producers, the average annual wage and salary costs per employee during the 2004–07 period were approximately $59,000, compared with $110,000 for conventional liquid fuel producers.[43] This difference is likely due to the more rural location of production plants in the biofuel industry.

[43] Based on questionnaire responses for companies that were able to provide both the number of employees on a full-time equivalent basis and corresponding total wages and salaries for these employees.

TABLE 2-10
Liquid fuels: Selected financial data for respondents' operations, 2004–07

Item	2004	2005	2006	2007	2004/07 percent change
Conventional fuel producers:					
Total net sales (*1,000 dollars*)	395,794,193	535,832,352	600,342,529	632,120,693	59.7
Operating costs (*1,000 dollars*)	359,321,304	484,954,737	538,213,132	564,118,588	57.0
Operating income (*1,000 dollars*)	**36,472,889**	**50,877,615**	**62,129,397**	**68,002,105**	**86.4**
Ratios (*percent*):					
Operating cost to total net sales	91	91	90	89	-1.7
Operating income to total net sales	9	9	10	11	16.7
Respondents reporting (*number*):					
Operating gains	32	33	34	35	([1])
Operating losses	1	0	1	1	([1])
Corn ethanol producers:					
Total net sales (*1,000 dollars*)	1,425,212	1,786,294	3,274,252	4,432,646	211.0
Operating costs (*1,000 dollars*)	1,158,085	1,386,223	2,044,434	3,537,215	205.4
Operating income (*1,000 dollars*)	**267,127**	**400,071**	**1,229,818**	**895,431**	**235.2**
Byproduct sales (*1,000 dollars*)	294,636	289,315	434,516	772,672	162.2
Operating income including byproducts (*1,000 dollars*)	561,763	689,386	1,664,334	1,668,103	196.9
Ratios (*percent*):					
Operating costs to total net sales:					
Without byproducts	81	78	62	80	-1.8
Including byproducts	61	61	49	62	2.9
Operating income to total net sales:					
Without byproducts	19	22	38	20	7.8
Including byproducts	39	39	51	38	-4.5
Respondents reporting (*number*):					
Operating gains	23	27	35	45	([1])
Operating losses	2	3	0	1	([1])
Virgin biodiesel producers:					
Total net sales (*1,000 dollars*)	([2])	50,948	167,082	397,617	([2])
Operating costs (*1,000 dollars*)	([2])	39,880	170,005	396,961	([2])
Operating income (*1,000 dollars*)	**([2])**	**11,068**	**-2,923**	**657**	**([2])**
Byproduct sales (*1,000 dollars*)	([2])	4,262	9,484	10,392	([2])
Operating income including byproducts (*1,000 dollars*)	([2])	15,330	6,561	11,049	([2])
Ratios (*percent*):					
Operating costs to total net sales:					
Without byproducts	105	78	102	100	-5.1
Including byproducts	57	70	96	97	72.0
Operating income to total net sales:					
Without byproducts	-5	22	-2	0	([1])
Including byproducts	43	30	4	3	-93.6
Respondents reporting (*number*):					
Operating gains	2	5	17	30	([1])
Operating losses	2	2	11	19	([1])

[1] Not meaningful.
[2] Data withheld to avoid disclosure of confidential business information.

Note.—To isolate financial results, data for companies that produced only the indicated products are included. As a result, these sales will not equal sales shown in other sections of this report. Calculations based on unrounded data.

Source: Compiled from data submitted in response to U.S. International Trade Commission questionnaire.

Improved fermentation technology and improved corn seed have moderated somewhat the impact of corn cost increases for corn ethanol producers in recent years. Ethanol yield has increased from 2.66 gallons per bushel to about 2.75 gallons per bushel.[44] Although energy costs also increased sharply, energy-saving technologies have led to a decline in the input quantity of thermal and electrical energy used to produce ethanol.[45] Similarly, process automation and other production efficiency improvements have reduced labor costs.[46]

Several recent technological developments have reduced biodiesel production costs. Continuous-flow plants recapture co-products and reuse some of the inputs, but require a greater capital investment. Additionally, concurrent with the construction of plants with greater throughput, technological advances have increased yields and allow the use of multi-feedstock inputs. With multi-feedstock inputs, producers are able to take advantage of price differentials among feedstocks.[47]

Chemical Industry

The ratio of operating income to total net sales was roughly equivalent for conventional chemicals and nonpharmaceutical bio-based chemicals, but was much greater for bio-based pharmaceuticals, likely because many pharmaceuticals are high margin, differentiated products (table 2-11). The bio-based chemical sector is relatively less affected by agricultural feedstocks costs because many products, especially bio-based pharmaceuticals, do not use agricultural feedstocks.

Although the Commission's questionnaire did not specifically request cost breakouts within operating expenses (cost of good sold, and selling, general and administrative expenses, or SG&A), the American Chemistry Council's (ACC) *Guide to the Business of Chemistry 2007* provides limited information on average operating costs for the basic chemicals, specialty chemicals, pharmaceuticals, and chemical consumer product segments.[48] Feedstock costs and energy for basic chemicals accounted for about 62 percent of the value of total net sales.[49] For the other three industry segments, feedstock, energy, and other raw materials accounted for a much lower percentage of total net sales—25 to 35 percent. In these three segments,

---

[44] Shapouri and Gallagher, *USDA's 2002 Ethanol Cost-of-Production Survey*, July 2005, 2.

[45] The increase in energy costs (electricity and natural gas) was estimated at $0.10–$0.15 per gallon of ethanol from 2002 to 2006, but remained at that level in 2006–07. Collins, Office of the Chief Economist, USDA, statement before the U.S. Senate Committee on Environment and Public Works, September 6, 2006.

[46] Ibid.

[47] Carriquiry, "U.S. Biodiesel Production," Spring 2007, 9.

[48] Basic chemicals, specialty chemicals, pharmaceuticals, and chemical consumer product segments are analogous to the Commission's category of conventional chemicals referred to in this section of the report. However, these four segments do not include agricultural chemicals (fertilizer and plant protection chemicals) that are included in the Commission's category. According to the ACC, the costs of making fertilizers tend to reflect those of basic chemicals, and costs of making plant protection chemicals tend to reflect those of making pharmaceuticals. Swift, Myers Levi, and Gilchrist Moore, *Guide to the Business of Chemistry 2007*, 2007, 11. Although the data are for the year 2006, they represent a composite mean of several years. ACC staff, interview by Commission staff, March 10, 2008.

[49] Swift, Myers Levi, and Gilchrist Moore, *Guide to the Business of Chemistry 2007*, figure 2.1, 2007, 11. Feedstocks and other raw materials for conventional chemicals are petroleum liquids and natural gas used to make products as well as fuel for processing. Such costs are highly variable due to the underlying volatility of fuel prices. For example, prices of feedstocks rose by approximately 41 percent from 2004 to 2006 and the industry has undergone plant closures as well as efforts to improve efficiency in recent years because of high natural gas prices. Ibid., 13 and 108–111.

TABLE 2-11
Chemicals: Selected financial data for respondents' operations, 2004–07

Item	2004	2005	2006	2007	2004/07 percent change
Conventional chemical producers:					
Total net sales (*1,000 dollars*)	83,203,837	96,087,333	110,513,223	116,537,602	40.1
Operating costs (*1,000 dollars*)	75,856,287	85,084,384	97,559,322	100,041,237	31.9
Operating income (*1,000 dollars*)	**7,347,550**	**11,002,949**	**12,953,901**	**16,496,365**	**124.5**
Ratios (*percent*):					
Operating costs to total net sales	91	89	88	86	-5.8
Operating income to total net sales	9	11	12	14	60.3
Respondents reporting (*number*):					
Operating gains	72	76	79	87	([1])
Operating losses	15	12	12	6	([1])
Bio-based pharmaceutical producers:					
Total net sales	([2])	([2])	([2])	([2])	26.0
Operating costs (*1,000 dollars*)	([2])	([2])	([2])	([2])	25.7
Operating income (*1,000 dollars*)	**([2])**	**([2])**	**([2])**	**([2])**	**26.3**
Byproduct sales (*1,000 dollars*)	([2])	([2])	([2])	([2])	0.0
Operating income including byproducts (*1,000 dollars*)	([2])	([2])	([2])	([2])	26.3
Ratios (*percent*):					
Operating costs to total net sales:					
Without byproducts	49	48	46	49	-0.2
Including byproducts	49	48	46	49	-0.2
Operating income to total net sales:					
Without byproducts	51	52	54	51	0.2
Including byproducts	51	52	54	51	0.2
Respondents reporting (*number*):					
Operating gains	7	7	7	7	([1])
Operating losses	0	0	0	0	([1])
Bio-based chemical, except pharmaceutical, producers:					
Total net sales (*1,000 dollars*)	4,873,593	4,885,459	5,180,765	5,498,676	12.8
Operating costs (*1,000 dollars*)	4,360,677	4,358,738	4,626,431	4,927,812	13.0
Operating income (*1,000 dollars*)	**512,916**	**526,721**	**554,334**	**570,864**	**11.3**
Byproduct sales (*1,000 dollars*)	87,400	97,835	116,508	127,954	46.4
Operating income including byproducts (*1,000 dollars*)	600,316	624,556	670,842	698,818	16.4
Ratios (*percent*):					
Operating costs to total net sales:					
Without byproducts	89	89	89	90	0.2
Including byproducts	88	87	87	87	-0.4
Operating income to total net sales:					
Without byproducts	11	11	11	10	-1.4
Including byproducts	12	13	13	13	3.2
Respondents reporting (*number*):					
Operating gains	39	38	42	44	([1])
Operating losses	5	10	8	7	([1])

[1] Not meaningful.
[2] Data withheld to avoid disclosure of confidential business information.

Note.—To isolate financial results, data for companies that produced only the indicated products are included. As a result, these sales will not equal sales shown in other sections of this report. Calculations based on unrounded data.

Source: Compiled from data submitted in response to U.S. International Trade Commission questionnaire.

advertising and other SG&A expenses comprised a much larger share of total net sales, on the order of 50 percent in the case of consumer products and 20 and 25 percent for pharmaceuticals and specialty chemicals, respectively.[50]

The average annual wage and salary costs per employee during the 2004–07 period were approximately $88,000 for conventional chemical producers and $83,000 for nonpharmaceutical bio-based chemical producers.[51] However, the comparable average for employees of pharmaceutical producers engaged in bio-based chemical production was almost $119,000, likely reflecting a higher percentage of technical personnel in the production process.

R&D Expenditures and Employment

IB-related R&D expenditures increased strongly during the 2004–07 period, at a rate more than three times faster than the increase for conventional R&D spending (table 2-12). R&D spending focused on liquid biofuels rose even faster, although, in absolute terms, it constitutes a small share of total bio-based R&D expenditures. Government programs encouraging research, mandates imposed by EPAct 2005, other federal government policies, and various state mandates that require liquid biofuels to account for an increasing share of the U.S. fuel supply have all led to increased liquid biofuel R&D expenditures. There has been a particular focus on R&D aimed at commercializing cellulosic ethanol (see chapter 3 for more information). R&D in this area has been funded by private venture capitalists as well as a variety of federal and state government programs.[52] R&D efforts in bio-based chemicals have been spurred by consumer interest in environmentally friendly, biodegradable products such as bioplastics and industry interest in more efficient and sustainable manufacturing alternatives. However, unlike liquid biofuels, there are no significant government mandates and very few government programs encouraging the development of bio-based chemicals.[53]

A handful of pharmaceutical companies account for the overwhelming majority of R&D expenditures (table 2-13 and figure 2-2).[54] This reflects the research-intensive nature of pharmaceutical companies; the sector has traditionally reinvested 15–20 percent of annual revenues in R&D. Bio-based R&D expenditures by dedicated R&D firms more than doubled during the period, but these firms accounted for only a small share of total bio-based R&D spending. The bulk of dedicated R&D firms' funding comes from grant money or private investment sources such as venture capital firms; these sources provide less funding than is generally available to many large corporate producers of chemicals and agricultural products. Many liquid biofuel producers are small ethanol and biodiesel producers that perform little, if any, R&D for new products and processes.

---

[50] Ibid., 11.

[51] Based on questionnaire responses for companies that were able to provide both the number of employees on a full-time equivalent basis and corresponding total wages and salaries for these employees.

[52] For more information on these programs, see chap. 4.

[53] Industry representatives, interviews by Commission staff, Nebraska, May 24, 2007, and Washington, DC, March 20, 2007.

[54] The data for pharmaceutical companies are not provided separately to avoid revealing confidential business information.

TABLE 2-12
Research and development: Respondents' U.S. expenditures and employment, 2004–07

Item	2004	2005	2006	2007	2004/07 percent change
	Value (*1,000 dollars*)				
R&D expenditures:					
Conventional fuel and chemical products	19,757,219	21,896,370	24,395,866	24,177,792	22.4
Bio-based products:					
Liquid biofuel R&D	29,096	39,858	74,195	152,536	424.3
Bio-based chemical R&D	2,014,363	1,953,849	3,425,432	3,432,427	70.4
Liquid biofuel and bio-based chemical R&D[1]	160,061	167,072	189,490	204,089	27.5
Total	2,203,520	2,160,779	3,689,117	3,789,052	72.0
Grand total	21,960,739	24,057,149	28,084,983	27,966,844	27.3
	Number of employees (*FTE*)				
R&D employment:					
Conventional fuel and chemical products	61,520	62,732	65,396	60,885	-1.0
Bio-based products:					
Liquid biofuel R&D	164	209	324	561	242.1
Bio-based chemical R&D	5,819	6,386	7,424	7,584	30.3
Liquid biofuel and bio-based chemical R&D[1]	1,065	1,036	1,192	1,364	28.1
Total	7,048	7,631	8,940	9,509	34.9
Grand total	68,568	70,363	74,336	70,394	2.7

[1] This category used when respondents were unable to separate their liquid biofuel and bio-based chemical amounts.

Source: Compiled from data submitted in response to U.S. International Trade Commission questionnaire.

TABLE 2-13
Research and development: Respondents' U.S. expenditures and employment for their bio-based activities, by company groups, 2004–07

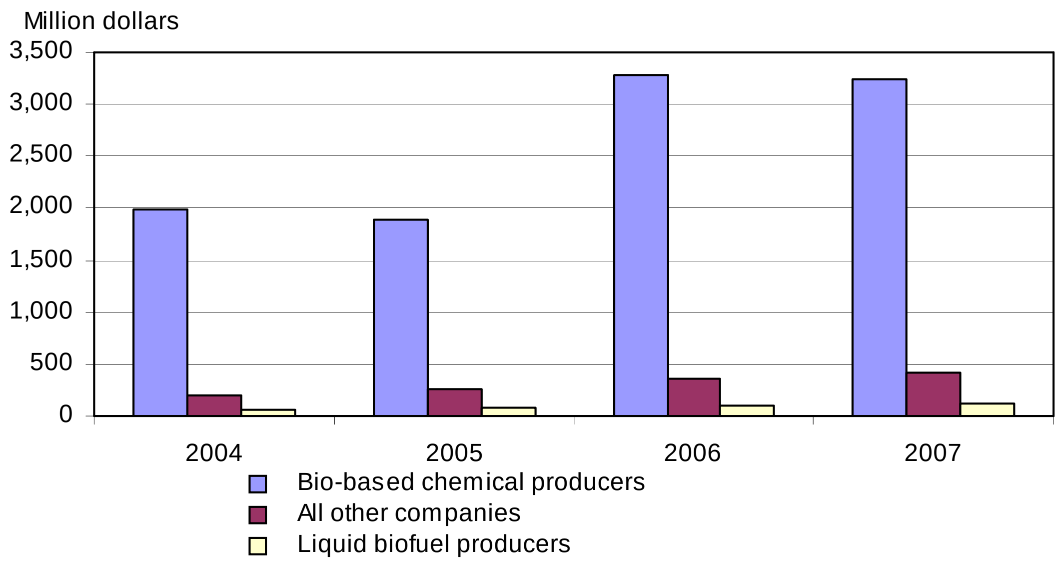
Item	2004	2005	2006	2007	2004/07 percent change
	Value (*1,000 dollars*)				
R&D expenditures:					
Liquid biofuel producers	64,860	71,402	102,019	127,179	96.1
Bio-based chemical producers[1]	1,988,601	1,889,467	3,281,730	3,235,052	62.7
Dedicated research and development companies:					
Pharmaceutical companies	116,650	165,028	253,859	272,786	133.8
All other companies	81,393	86,248	105,447	146,543	80.0
	Number of employees (*FTE*)				
R&D employment:					
Liquid biofuel producers	404	380	446	523	29.5
Bio-based chemical producers:					
Pharmaceutical producers	4,805	5,227	6,221	6,269	30.5
All other producers	847	805	836	920	8.6
Dedicated research and development companies:					
Pharmaceutical companies	766	890	1,017	1,065	39.0
All other companies	562	574	614	766	36.3

[1] Detailed company group data withheld to avoid disclosure of confidential business information.

Note.—Group data are not mutually exclusive in all cases. For example, some companies produce both liquid biofuels and bio-based chemicals, and are included in both groups. Ungrouped data, including totals, are shown in table 2-12.

Source: Compiled from data submitted in response to U.S. International Trade Commission questionnaire.

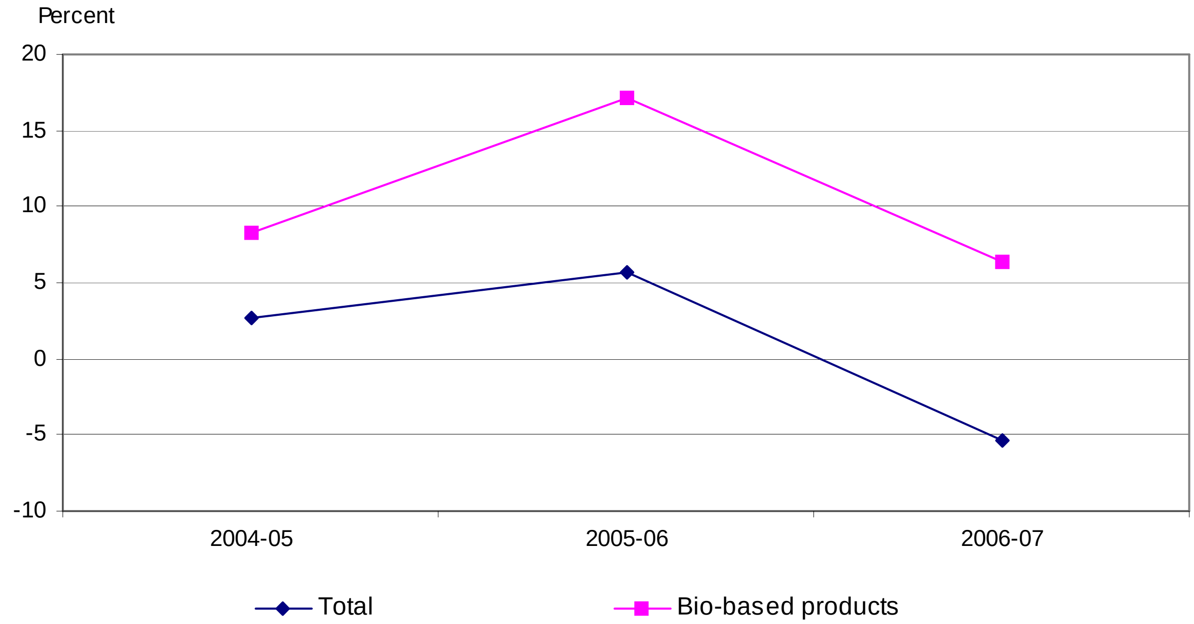
FIGURE 2-2
Research and development: Respondents' U.S. expenditures for their bio-based activities, by company groups, 2004–07



Source: Compiled from data submitted in response to U.S. International Trade Commission questionnaire.

Bio-based R&D employment increased in tandem with increased expenditures on bio-based R&D throughout the 2004–07 period. The employment growth rate for total R&D employment increased at a substantially slower rate between 2004 and 2006 as compared with the growth rate for bio-based R&D employment, although the growth rate for both decreased in 2007 (figure 2-3). Pharmaceutical companies (both producers and dedicated R&D firms) accounted for the largest share of bio-based R&D employment growth.

FIGURE 2-3
Research and development: Respondents' employment growth, 2004–07



Source: Compiled from data submitted in response to U.S. International Trade Commission questionnaire.

Government Funding

Based on Commission questionnaire responses, government grants for IB activities increased by 45 percent from 2004 through 2007 (table 2-14). This increase was a result of increased state grants, as federal government grants decreased by nearly 27 percent. However, the decline in federal funding is somewhat misleading, as the federal government provides funding to several different entities that were not within the scope of the Commission questionnaire, such as universities and national laboratories. These entities, like private companies, compete for federal funding. Furthermore, the majority of the data regarding grants was reported by ethanol producers. According to industry sources, government grants to these producers are declining because current ethanol production capacity exceeds the amount needed to meet the renewable fuels standard.[55] More information on federal grant programs is found in chapter 4.

[55] Industry official, telephone interview by Commission staff, March 22, 2008.

TABLE 2-14
Government grants: Respondents' receipts and matching funds, total and by selected company groups, 2004–07

(*1,000 dollars*)

Funding	2004	2005	2006	2007	2004/07 percent change
All companies:					
Federal government:					
Grants	86,886	73,800	77,909	63,537	-26.9
Company matching	16,073	16,634	31,457	24,144	50.2
Total	102,959	90,434	109,366	87,681	-14.8
State governments:					
Grants	17,393	([1])	20,825	87,507	403.1
Company matching	575	([1])	9,294	20,745	3,507.8
Total	17,968	20,118	30,119	108,252	502.5
Grand total	120,927	110,552	139,485	195,933	62.0
By company groups:					
Liquid biofuel producers:					
Government grants	70,830	50,058	42,106	71,581	1.1
Company matching	6,614	9,167	26,651	31,451	375.5
Bio-based chemical producers[2]	16,611	27,597	17,779	21,377	28.7
Dedicated research and development companies:					
Government grants	26,851	26,708	53,888	31,463	17.2
Company matching	7,786	6,480	8,241	6,018	-22.7

[1] Data withheld to avoid disclosure of confidential business information.
[2] Detailed company group data withheld to avoid disclosure of confidential business information.

Note.—Group data are not mutually exclusive in all cases. For example, some companies produce both liquid biofuels and bio-based chemicals, and are included in both groups.

Source: Compiled from data submitted in response to U.S. International Trade Commission questionnaire.

Only the biodiesel, bio-based chemical, and dedicated R&D company groups reported growth in federal grants, with dedicated R&D companies reporting the most growth. Bio-based chemical producers reported that grants generally target enzyme and bio-based chemical R&D, whereas most liquid biofuel producers reported that their grants were generally used for the commercialization of liquid biofuels.[56]

Based on questionnaire responses, federal funding appears to be sporadic and unevenly distributed across all industries. Moreover, the amount of the average federal grant per respondent decreased from approximately $1.1 million in 2004 to $775,000 in 2007, whereas the average state grant increased from $245,000 in 2004 to $1.2 million in 2007.[57] The average company match per federal grant increased from $412,000 to $619,000, while the

[56] Based on Commission questionnaire responses.
[57] Two firms are responsible for the dramatic increase in state grants. Excluding these companies from the data reveals that the average state grant increased from $245,000 to $581,000.

average company match per state grant increased from $19,000 to $692,000 during the 2004–07 period.[58]

R&D support at the federal and state levels comes in the form of direct grants, technology transfer, and cooperative research agreements.[59] Federal legislation provides government agencies with guidance as to which types of research projects to support, from specific goals, such as lowering the production cost of cellulosic ethanol, to general goals such as advancing the competitiveness of industrial biotechnology in general. Firms report that federal and state R&D support, although needed for the development of innovative technologies, is difficult to obtain and sometimes short-lived.[60]

Investment

Investment in both IB production and R&D facilities increased more than four times faster than investment in conventional liquid fuel and chemical facilities during the 2004–07 period (table 2-15). The percentage of total liquid fuel and chemical industry investment devoted to bio-based chemicals and liquid biofuels nearly doubled during the period, from 11.4 percent in 2004 to 21.7 percent in 2007.

Investment by liquid biofuel producers accounted for the majority of total bio-based investment in production (non-R&D) facilities (table 2-16 and figure 2-4). Such investment was a result of the large expansion in both corn ethanol and biodiesel production and was spurred by government tax incentives and usage mandates for biofuels.

Total spending on IB R&D facilities, including new laboratory space, pilot and demonstration plants, and purchases of new capital equipment for research purposes, showed a steady upward trend, more than doubling from 2004 through 2007. Investment in bio-based chemical R&D facilities—mostly by research-intensive pharmaceutical companies—is much higher than investment in liquid biofuel R&D facilities (figure 2-5). Much of the spending on liquid biofuel R&D facilities is likely for pilot or demonstration plants that are increasingly focused on cellulosic ethanol production.

[58] The large increase in company matches for state grants is attributable to the growth in the number of companies providing state grant matches. The number of companies providing such matches increased from 4 to 21 during the 2004–07 period.

[59] Through technology transfer and cooperative research agreements, the federal government provides funds for R&D that is cooperatively undertaken by national laboratories and private companies.

[60] Based on Commission questionnaire responses.

TABLE 2-15
Investment: Respondents' U.S. expenditures, 2004–07
(*1,000 dollars*)

Item	2004	2005	2006	2007	2004/07 percent change
Conventional fuels and chemicals	19,653,324	22,970,901	25,306,557	29,013,442	47.6
Bio-based products:[1]					
Research and development facilities	208,441	266,787	371,768	438,661	110.4
Production facilities	2,317,499	2,463,876	4,674,595	7,623,135	228.9
Total	2,525,940	2,730,663	5,046,363	8,061,796	219.2
Grand total	22,179,264	25,701,564	30,352,920	37,075,238	67.2

[1] Detailed data aggregated to avoid disclosure of confidential business information.

Source: Compiled from data submitted in response to U.S. International Trade Commission questionnaire.

TABLE 2-16
Investment: Respondents' U.S. expenditures for bio-based activities, by company groups, 2004–07
(*1,000 dollars*)

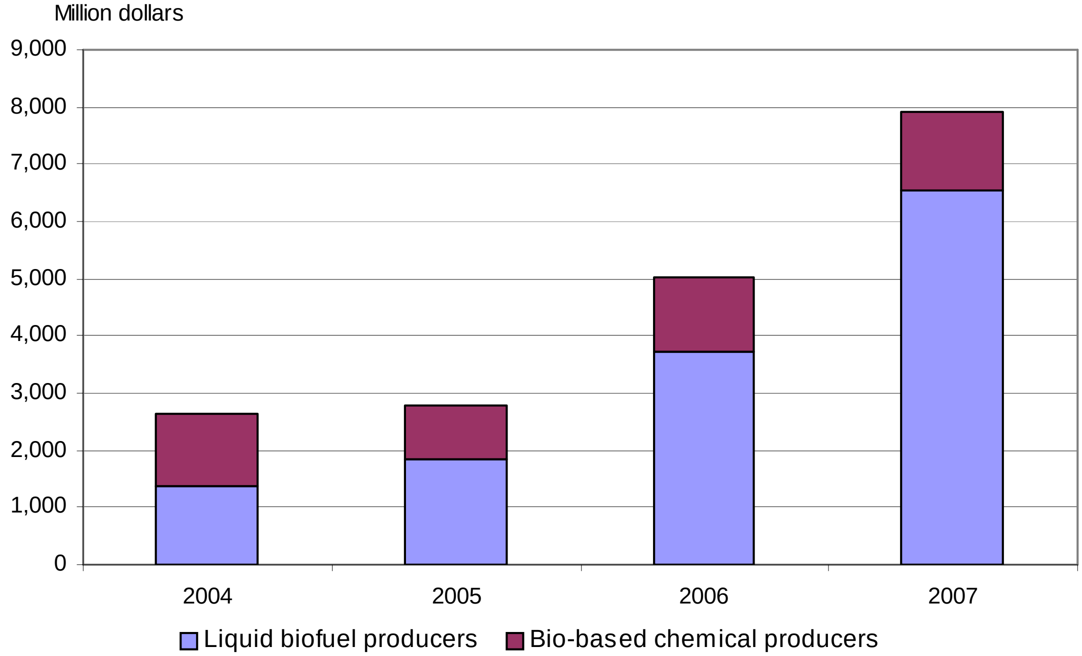
Item	2004	2005	2006	2007	2004/07 percent change
Research and development facilities:					
Liquid biofuel producers	20,828	22,906	35,160	40,592	94.9
Bio-based chemical producers[1]	172,784	233,762	307,283	293,558	69.9
Dedicated research and development companies:					
Pharmaceutical companies	11,859	18,120	23,312	33,313	180.9
All other companies	7,332	9,000	16,283	75,487	929.6
Production facilities:					
Liquid biofuel producers	1,386,950	1,832,689	3,735,099	6,528,001	370.7
Bio-based chemical producers[1]	1,247,237	949,102	1,300,205	1,381,570	10.8
Dedicated research and development companies[1]	15,934	16,397	82,495	22,027	38.2

[1] Detailed company group data aggregated to avoid disclosure of confidential business information.

Note.—Group data are not mutually exclusive in all cases. For example, some companies produce both liquid biofuels and bio-based chemicals, and are included in both groups. Ungrouped data, including totals, are shown in table 2-15.

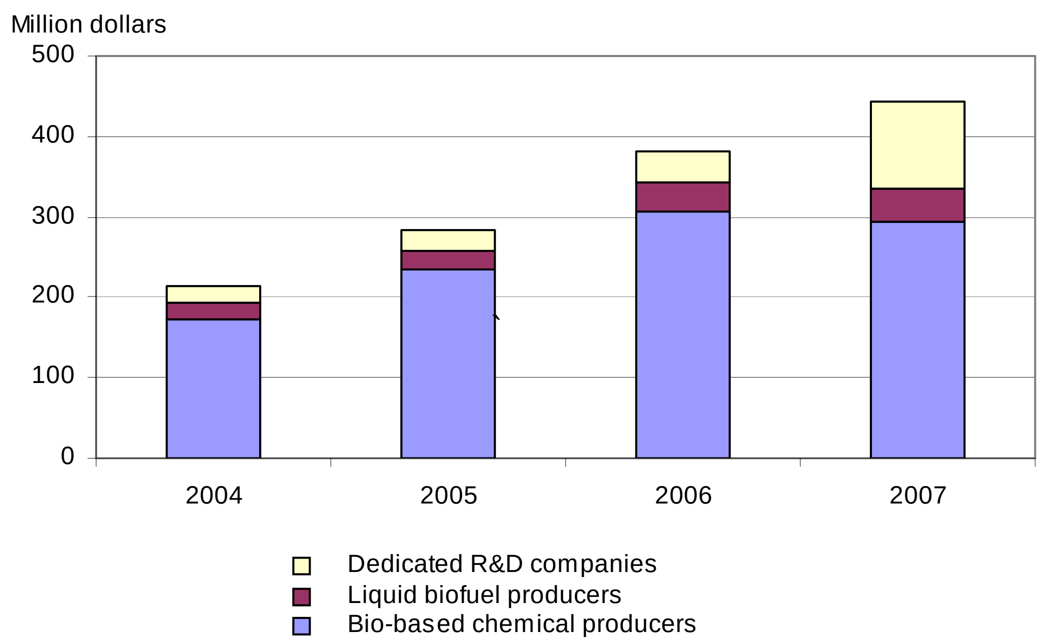
Source: Compiled from data submitted in response to U.S. International Trade Commission questionnaire.

FIGURE 2-4
Investment: Respondents' U.S. expenditures for bio-based production facilities, by company groups, 2004–07



Source: Compiled from data submitted in response to U.S. International Trade Commission questionnaire.

FIGURE 2-5
Investment: Respondents' U.S. expenditures for bio-based research and development facilities, by company groups, 2004–07



Source: Compiled from data submitted in response to U.S. International Trade Commission questionnaire.

Dedicated R&D companies (those with only limited production facilities) are frequently in the forefront of innovation in liquid biofuels and bio-based chemicals. Investment in R&D facilities by dedicated R&D companies not involved in pharmaceuticals research grew more than tenfold during the 2004–07 period in absolute terms, and from 4 percent of all investment in R&D facilities by the liquid biofuel and bio-based chemical industries in 2004, to 17 percent in 2007.

Along with internal investments in production and R&D facilities, liquid fuel and chemical companies are pursuing mergers and acquisitions. The acquisition of domestic R&D firms, U.S.-located liquid fuel production operations, and foreign-located R&D operations were, respectively, the most prevalent types of acquisitions during the period (box 2-3).

BOX 2-3 Examples of recent industrial biotechnology merger and acquisition activity

One of the largest recent IB deals is the merger of Celunol and Diversa to create a new company, Verenium. The merger combined Celunol's cellulosic ethanol expertise with Diversa's enzyme technology expertise to create an integrated company to commercialize cellulosic ethanol. The deal was valued at $154.7 million, and was completed in June 2007. Verenium is structured into three divisions: the Specialty Enzymes Business Unit, focusing on generating commercial revenues from enzyme product sales and technology licenses; the Biofuels Business Unit, focused on achieving commercial production and sale of cellulosic ethanol; and the Research and Development division, which supports both business units.

In another, more typical merger, four small ethanol producers—Atlantic Ethanol, LLC, Mid-Atlantic Ethanol, LLC, Florida Ethanol, LLC, and Palmetto Agri-Fuels, LLC—merged to form East Coast Ethanol in September 2007, allowing them to consolidate financing, construction, and some operating costs for four separate ethanol plants.

Sources: Verenium Corporation Web site, http://www.verenium.com/ (accessed March 18, 2008); Fraser, "Diversa, Celunol Merger Creates Cellulosic Ethanol Powerhouse," February 15, 2007; Bureau van Dijk, Zephyr Mergers and Acquisitions database (accessed March 17, 2008); Verenium Corporation, "Diversa and Celunol Complete Merger," June 20, 2007; and *Ethanol Producer Magazine*, "East Coast Ethanol, LLC to Build Four 100-Million Gallon Per Year Ethanol Plants," September 14, 2007.

Mergers and acquisitions in the liquid biofuel industry, and the ethanol industry in particular, represent an attempt by firms to achieve economies of scale in a difficult business environment characterized recently by overcapacity and rising feedstock prices.[61] Biodiesel producers also face a market situation encouraging industry consolidation, as firms adjust to rising feedstock prices for soybean and palm oils.[62] In addition to acquiring production facilities, companies have pursued acquisitions aimed at acquiring new technology. There have been fewer reported acquisitions related to bio-based chemicals.

[61] Shinn, "Ethanol Industry Consolidation Likely, Normal," October 2, 2007.
[62] Askren and West, "Tremors in the Biodiesel Industry," February 19, 2008.

CHAPTER 3
Factors Affecting the Development and Adoption of Industrial Biotechnology

The development and adoption of IB by liquid fuel and chemical producers depends in large part on the ability of firms to commercialize bio-based products. Successful commercialization requires that bio-based products establish a market by having physical or performance characteristics that can compete with conventional products and that such products can be developed and produced economically.

Respondents rated a number of commercialization impediments and competitive factors (tables 3-1 and 3-2). Supply-side and demand-side risk is explicitly and implicitly inherent in many of these impediments. Factors related to technology are a major supply-side risk; this risk is high because there may be no payoff if the technology related to producing the bio-based product does not prove viable. In addition, attracting capital for unproven technology is difficult because of this risk.

Financial factors create other supply-side risks; many respondents indicate that the profit potential is not commensurate with the risk of commercializing a bio-based product. These factors are especially relevant to production cost uncertainty. Raw material costs are problematic because feedstocks can represent a major portion of total production costs. The cost of agricultural feedstocks varied widely during the 2004–07 period, demonstrating the cost uncertainty related to producing many bio-based products. Because crude petroleum is the raw material for many of the conventional products that compete with bio-based products, a decrease in the price of crude petroleum may make the production of bio-based products relatively less profitable.

Risk is also inherent in demand-side factors. Many bio-based products are commodity-type items, such as certain plastics, for which consumers are unwilling to pay an even marginally higher price. (This may not always be true, however, with respect to pharmaceuticals; drugs can be highly differentiated products for which consumers are willing to pay premium prices.) Demand-side risk can also be high if poor public acceptance of the bio-based products (e.g., if the public is uninformed about product performance and "green" characteristics) results in decreased sales. U.S. regulations, such as drug approval regulations and liquid fuel standards, are another demand-side factor. Some bio-based firms characterize these as impediments insofar as there may be regulatory delays in the ability to market products.

Of the 559 companies that responded to the Commission's questionnaire, 176 indicated that these commercialization impediments have resulted in their companies either deciding against pursuing any IB activity or abandoning one or more specific IB projects.

Firms employ various strategies to reduce risk and compete for market share. Risk can be reduced by establishing strategic alliances and protecting intellectual property (IP). R&D can result in innovative bio-based products that can enhance the productivity and

TABLE 3-1
Industrial biotechnology adoption: Respondents' indication of the significance of commercialization impediments

Impediment	Total responses	Percentage indicating: Very significant	Least significant
Feedstock price	398	57	31
Lack of capital (debt or equity)	399	46	36
Risk level to profit potential is high	397	45	31
Final product cost not competitive	396	44	37
Crude petroleum price uncertainty	397	36	44
U.S. regulatory barriers	393	32	45
Transportation costs	397	31	44
Feedstock unreliability	401	30	57
Market dominated by other companies	394	25	54
Transportation capacity limitations	393	25	56
Co/byproduct profitability	399	24	53
Limits of available technology	398	24	50
Lack of distribution/marketing channels	394	23	58
Poor public perception of bio-products	395	22	58
Foreign country regulatory barriers	380	18	65
Enzyme price	392	16	67
High licensing costs	386	15	69
Lack of market knowledge	390	15	63
Difficult to integrate into existing production	390	14	70
Lack of human resources with adequate education	396	13	68
Enzyme availability	390	13	74
Not related to current business	398	12	76
Foreign market tariffs	386	9	79
Water availability	390	9	78
Patent barriers	384	9	73
Absence of product standards	392	8	76
Lack of production workers	393	7	76
Other foreign market barriers	294	7	83

Source: Compiled from data submitted in response to U.S. International Trade Commission questionnaire.

TABLE 3-2
Liquid biofuel and bio-based chemical companies: Respondents' indication of most important competitive factors affecting ability to market products

Factor	Total responses	Percentage indicating: Very important	Least important
Feedstock price	282	80	11
Government incentives/support	173	48	36
Production cost	281	47	29
Product performance characteristics	113	43	35
Financing availability	119	43	34
Technology availability	102	41	42
Ability to price product appropriately	199	39	37
Plants that are able to produce co-products	39	28	51
Consumer acceptance of product	128	24	55
Product quality	152	24	43
Delivery time	20	15	70
Hedging instruments for feedstocks	47	15	72
Product standards	54	9	74
Transportation costs	110	9	71
Hedging instrument for product	30	7	67

Source: Compiled from data submitted in response to U.S. International Trade Commission questionnaire.

competitiveness of firms. As a result, firms may gain market share and/or lower production costs.

U.S. government programs play a major role in risk minimization. Mandatory use regulations and tax incentives guarantee a market and lower costs, although, in general, these currently apply only to ethanol and biodiesel. Because government policies have played such a prominent role in the development and adoption of IB in the United States and in foreign countries, they are examined in greater detail in chapter 4.

The rest of this chapter describes development and adoption factors in more detail, including cost and availability of feedstocks, availability of capital, and research and development. A discussion of key strategies employed by firms to overcome impediments and promote greater development and adoption of IB follows, including strategic alliances and IP protection.

Cost and Availability of Feedstocks

Cost and availability of feedstocks are important competitive factors affecting liquid biofuel and many bio-based chemical producers. In the United States, corn and soybeans are the most common feedstocks for ethanol and biodiesel, respectively; the costs of the two leading feedstocks account for a majority of the operating costs of production of corn ethanol (57 percent) and of soybean-oil biodiesel (70–78 percent) (box 3-1).[1]

BOX 3-1 U.S. agricultural feedstocks

Agricultural feedstocks, used in the liquid biofuel and bio-based chemical industries, consist of grain and oilseed crops and, potentially, their field residues (primarily corn, sorghum, soybeans, and wheat, but also barley and rice); switchgrass and other forage crops; animal fats; potatoes; recycled cooking oils; and sugar and molasses derived from sugarcane and sugarbeets. The primary crops used for biofuels and bio-based chemicals in the United States are corn and soybeans; small amounts of sorghum, barley, wheat, cheese whey, and potatoes are used as well.[1] No sugar feedstocks are currently used for biofuels in the United States, although countries such as Brazil utilize large volumes of sugar for this purpose.[2] Agricultural residues and forest products are not yet widely used in the production of liquid biofuels or bio-based chemicals;[3] however, reflecting the potential for their increased use as a cellulosic feedstock, recent federal and state initiatives have increased the financial incentive to use such biomass for the production of ethanol in the United States.

[1] Schnepf, *Agriculture-Based Renewable Energy Production*, May 18, 2006, 5; Koplow, *Biofuels—At What Cost?* 2006, 38; and Koplow, *Biofuels—At What Cost?* October 2007, 25.

[2] Shapouri and Salassi, *The Economic Feasibility of Ethanol Production*, July 2006, vi.

[3] Most forest-derived biomass or feedstocks are currently used as dry fuel. See USDA and USDOE, *Biomass as Feedstock for a Bioenergy and Bioproducts Industry*, April 2005, 5–16.

[1] Data for 2002 from USDOE, EIA, *Biofuels in the U.S. Transportation Sector*, February 2007, 4. For 2007 data, see Tokgoz, et al., *Emerging Biofuels: Outlook for U.S. Grain, Oilseed and Livestock Markets*, May 2007; and USDA, Office of the Chief Economist, *USDA Agricultural Projections to 2016*, February 2007, 20–26.

Table 3-3 presents rankings of the importance of agricultural feedstock issues affecting producers' operations. Of the companies that provided a response, nearly 97 percent cited the cost of agricultural feedstocks as a very important issue, and 54 percent reported poor crop yields as very important. Lack of storage capacity, supply disruptions, transportation bottlenecks, the poor quality of feedstocks, and the unavailability of new varieties were also frequently cited as very important issues affecting operations.[2]

TABLE 3-3
Agricultural feedstocks: Respondents' ranking of issues affecting their operations

Issue	Total responses	Percentage indicating: Very important	Least important
Costs	214	97	1
Poor crop yields	111	54	23
Supply disruptions	102	37	37
Lack of storage capacity	64	36	39
Poor quality	81	33	31
Unavailability of new varieties	45	33	31
Transportation bottlenecks	88	31	40

Note.—Respondents indicated multiple reasons in most cases.

Source: Compiled from data submitted in response to U.S. International Trade Commission questionnaire.

The primary factors affecting the economic viability of the U.S. liquid biofuel industry are the price of the agricultural feedstocks used to produce these fuels, the market prices of the biofuels, and the price of petroleum motor fuels. Rising petroleum prices have the potential to increase the viability of the U.S. liquid biofuel industry because prices for ethanol and biodiesel typically rise in line with the prices for gasoline and diesel. The two primary U.S. liquid biofuels, ethanol and biodiesel, compete directly with gasoline and diesel sales, but provide less energy value per gallon than petroleum, and are priced less than the competitive petroleum fuel type.[3] When rising biofuel prices outpace increases in agricultural feedstock prices, biofuel production becomes more profitable.

However, prices of the two primary feedstocks used in biofuels, corn and soybeans, increased over the past several years, and, as a result, profits for biofuel producers fell despite rising gasoline and diesel prices. The price of corn rose by 65 percent from 2004 through 2007, and the price of soybean oil rose by 50 percent (table 3-4).[4]

[2] Based on Commission questionnaire responses.

[3] Ethanol provides about 33 percent less energy value per gallon than unleaded gasoline. USDOE, EIA, *Biofuels in the U.S. Transportation Sector*, table 12, February 2007, errata as of October 15, 2007. Energy content for biodiesel is about 8.65 percent less than for No. 2 diesel. NBB, "Energy Content," undated (accessed May 29, 2008).

[4] The price of soybeans (roughly 17 percent of the soybean is soybean oil) rose by 42 percent.

TABLE 3-4
U.S. prices of agricultural feedstocks, biofuels, and petroleum products, 2004–07, and December 2007

Item	2004	2005	2006	2007	Dec 2007	2004/Dec. 2007 percent change
Agricultural feedstocks:[1]						
Corn (farm price, $/bushel)	2.42	2.06	2.00	3.04	4.00	65
Soybeans (farm price, $/bushel)	7.34	5.74	5.66	6.43	10.40	42
Soybean oil (crude, Decatur, $/pound)	0.30	0.23	0.23	0.31	0.45	50
Biofuels:						
Ethanol (Rack price, Nebraska, $/gallon)	1.69	1.80	2.58	2.24	2.24	33
Biodiesel (f.o.b plant, B-99/B-100, $/gallon)	([2])	3.40	3.43	3.32	[3]3.92	([2])
Petroleum:						
Crude (Cushing, OK, futures, $/barrel)	41	57	66	72	92	124
Gasoline ($/gallon):						
Average U.S. price, for resale	1.42	1.83	2.12	2.34	2.61	84
Rack price, Nebraska	1.25	1.66	1.94	2.23	2.35	88
Diesel fuel, No. 2 ($/gallon):						
For resale	1.34	1.90	2.18	2.35	2.85	113
Average U.S. retail	1.81	2.40	2.70	2.88	3.34	185

[1] Crop year data ending in the year shown.
[2] Not available.
[3] B-100, Iowa plants, f.o.b.

Source: Agricultural feedstocks compiled from official statistics of the U.S. Department of Agriculture; biodiesel and petroleum prices compiled from official statistics of the U.S. Department of Energy, Energy Information Administration, and the Alternative Fuels & Advanced Vehicles Data Center; ethanol and gasoline from Nebraska Energy Office, State of Nebraska; and Iowa biodiesel price from USDA, AMS, "National Weekly Ag Energy Round-up," December 2007.

According to the USDA, U.S. ethanol producers are profitable with a $0.51 per gallon federal excise tax credit when the price of crude petroleum rises to $80 per barrel and corn prices are below $5.43 per bushel.[5] For biodiesel production, with soybean oil at $0.45 per pound (the December 2007 price) and a $1 per gallon federal tax credit, the price of biodiesel (f.o.b. plant) must exceed $4.00 per gallon for the typical U.S. plant to operate at a profit.[6] In December 2007, the price of U.S. biodiesel (f.o.b. plant) was $3.92 per gallon, suggesting that the soybean-oil biofuel plants had an operating profit close to or below zero. This is consistent with the financial performance analysis based on questionnaire responses (chapter 2).

Lack of storage capacity, supply disruptions, and transportation bottlenecks are also issues recognized by industry participants as having an effect on the sector's competitiveness. A USDOE official noted in 2007 that, to spur the commercial development of cellulosic ethanol, the logistics of biomass handling, namely management, transport, storage, and

[5] Tokgoz, et al., *Emerging Biofuels,* May 2007; USDA, Office of the Chief Economist, *USDA Agricultural Projections to 2016,* February 2007, 20–26; and Hurt, Tyner, and Doering, *Economics of Ethanol,* December 2006. As of June 26, 2008, the per barrel price for crude petroleum was $129.70, according to official statistics of the USDOE; the per bushel price for corn in May 2008 was $5.58, according to official statistics of the USDA.

[6] Carriquiry and Babcock, "A Billion Gallons of Biodiesel," Winter 2008, 6. In 2008, the per gallon price of biodiesel surpassed $4.00. Ibid. The per pound price of soybean oil in May 2008 was $0.58, according to official statistics of the USDA.

delivery, all urgently need to be addressed.[7] One ethanol producer noted that "a basic problem is to find a steady source of feedstock that has or can develop a transportation and storage system to allow the facilities to operate year round at maximum rates. Transportation is a large part of the costs we all face in business so the further you have to transport that feedstock the more costly it becomes. Corn has a nationwide system for storage and handling, but stover, switchgrass, and wood chips do not."[8]

Transportation costs to bring feedstocks to the processing facility are the third highest expense for an ethanol plant, after the cost of the feedstock itself and energy. Rail, barge, and truck transportation in the United States is at or near capacity constraints,[9] and shipping agricultural feedstocks to new ethanol and biodiesel facilities in the United States is affecting U.S. transportation infrastructure and creating bottlenecks. These networks are very sensitive to changes in transportation demand and distribution patterns.[10] Trucks are currently used to transport much of the corn used in ethanol plants, but newer ethanol plants with larger capacities may also use rail as an alternative transportation method.[11] Cellulosic feedstocks, increasingly used around the country in pilot demonstration plants, face similar transportation costs and concerns.

Because feedstock transportation costs are an increasing burden for liquid biofuel producers, the acquisition of feedstocks from local suppliers is important. Therefore, producers noted concern about the potential for poor crop yields or crop failures on farms close to liquid biofuel facilities. For example, according to one biodiesel producer in south central Kansas, a hard freeze in 2007 destroyed the local canola crop used to make biodiesel in that area, halting biodiesel production.[12] One ethanol producer reported that a drought in the Midwest "could be devastating" to the entire ethanol sector.[13] Biodiesel producers in particular note the tremendous challenge of finding soybeans if the regional soybean crop fails.[14]

Feedstock quality is also cited as an impediment to the development and adoption of IB. Poor quality feedstocks lower biofuel yields and increase production costs per finished gallon. According to one industry representative, U.S. feedstock suppliers lag European suppliers in quality control.[15]

One biodiesel producer reported that his facility, like many others, switched from soybean oil to animal fats due to the cost of soybean oil.[16] Animal fats have traditionally been sold to feed markets, all of which require certain free fatty acid and moisture content. Biodiesel producers, on the other hand, are seeking the proper triglyceride content in these animal fats because that is the only component that converts to biodiesel in the process typically used by biodiesel producers. This biodiesel producer stated that it sometimes receives animal fats that meet the free fatty acid and water specifications, but that there may be other contaminants that negatively affect conversion to biodiesel. According to the biodiesel

[7] National Agricultural Biotechnology Council, Fourth Annual World Congress on Industrial Biotechnology and Bioprocessing (2007), Summary Proceedings, March 21–24, 2007, 12–13.

[8] Industry representative, e-mail message to Commission staff, May 13, 2008.

[9] USDA, AMS, Transportation and Marketing Programs, *Ethanol Transportation Backgrounder*, September 2007, 7.

[10] Ibid.

[11] Ibid., 3.

[12] Industry representative, e-mail message to Commission staff, May 20, 2008.

[13] Industry representative, e-mail message to Commission staff, May 20, 2008.

[14] Industry representative, e-mail message to Commission staff, May 20, 2008.

[15] Industry representative, e-mail message to Commission staff, May 13, 2008.

[16] Industry representative, e-mail message to Commission staff, May 13, 2008.

producer, its animal fat suppliers indicate that their target customers are in the feed market and that they produce to satisfy that market. The biodiesel producer also reported receiving animal fats from suppliers that did not meet the free fatty acid specification as claimed.[17]

Biodiesel producers deal with similar issues when they purchase soybean oil as their primary feedstock. Some biodiesel producers report that feedstock suppliers view biodiesel producers as residual customers, a channel through which they can sell any feedstock that could not be used in food applications, even though the biodiesel producers are paying for, and expect to receive, refined and bleached soybean oil.[18] One biodiesel producer noted that even the major oil suppliers supply poor quality feedstock because their operations are not designed to supply the degummed oils preferred by biodiesel facilities.[19] Instead, these suppliers deliver food grade oils, and ship feedstocks that are supposedly degummed oils in crude oil railcars that have a “2–6 inch heel of gums in the bottom.”[20]

Several ethanol producers noted that corn that does not meet their specifications is not desirable because it lowers yields and raises costs.[21] Corn feedstock arriving at ethanol facilities is typically sampled and checked for moisture content, damage, and foreign material. Although “off-spec” corn should be price discounted, storage elevators blend it with grains from many different farmers into larger batches of corn that meet all specifications.

The issue in many of these examples is that many potential feedstocks have benefits and disadvantages that must be accounted for in the production process. No one feedstock is ideal for every end use. Research in plant breeding and molecular genetic technologies continues.[22]

Availability of Capital

Lack of capital ranks as the second most significant impediment (after feedstock price) to the commercialization of liquid biofuels or bio-based chemicals and the largest impediment to R&D. Capital can be difficult to attract for unproven technologies. Also, many IB firms are small companies with limited internal financial resources and need to attract capital from external sources to grow. Several smaller R&D firms reported difficulties finding private financing, partly due to private investors’ tendency to support research that promises to achieve commercial viability relatively quickly and generate profits. Therefore, many dedicated R&D firms, engaged in longer-term research, rely primarily on state and federal grant funding. Firms working on products that have the potential to be more easily commercialized are more likely to rely on private investment, such as venture capital (VC) funding.[23]

[17] Industry representative, e-mail message to Commission staff, May 13, 2008.

[18] Industry representative, e-mail message to Commission staff, May 13, 2008.

[19] Soybean oil and other plant oils contain small amounts of chemicals called phospholipids. These phospholipids are also referred to as gums since they have high viscosity and a sticky texture. Degummed oils are oils that have had these phospholipids removed. Hochhauser, “Fats and Fatty Oils,” 2005.

[20] Industry representative, e-mail message to Commission staff, May 13, 2008.

[21] Industry representative, e-mail message to Commission staff, May 13, 2008.

[22] Duffield, et al., *U.S. Biodiesel Development*, September 1998.

[23] Industry representatives, interviews by Commission staff, Chicago, IL, May 16, 2007.

The U.S. liquid biofuel and bio-based chemical industries have access to a wide variety of potential funding sources for investment capital. Retained earnings and debt (including bank lending) were the sources of capital during the 2004–07 period cited most often by all types of producers, followed by sales of equity other than initial public offerings (table 3-5). Dedicated R&D companies—with less access to retained earnings or bank financing—were more likely to use VC, collaborative alliance partners, and federal government funding sources. These sources were followed by equity sales, and then by retained earnings.

As reported by Thomson Financial, VC financing of IB increased strongly from 1995 to 2007 (figure 3-1). In addition, individual projects are getting larger, average VC investment per company has increased, and more IB companies have been able to access VC funding in recent years (figure 3-2).[24] The largest share of VC funding in the liquid biofuel sector has been concentrated on second generation biofuel technologies,[25] including ethanol and biodiesel production that rely on cellulosic and other new feedstocks such as wood, straw, and jatropha.[26]

During the 2004–07 period, U.S. VC firms invested in 31 domestic IB companies, for an average of $33.7 million per biotechnology company and a total of $733.3 million. U.S. VC deals were widely distributed around the country, with the largest concentrations of both VC firms and IB company investment destinations in New England, followed by Silicon Valley, CA, and the Washington, DC, metropolitan area.[27] U.S. VC firms invested in 26 foreign IB companies during the 2004–07 period, for an average of just over $4 million per biotechnology company and a total of $105.9 million.[28]

[24] Data by Thomson Financial for PWC/NVCA, *Moneytree Report*. The *Moneytree Report* is a quarterly study of venture capital investment activity in the United States, published as a collaboration between PricewaterhouseCoopers and the National Venture Capital Association, based upon data from Thomson Financial. The data used in this section of the study reflect venture capital transactions identified as industrial biotechnology by the National Venture Capital Association and may not reflect the same data as the questionnaire results that provide the majority of data for this study.

[25] New Energy Finance, *Monthly Briefing,* January 2008.

[26] Jatropha is a drought- and pest-resistant plant that produces seeds containing up to 40 percent oil. The oil extracted by crushing and processing the seeds can be used in a standard diesel engine, and the residue can be processed into biomass to power electricity plants.

[27] Data by Thomson Financial for PWC/NVCA, *Moneytree Report*.

[28] Ibid.

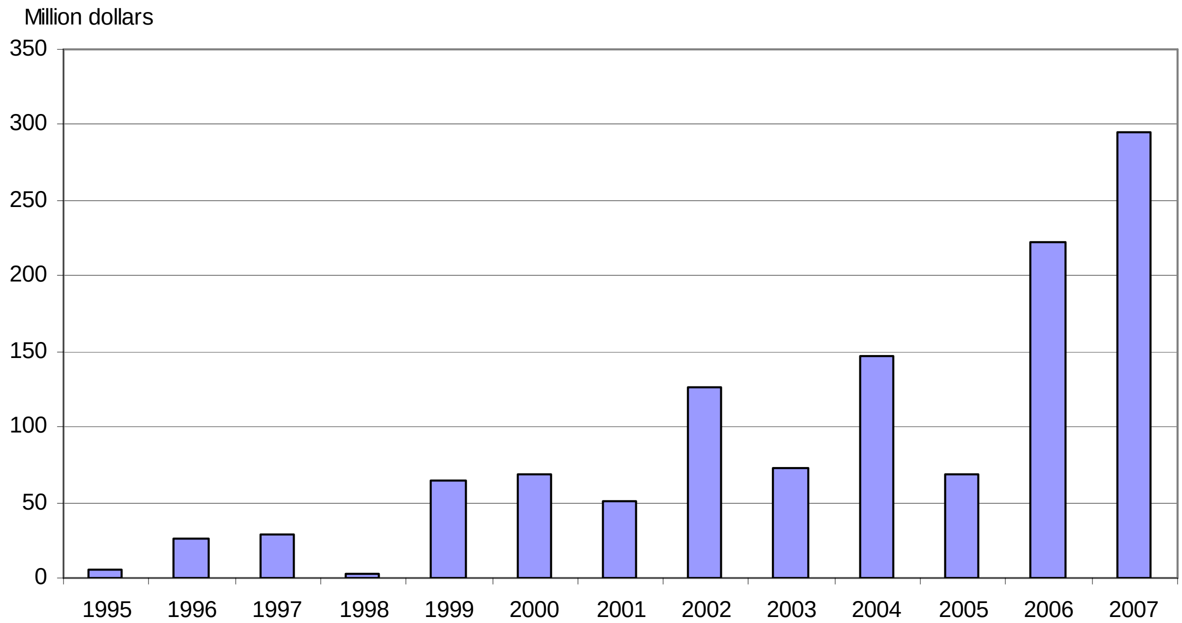
TABLE 3-5
Investment: Respondents' indication of funding importance

Program	Total responses	Percentage indicating: Very important	Least important
All companies:			
Sales of equity other than IPO	93	83	15
Domestic-sourced venture capital	79	81	11
Retained earnings	194	80	9
Debt	182	77	9
Angel investors	67	75	18
Liquid biofuel producers:			
Debt	122	92	4
Sales of equity other than IPO	52	88	12
Retained earnings	89	85	9
Domestic-sourced venture capital	35	74	14
Angel investors	41	73	20
Bio-based chemical producers:			
Pharmaceutical producers:			
Retained earnings	10	80	0
Federal government	6	67	17
Domestic-sourced venture capital	3	67	33
State or local government	2	50	50
Debt	8	50	38
All other producers:			
Retained earnings	50	78	8
Debt	23	65	9
State or local government	8	63	25
Sales of equity other than IPO	8	63	25
Domestic-sourced venture capital	5	60	40
Dedicated research and development companies:			
Pharmaceutical companies:			
Domestic-sourced venture capital	10	100	0
Initial public offering of stock	3	100	0
Sales of equity other than IPO	10	90	0
Retained earnings	6	83	0
Collaborative alliance partner	6	83	0
All other companies:			
Domestic-sourced venture capital	18	89	6
Angel investors	8	88	13
Collaborative alliance partner	18	78	17
Sales of equity other than IPO	8	75	25
Federal government	17	71	6

Note.—Group data are not mutually exclusive in all cases. For example, some companies produce both liquid biofuels and bio-based chemicals, and are included in both groups. An angel investor provides capital for a business start-up, usually in exchange for an ownership stake in the company. Angel capital is a common second round of financing for start-up companies, filling the gap between initial investors who provide seed funding, and venture capital.

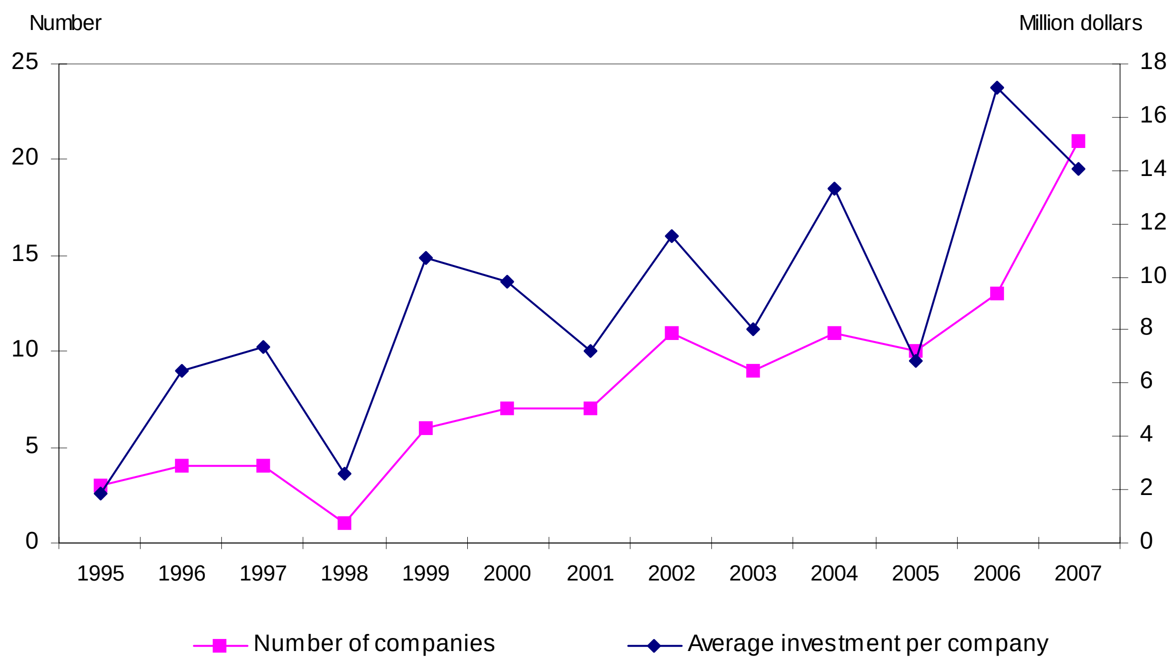
Source: Compiled from data submitted in response to U.S. International Trade Commission questionnaire.

FIGURE 3-1
Total venture capital investment in industrial biotechnology, 1995–2007



Source: Thomson Financial for PWC/NVCA *Moneytree Report*.

FIGURE 3-2
Venture capital investment in industrial biotechnology, 1995–2007



Source: Thomson Financial for PWC/NVCA *Moneytree Report*.

Capital-related Impediments

IB firms report several impediments to attracting investment capital from outside investors including banks, VC firms, or other types of investors. First, companies need to prepare extensive documentation for potential investors. One lender specified the following preferred factors for attracting investor interest to corn ethanol plants: "proven repeatable technology and process design"; "proven builders and technology providers"; "realistic" business plans; and "longer term government support through subsidies, market access mandates, and government loan guarantees."[29] Lenders are also concerned about business factors outside the control of the company, including uncertainty about future renewable fuels-related legislation, producers' and blenders' credits, "funding reliability given state and federal budget problems," and planned termination of government programs.[30] According to another observer, two crucial factors for IB firms in attracting investment are dependable feedstock supplies and the development of industry standards, which will assure investors that their dollars are being invested wisely.[31] Other industry representatives have stated that government needs to help share the risks of new facilities, especially when companies are facing a financing gap, because the private sector cannot cover the total cost of new innovation.[32]

R&D and Innovation

Research, development, and innovation are important to improving the competitiveness and productivity of IB companies. R&D can result in more efficient production processes, finding alternative feedstocks, and the discovery of new products and co-products, all of which can potentially improve firm profitability.

One of the most visible focus areas of IB R&D in the United States is the development and adoption of cellulosic ethanol technology. Federal and state governments provide extensive support for this technology in the form of usage mandates that begin in 2012 and immediate R&D funding. Other innovative technology research focuses on enzyme and micro-organism improvements, new liquid biofuels, new processes for liquid biofuel production, and new bio-based chemical products.

Cellulosic Ethanol

The primary advantage of cellulosic ethanol as a biofuel, compared with corn ethanol, is the ability to efficiently use nonfood feedstocks such as agricultural residues and municipal waste. A number of significant pilot or demonstration plants producing cellulosic ethanol have started operations in recent years, with plans to begin commercial operations in the United States over the next several years. One such plant, Western Biomass Energy LLC, operated by KL Process Design Group, brought onstream in early 2008, uses enzymatic

---

[29] Aberle, AgCountry Farm Credit Services, "Attracting Senior Debt to the Cellulosic Ethanol Industry," November 14, 2006.

[30] Ibid.

[31] Washer, Phylogica, presentation at Pacific Rim Summit on Industrial Biotechnology & Bioenergy, November 14, 2007.

[32] Firms can encounter a financing gap when their initial start-up funding runs out and they are not large enough to attract funding from larger sources such as banks and venture capitalists. Passmore, Iogen Corporation, "The Developer Community's Perspectives on the Value Chain," November 14, 2006.

processes to convert wood residue to cellulosic ethanol. Several companies have scheduled their demonstration plants to come onstream in 2008, including BlueFire and Verenium. These firms use a variety of feedstocks ranging from wheat straw to municipal waste. Systematic quantitative data are not available on existing pilot or demonstration plants; however, table 3-6 presents details of selected plants, most of which were still under construction as of March 2008. As of January 2008, only one biofuels company, Range Fuels, was expected to begin cellulosic ethanol production on a commercial scale in 2008. The plant will use Range Fuels' proprietary two-step thermochemical process that converts biomass to synthesis gas, and then converts the gas to ethanol, using a variety of feedstocks including wood chips, agricultural wastes, olive pits, grasses, cornstalks, hog manure, municipal garbage, sawdust, and paper pulp.[33]

Other Technologies

Table 3-7 shows examples of other important technologies under development in the United States. In the chemical industry, the research focus is more diverse than in liquid biofuels, but is largely focused in two areas: (1) the development of newer, more effective, and more cost-effective enzymes that enable the development and production of economically- and technologically-competitive bio-based products and bioprocesses, and (2) the development of such novel and innovative products and processes themselves.

[33] USDOE, "DOE Selects Six Cellulosic Ethanol Plants," February 28, 2007.

TABLE 3-6
Selected cellulosic ethanol pilot and demonstration plants

Lead company	Plant location	Feedstock	Expected annual capacity
Abengoa Bioenergy	Hugoton, KS	Corn stover, wheat straw, milo stubble, switchgrass	11.6 million gallons
Abengoa Bioenergy	York, NE	Ligno-cellulosic biomass	Not available
AE Biofuels	Butte, MT	Non-food feedstocks, including switchgrass, grass seed, grass straw, and cornstalks	Not available
Alico	LaBelle, FL	Yard, wood, and vegetative wastes	13.9 million gallons
BlueFire Ethanol	Corona, CA	Sorted green waste and wood waste from landfills	17 million gallons
BlueFire Ethanol	Lancaster, CA	Municipal solid waste	3.1 million gallons
Iogen[1]	Shelley, ID	Agricultural residues (wheat, barley, rice straw, corn stover) and switchgrass	18 million gallons
KL Process Design Group	Upton, WY	Waste wood	1.5 million gallons
Pacific Ethanol	Boardman, OR	Wheat straw, wood chips, corn stover	2.7 million gallons
Poet	Emmetsburg, IA	Corn fiber, cobs, stalks	125 million gallons (of which 25% will be cellulosic ethanol)
Range Fuels	Soperton, GA	Wood chips, agricultural waste, olive pits, municipal garbage, and other feedstocks	20 million gallons
Verenium	Jennings, LA	Sugarcane bagasse, specially-bred energy cane, and other feedstocks	1.4 million gallons (adding a demonstration plant to existing pilot plant capacity)
Zeachem	Port of Morrow, OR	Sugar, wood chips	1.5 million gallons

[1] This company recently announced a reduction of activities at this plant location, pending future financial developments.

Sources: Various industry publications.

TABLE 3-7
Examples of innovative industrial biotechnology

Technology	Description and advantages
Biobutanol production process	An alcohol fuel that, like ethanol, can be fermented from either conventional feedstocks like corn or from cellulosic feedstocks and can be blended with gasoline for use in automobiles. Biobutanol is not yet produced commercially in the United States. Several companies are reportedly working on the technology. For example, a BP/DuPont partnership expects to introduce biobutanol to the U.S. market around 2010 after first introducing it in the United Kingdom. Among the advantages of biobutanol compared to ethanol are that biobutanol does not absorb water from the atmosphere so it can be more easily transported by pipeline and utilize the existing fuel infrastructure; its energy content is closer to gasoline than that of ethanol; and it is more compatible with existing engines than ethanol.
Biodiesel production process	Biodiesel, a biomass-derived fuel that can replace or be blended with petroleum diesel for transportation and home heating, is produced from plant oils and animal fats. One current research area is the study and development of the use of isolated enzymes to produce biodiesel. Biocatalysis reportedly results in competitive advantages such as cost and environmental benefits (e.g., the use of a single, mild, reusable enzyme results in reduced energy consumption and waste disposal, purer output and co-products, more efficient conversion of both types of biodiesel feedstocks, and reduced expenses associated with buying new catalysts).[1] In other work, a research team in Germany developed a modified version of *E. Coli* in 2006 that could convert a mixture of glucose and olive oil into a version of biodiesel called "microdiesel." The *E. Coli* contains three genes transferred from two other bacteria that allow the modified micro-organism to convert sugar to alcohol and then react the alcohol with an oil (e.g., olive oil) to create the "microdiesel." Reported advantages of the developmental process include production of 100 percent bio-based biodiesel; competitive pricing of the biofuel because of lower-cost inputs; and, if the micro-organism is further modified, the ability to use waste feedstocks such as recycled waste paper or plant waste derived from food production, potentially reducing acreage needed for biodiesel crops.[2]
Corn kernel fractionation	Advanced corn fractionation technologies would separate the corn fiber for conversion to ethanol, increasing the ethanol yield per bushel of corn, potentially increasing productivity. Fractionation could also produce higher value co-products, such as high-protein animal feed or corn oil for human consumption.[3]

See footnotes at end of table.

TABLE 3-7—*Continued*
Examples of innovative industrial biotechnology

Technology	Description and advantages
Enzyme/ micro-organism development	Novel enzymes and micro-organisms can improve competitiveness and productivity in several ways. For example, they have been key to commercializing new bio-based products, many of which were not previously economically or technically feasible or competitive with their petrochemical-based counterparts. In the biofuel sector, numerous entities are working to develop technically competitive and cost-effective enzymes for use in producing cellulosic ethanol. Companies such as Genencor and Novozymes, awarded multi-year contracts by the National Renewable Energy Laboratory (NREL) in 2001 for such work, reduced the cost of cellulosic ethanol enzymes by as much as 30-fold. Numerous entities are working to develop other enzymes, including universities, the national laboratories, and stand-alone research firms. The USDOE, particularly NREL, continues to play a significant role in such development. In the chemicals sector, enzymes and micro-organisms are increasingly used either in addition to or in lieu of existing or planned chemical syntheses. The use of enzymes and micro-organisms, themselves biodegradable, allows for the simplification of production processes and related reductions in the consumption of fossil fuel inputs, energy consumption, production costs, emissions, and waste production, resulting in cost savings and environmental benefits (see appendix D). Such bioprocesses can potentially enhance industry competitiveness, particularly given significant increases in energy/input costs in recent years. Novel enzymes and micro-organisms are also being used to convert renewable resources such as corn into bio-based chemicals. For example, development of a modified strain of *E. Coli* allowed for production by a DuPont and Tate & Lyle joint venture of a bio-based version of 1,3-propanediol (Bio-PDO™) starting in late 2006 using corn as the input. The novel micro-organism contains six genes transplanted from two other micro-organisms allowing the modified *E. Coli* strain to produce four unique enzymes that sequentially convert corn-based glucose to glycerol and glycerol to Bio-PDO™.[4]
New drug development	Like many pharmaceutical companies, Pfizer has developed and is using biocatalytic processes in the United States. Competitive advantages of the bioprocesses include reduced production costs and increased safety versus existing chemical processes, beneficial environmental effects (i.e., such processes reduce GHG emissions, consumption of energy and inputs, and use of organic solvents, meshing with Pfizer's ongoing commitment to "green" chemistry), and increased product purity. Pfizer is also using biocatalysis in the production of pregabalin (the active ingredient in a pharmaceutical marketed under the brand name Lyrica®) and atorvastatin (the active ingredient in a pharmaceutical marketed under the brand name Lipitor®). More information about the environmental benefits of these and other bioprocesses is presented in appendix D.[5]
Bio-based products from sugar platforms	Numerous liquid biofuels and bio-based chemicals can be produced via sugar platforms. Examples of liquid biofuels include ethanol and biobutanol. In August 2004, the USDOE published a list of the top 12 chemicals likely to be produced through the biological or chemical conversion of sugars that can then be used as building blocks in the production of higher-value bio-based chemical derivatives. Such products could eventually be produced in integrated biorefineries as liquid biofuel co-products, potentially reducing the cost to produce the liquid biofuels. Companies are currently developing bio-based production of many of the 12 basic chemicals identified by the USDOE, including 3-HPA and bio-based succinic acid, as well as their derivatives, in efforts to eventually commercialize such production. Succinic acid, for example, is a building block for dozens of derivatives valued at more than $1 billion annually. Derivatives of 3-HPA include acrylic acid as well as numerous other chemicals.

See footnotes at end of table.

TABLE 3-7—*Continued*
Examples of innovative industrial biotechnology

Technology	Description and advantages
Using bioprocesses to convert renewable resources to chemicals and biopolymers	Companies are producing numerous bio-based chemicals in the United States from renewable resources such as corn, including biopolymers. As noted in appendix D, such bioprocesses, when compared to their petrochemical-based counterparts, provide environmental benefits ranging from reduced GHG emissions to reduced energy and input consumption. Examples of such biopolymers include: • PHA–Telles™, a Metabolix/Archer Daniels Midland (ADM) joint venture, is starting commercial production in Clinton, IA, in 2008; • PLA–produced by NatureWorks LLC in Blair, NE; and • Sorona®–manufactured by DuPont in the United States and China; Sorona® derived from Bio-PDO™ has a bio-based content of 37 percent. Companies are also developing and producing products such as propylene glycol in the United States and Europe using bio-based glycerin as a feedstock. The glycerin is produced as a byproduct of biodiesel production. Companies are also working to generate bio-based chemicals (e.g., biopolymers) in plants. Metabolix is currently studying production of PHA in *Arabidopsis* and switchgrass. A Rohm and Haas and Ceres collaboration is focusing on developing genetically-engineered plants—eventually energy crops such as switchgrass—that will produce enhanced amounts of methacrylate monomers; the monomers would be extracted from the dried stalks, stems, and leaves before the plant itself is converted into cellulosic ethanol in a biorefinery.[7] Cargill developed and commercialized production of bio-based flexible foam polyols (marketed under the BiOH™ brand name) derived from vegetable oils such as soybean oil. Other companies, including DuPont, are deriving bio-based chemicals from soybeans.
Second-generation biorefineries	Numerous biorefineries are being developed to produce cellulosic ethanol. Once the technology fully evolves, integrated biorefineries will also be able to produce other liquid biofuels (e.g., biobutanol), as well as a variety of chemical co-products that are expected to offset the cost of producing the biofuel(s), potentially improving the biofuels' competitiveness. Such technology is the focal point of projects such as the expected demonstration facilities being brought onstream in 2008 in the United States by companies such as Abengoa, BlueFire, Iogen, Verenium, and future projects, including a facility proposed by the newly-formed joint venture between DuPont and Genencor.

[1] Industry official, e-mail message to Commission staff, May 12, 2008, and telephone interview with Commission staff, May 13, 2008.
[2] Simonite, "GM Bacteria Churn Out 'Microdiesel' Fuel," September 19, 2006; and Society for General Microbiology, "New Fuels from Bacteria," September 26, 2006.
[3] USDOE, Pacific Northwest Laboratory, "Bio-Based Products," undated (accessed May 12, 2008); and USDOE, NREL, "Biochemical Conversion Technologies–Projects," November 6, 2007.
[4] Ran, et al., "Recent Applications of Biocatalysis," December 4, 2007; Weintraub, "Biotech Heads for the Factory Floor," August 2, 2004; and DuPont, "Fermentation: A New Take on Old Technology," 2007.
[5] Truesdell, Pfizer, "Biotransformations for a Green Future," October 2005, 44–47; and industry officials, e-mail messages to Commission staff, February 12, 2008, and April 8, 2008.
[6] Range Fuels, "U.S. Department of Energy Awards Range Fuels up to $76 Million Grant," February 28, 2007.
[7] Ahmann and Dorgan, *Bioengineering for Pollution Prevention*, 2007, 48; industry officials, interview by Commission staff, Washington, DC, March 20, 2007; Metabolix, Inc., "Form 10-K. . . for Fiscal Year Ended December 31, 2006"; Kourtz, et al., "Chemically Inducible Expression of the PHB Biosynthetic Pathway in *Arabidopsis,*" December 2007; Ceres Inc., "Ceres and Rohm & Haas to Study Plant-Based Bioproducts," April 30, 2007; Dorgan, et al., "Ecobionanocomposites: A New Class of Green Materials," June 2007; and Graff, "Biofuel Bonanza Could Create Specialty Chemical Fountainhead," December 13, 2007.

Source: See table footnotes.

In contrast with liquid biofuels, there are reportedly fewer demonstration facilities focused on innovative bio-based chemicals; however, one project is underway to commercialize PHA bio-based plastics. Metabolix has formed a joint venture with ADM, called Telles™, aimed at commercializing their biodegradable bioplastics product, to be marketed under the brand name Mirel™. At the consumer level, the bioplastic can be used in numerous applications, including disposable items such as food containers or flatware, providing a potentially beneficial environmental impact compared with petroleum-based counterparts that are neither biodegradable nor compostable. The Mirel™ biorefinery is a commercial scale operation and is expected to begin operations by the end of 2008. The biorefinery, in Clinton, IA, will be able to produce 110 million pounds of PHA plastic resin annually.[34]

R&D Impediments

Although IB R&D activities are robust, more than 50 percent of respondents report lack of capital as a major impediment; about one-third mentioned U.S. regulatory requirements and the limits of available technology (table 3-8).[35] With respect to U.S. regulatory requirements, one industry representative noted that "development costs in the field are clearly influenced by the costs of regulation and by regulatory uncertainty. IB is such a new field that it is still unclear what regulatory requirements will be applicable or even which federal agency will be the primary regulator."[36] R&D is also impeded by the limits of technology. Technological breakthroughs may be elusive, or, once attained, may not prove viable.

TABLE 3-8
Industrial biotechnology development: Research and development impediment significance, ranked by respondents

Impediment	Total responses	Percentage indicating: Very significant	Least significant
Lack of capital (debt or equity)	396	54	30
U.S. regulatory requirements	390	30	46
Limits of available technology	389	30	43
Inability to qualify for federal grants	389	26	57
Inability to qualify for state grants	383	25	60
Lack of human resources	392	24	52
Poor public perception of bio-products	386	22	61
Inability to establish alliances	385	15	64
Patent barriers	379	10	71
Difficulties accessing university technology	379	9	71

Source: Compiled from data submitted in response to U.S. International Trade Commission questionnaire.

[34] ADM, "Metabolix and ADM to Produce Mirel™," April 23, 2007; and Metabolix Inc., "About Telles," 2006.

[35] A greater number of respondents indicated that U.S. regulatory requirements and the limits of available technology were insignificant. These impediments are likely to be more important to firms developing new, innovative products for which regulations may not exist or the application of existing regulations is unclear, and where technology is unproven.

[36] The Environmental Protection Agency and the Food and Drug Administration were both mentioned as possibilities. Industry representative, interview by Commission staff, Washington, DC, January 11, 2007.

Over one-quarter of respondents stated that R&D impediments were severe enough to dissuade them from pursuing any IB-related R&D activities. This effect was strongest among liquid fuel companies, particularly biodiesel companies (table 3-9). Approximately the same share of respondents (primarily bio-based chemical producers) reported abandoning an ongoing R&D project due to impediments.

TABLE 3-9
Research and development decisions by respondents: All companies and selected company groups

Company type	Number responding: No	Yes	Share of total responding Yes
Decision not to pursue any industrial biotechnology R&D activities:			
All companies	312	116	27
By company groups:			
Liquid biofuel producers	114	53	32
Bio-based chemical producers:			
Pharmaceutical producers	13	4	24
All other producers	57	12	17
Dedicated research and development companies:			
Pharmaceutical companies	24	7	23
All other companies	38	11	22
Decision to abandon one or more industrial biotechnology R&D project:			
All companies	321	109	25
By company groups:			
Liquid biofuel producers	127	41	24
Bio-based chemical producers:			
Pharmaceutical producers:	9	8	47
All other producers	47	22	32
Dedicated research and development companies:			
Pharmaceutical companies	24	7	23
All other companies	32	17	35

Note.—Group data are not mutually exclusive in all cases. For example, some companies produce both liquid biofuels and bio-based chemicals and are included in both groups.

Source: Compiled from data submitted in response to U.S. International Trade Commission questionnaire.

Strategic Alliances

The competitiveness of IB firms often depends on their success in establishing new supply chain alliances to obtain nontraditional feedstocks and develop markets for bio-based products and new technology transfer alliances to access the latest innovations quickly and cost effectively.[37] Alliance activity in IB is strong, particularly in the United States, and strategic alliances in IB are global in scope.

[37] Industry officials, interviews by Commission staff, Washington, DC, March 20, 2007, April 10 and 12, 2007, and June 6, 2007.

Strategic alliances are focused on supply chains—collaborations with agricultural feedstock or enzyme producers, intermediate and end product producers, and distributors and retailers—and technology transfer arrangements. Technology transfer refers to "the movement of know-how, technical knowledge, or technology from one organizational setting to another,"[38] and includes collaborations with universities, R&D organizations (whether independent or part of a larger company), and government entities (federal, state, or local).[39]

Liquid biofuel producers were the largest contributors to the increase in domestic supply chain alliances, and bio-based chemical producers were the largest contributors to the growth in domestic technology transfer alliances. Dedicated R&D companies also engaged in substantially more domestic technology transfer alliances than supply chain alliances. With respect to foreign alliances, liquid biofuel producers were responsible for much of the growth in both supply chain and technology transfer alliances. R&D organizations were the most common foreign partners overall.

The most frequently cited reason for entering into strategic alliances was access to R&D resources and production knowledge, followed closely by access to the domestic market or distribution channels, and agricultural feedstock access (table 3-10). Access to intellectual property, lower operating expenses, and risk reduction also were frequently cited motives for strategic alliances. Bio-based chemical producers, and dedicated R&D companies in particular, identified access to R&D resources, production knowledge, and intellectual property as their top reasons for entering into alliances. In contrast, liquid biofuel companies identified access to feedstocks, domestic markets, and distribution channels as their top reasons for alliances.

TABLE 3-10
Strategic alliances: Respondents' reasons

Reason	Number of responses
Research and development resource access	142
Production knowledge access	116
Domestic market or distribution channel access	110
Agricultural feedstock access	103
Intellectual property access	98
Lower operating expenses	78
Risk reduction	70
Capital access	60
Foreign market or distribution channel access	40
Other biomass access	20

Source: Compiled from data submitted in response to U.S. International Trade Commission questionnaire.

Domestic Supply Chain and Technology Transfer Alliances

Domestic supply chain alliances grew strongly from 2004 through 2007, reflecting the expanding applications and uses of IB products and processes (table 3-11). Alliances with agricultural feedstock providers was the largest category of supply chain alliances,

[38] Bozeman, "Technology Transfer and Public Policy," 2000, 629.
[39] Supply chain and technology transfer alliances may overlap. For example, supply chain alliances with enzyme producers may include technology transfer in the customization of enzymes and processing procedures to meet the customer's particular needs.

TABLE 3-11
Domestic strategic alliances: Number formed by respondents, 2004–07
(*Number*)

Item	2004	2005	2006	2007	2004/07 percent change
Primarily for technology transfer alliances:					
University	93	98	119	186	100.0
Federal government entity	38	30	44	64	68.4
State or local government entity	18	15	44	74	311.1
Other research and development organizations	67	70	104	133	98.5
Total	216	213	311	457	111.6
Primarily for supply chain alliances:					
Agriculture feedstock provider	57	63	133	229	301.8
Enzyme or micro-organism developer or producer	28	24	36	55	96.4
Intermediate product producer	12	25	47	85	608.3
End product producer	51	101	144	188	268.6
Retail marketer	47	63	98	176	274.5
Total	195	276	458	733	275.9
Grand total	411	489	769	1,190	189.5

Source: Compiled from data submitted in response to U.S. International Trade Commission questionnaire.

followed by those with end product producers and retail marketers. Supply chain alliances with agricultural feedstock providers, retail marketers, and end product producers were the leading types of alliances for liquid biofuel producers. The leading category of alliance for bio-based chemical producers was supply chain alliances with end product producers.[40]

Industry representatives report that supply chain alliances are increasing in quantity and scope in concert with the development of new IB products and processes. For example, liquid biofuel and bio-based chemical producers may have alliances with seed companies to develop particular corn varieties best suited to production needs; with farm cooperatives to provide particular crop and biomass inputs; with firms that provide advice and resources to meet transportation, storage and energy requirements; with firms interested in standard and custom co-products; with local and national associations for bio-business promotion; and with retailers for the marketing of bio-based products (box 3-2).[41]

[40] Alliances with end product producers are as varied as the business lines in which IB firms operate; for example, a bio-based chemical producer may have an alliance with a medical device equipment manufacturer to produce inputs that will meet stringent regulatory requirements applicable to the end product. Industry official, telephone interview by Commission staff, February 28, 2008.

[41] Industry official, e-mail message to Commission staff, March 31, 2008; industry official, interview by Commission staff, Blair, NE, May 24, 2007; and industry officials, telephone interviews by Commission staff, February 28, 2008, and March 3 and 13, 2008. See also Caesar, Riese and Seitz, "Betting on Biofuels," 2007, 62.

BOX 3-2 Examples of domestic supply chain strategic alliances

Biofuels: Iogen has negotiated a number of supply chain alliances with farmers and harvesters to manage the supply of wheat straw for the new cellulosic ethanol plant it plans to construct in Idaho. Iogen is attempting to replace the current ad hoc and informal system for the supply of wheat straw with more predictable and formal relationships to ensure access to feedstocks. Contracts with farmers and harvesters reportedly address such issues as supply, pricing, storage, harvesting, and delivery of the biomass.

Bio-based chemicals: NatureWorks has developed new supply chain alliances for its corn-based biopolymer, PLA, which is used in packaging and textile applications. Supply chain alliances with firms that convert the PLA pellets, manufacturers of packaging materials, and retailers all have been critical to production and market development for NatureWorks' new bio-based products. In 2005, for example, NatureWorks and Wal-Mart allied to test PLA-based packaging for various uses, resulting in Wal-Mart's decision to use the product for packaging of fruits and vegetables and to expand uses in the near future. In 2007, NatureWorks reported new uses and applications of its products by an expanded group of retailers, consumer products companies, and packagers.

Sources: ICMR, "NatureWorks: Market Development for Bioplastics," 2007; USDOE, EERE, "Wal-Mart Launches Second Energy-Saving Store in Colorado," November 16, 2005; NatureWorks LLC, "NatureWorks LLC Corporate Overview," April 2007; Altman, Boessen, and Sanders, "Contracting for Biomass," 2006; and Idaho State Journal, "Progress Slow on Shelley Ethanol Plant," May 17, 2007.

Domestic technology transfer alliances showed strong growth during the 2004–07 period, reflecting the increasing movement of IB know-how and technologies among universities, R&D organizations, and government entities. University alliances were the largest category of technology transfer alliances, followed by alliances with R&D organizations and government entities. Technology transfer alliances were particularly important to dedicated R&D companies; the leading categories of alliances were with universities, R&D organizations, and government entities. Bio-based chemical producers focused on alliances with universities and R&D organizations. Although liquid biofuel producers entered into more supply chain alliances than technology transfer alliances, technology transfer alliances with government entities and universities increased rapidly during the period.

Industry representatives report that they are entering into increasing numbers of technology transfer alliances to obtain access to the best talent and cutting edge research and innovations. They seek technology transfer partners that have developed complementary areas of expertise that can be more rapidly and cost effectively accessed through alliances, than through the firm's own operations (box 3-3).[42]

[42] Industry officials, telephone interviews by Commission staff, June 6, 2007, February 22, 28 and 29, 2008, and March 3 and 5, 2008; industry officials, interview by Commission staff, Washington, DC, April 10 and 12, 2007, and June 6, 2007, and Cedar Rapids, Iowa, May 21, 2007.

BOX 3-3 Examples of domestic technology transfer alliances

Biofuels: DuPont is working with John Deere, Michigan State University, Verenium, and the National Renewable Energy Laboratory (NREL) in a project funded in part by a four-year USDOE matching grant to develop a cellulosic ethanol biorefinery. DuPont (through its seed company Pioneer) and John Deere will focus on feedstock collection and distribution; Michigan State is working on life-cycle assessments of farm technology; NREL is contributing technological information regarding pre-treatment options; and DuPont and Verenium are developing new enzymes to hydrolyze the corn stover feedstock. A separate joint venture between DuPont and Genencor also focuses on enabling commercial production of cellulosic ethanol.

BP has committed to invest $500 million over 10 years to establish the Energy Biosciences Institute at the University of California Berkeley in collaboration with the University of Illinois, Urbana-Champaign, and the Lawrence Berkeley National Laboratory to conduct both public and proprietary research into biofuels.

Bio-based chemicals: The Center for Environmentally Beneficial Catalysis (CEBC), a multi-university research center (funded largely by the federal government) involving the Universities of Kansas and Iowa, Washington University in St. Louis, and Prairie View A&M University, focuses on generating technologies that will transform the catalytic manufacture of chemicals into safe and ecological processes. The CEBC's industrial members include Archer Daniels Midland, BASF Catalysts, BP, Chevron, Conoco, DuPont, Eastman Chemical, ExxonMobil, Novozymes, and Procter & Gamble. These alliance partners have preferential access and input into the CEBC's research and often provide employment to its students.

Cargill and Novozymes are collaborating to produce a bio-based version of acrylic acid, a derivative of 3-HPA. The project is being funded in part by a $1.5 million matching cooperative agreement from the USDOE.

Ceres and Rohm and Haas are collaborating on a three-year research project, funded by a $1.5 million grant from the USDA, to determine if energy crops planted for cellulosic ethanol could simultaneously produce methacrylate monomers, a key raw material used in the manufacture of paint and coatings and building materials.

Sources: Schwartz, Masciangioli, and Boonyaratanakornit, "Bioinspired Chemistry for Energy," 2008, 50; Genencor, "DuPont and Genencor Create World-leading Cellulosic Ethanol Company," May 14, 2008; *Greenbiz.com*, "BP Funds $500 Million in Biofuels Research at Berkeley," February 2, 2007; Ceres Inc., "Ceres and Rohm & Haas to Study Plant-Based Bioproducts," April 30, 2007; CEBC, "CEBC News," Summer 2007; and Novozymes, Inc., "Cargill and Novozymes to Enable Production of Acrylic Acid," January 14, 2008.

University alliances in IB often focus on early stage research to determine if new technologies are viable. Viable technologies may then be licensed to spin-off companies for further R&D and progress toward commercialization.[43] A number of leading IB firms are spin-offs from academia. For example, in the 1990s, the University of Florida launched Celunol, a start-up company, to commercialize cellulosic ethanol technology discovered by one of its professors. Alliances with researchers from the University of Florida, Dartmouth, Auburn, the University of Colorado, and the University of California at Davis, helped Celunol to continue development of its core technology.[44] In 2007, Celunol merged with an enzyme producer with academic roots, Diversa, to form Verenium, a company with an

[43] APM Health Europe, "Acquisition vs. Academia," June 15, 2007, 6; Fisher, "How Strategic Alliances Work in Biotech," January 1, 1996, 2; and industry official, telephone interview by Commission staff, March 5, 2008.

[44] The core technology was patented as U.S. Patent No. 5,000,000 and is considered a landmark in the field. Verenium Corporation, "Cellulosic Technology," 2007.

"integrated end-to-end capability" to make cellulosic ethanol.[45] Other leading IB companies such as Metabolix, Mascoma, and Virent also grew from technology and talent with academic roots.[46]

Alliances with government entities take many forms. The federal government uses Cooperative Research and Development Agreements (CRADAs) for collaborative R&D efforts between its agencies and national laboratories and U.S. industries, academia, and other organizations. Each side typically retains its own intellectual property, and the parties negotiate terms for discoveries made during the project. Work-for-Others agreements, by contrast, permit government laboratories to do work for firms on a reimbursable basis. Technical Service and Analytical Service Agreements are for noncollaborative work of a more routine nature. Government entities also license their patents and other inventions to firms for research or commercialization purposes.[47] National laboratory discoveries are also available to state and local governments, as well as the public through the Federal Laboratory Consortium (FLC) for technology transfer. FLC actively supports and encourages the transfer of technology developed in federal laboratories to state and local governments and the private sector. The FLC's State and Local Government Committee is further responsible for ensuring that state and local government organizations are aware of the benefits of technology transfer partnerships with federal laboratories.[48]

Alliance activity of NREL, the lead USDOE laboratory for biomass work, is presented in table 3-12. NREL's CRADAs have included, among many others, biodiesel development partnerships with the National Biodiesel Board and engine maker Cummins Inc.; the development of an integrated corn refinery with DuPont; and research related to enzyme biochemistry, cost, and activity with Genencor and Novozymes.[49] The USDA also enters into CRADAs in IB and holds several patents on biofuel production processes that it licenses to technology transfer partners.[50]

---

[45] Diversa's co-founder, Karl Stetter, conducted ground-breaking research at Germany's University of Regensburg. *Genome News Network*, "A Talk with Microbe Hunter Karl Stetter," October 1, 2004. See also Verenium Corporation Web site, http://www.verenium.com/.

[46] For example, Metabolix's core biopolymer technologies came from research conducted at MIT by one of its founders, Dr. Oliver Peoples. The start-up has grown since its formation in 1992, going public in 2006 and announcing a 50/50 joint venture with ADM to commercialize PHA biopolymers. Metabolix Web site. http://www.metabolix.com/ (accessed March 24, 2008).

[47] USDOE, NREL, "NREL Technology Partnerships," January 10, 2007. For further discussion, see chap. 4.

[48] Federal Laboratory Consortium for Technology Transfer Web site. http://www.federallabs.org/ (accessed February 12, 2008).

[49] Goodman, NREL, "The Road Ahead," August 10, 2007.

[50] USDA, ARS, "Bioenergy and Energy Alternatives," August 2007.

TABLE 3-12
National Renewable Energy Laboratory biomass program technology transfer activities, 2003–07

Mechanism	Total number of agreements	Value of agreements
		Dollars
Cooperative Research and Development Agreements	18	33,080,737
Work-for-Others agreements	6	3,084,629
Technical Service and Analytical Service Agreements	17	533,437
Licenses	19	328,834

Note.— According to NREL, the dollar amounts indicated for CRADAs and WFOs represent combined public and private funding or work-in-kind commitments. The remaining figures represent private payments to NREL for technology transfer activities performed.

Source: National Renewable Energy Laboratory.

Industry representatives note that the federal government is a stable partner and has an important role in providing continuity of funding; university funding tends to be more grant dependent and variable. They also report that government alliances are valuable because they permit the retention of intellectual property rights; a small firm may not have as much negotiating power with a large firm as it does in its government relationships. Like university alliances, government collaborations enable firms to conduct cutting edge R&D of new technologies for which they otherwise may find it difficult to obtain access and funding.[51]

Foreign Supply Chain and Technology Transfer Alliances

The number of foreign strategic alliances increased steadily during the 2004–07 period, rising by 46 percent (table 3-13). Technology transfer alliances were the most prevalent; of these alliances, partnerships with private R&D organizations and foreign universities were the most common. Bio-based chemical producers were most likely to have technology transfer partnerships with foreign organizations.

The frequency of alliances with foreign R&D organizations, universities, and governments suggests that IB establishments with specialized technologies and research capacities are increasingly distributed across the globe (box 3-4). It is often more cost effective for firms to increase the scale of their R&D operations by partnering with establishments in distant countries than by building in-house technical capacities or relocating skilled experts.[52] In some areas, differing infrastructures and institutional capacities have attracted investment from multiple sources and created unique regional expertise advantages.[53]

[51] Industry officials, telephone interviews by Commission staff, February 28, 2008, and March 5, 2008; industry officials, interviews by Commission staff, Chicago IL, May 10 and 11, 2007.
[52] These partnerships also increase the pace of research in the IB industry and eliminate overlapping projects. See Duke University, "North Carolina and the Global Economy," Spring 2004.
[53] For example, a combination of public policies and private sector market developments have generated strong R&D capacities in places like Boston, Munich, Tokyo, and Paris. See Hoffman, "Select Global Biotechnology and Bioscience Clusters," March 5, 2008.

TABLE 3-13
Foreign strategic alliances: Number formed by respondents, 2004–07
(*Number*)

Item	2004	2005	2006	2007	2004/07 percent change
Primarily for technology transfer alliances:					
University	36	37	34	47	30.6
Federal government entity	3	4	5	8	166.7
State or local government entity	0	0	([1])	([1])	([2])
Other research and development organizations	46	34	46	56	21.7
Total	85	75	85	111	30.6
Primarily for supply chain alliances:					
Agriculture feedstock provider	4	3	5	15	275.0
Enzyme or micro-organism developer or producer	14	9	8	10	-28.6
Intermediate product producer	([1])	([1])	15	8	([1])
End product producer	9	13	19	19	111.1
Retail marketer	9	8	8	14	55.6
Total	36	33	55	66	83.3
Grand total	121	108	140	177	46.3

[1] Data withheld to avoid disclosure of confidential business information and not included in totals. However, these data are minor and do not appreciably affect trends.
[2] Not applicable.

Source: Compiled from data submitted in response to U.S. International Trade Commission questionnaire.

BOX 3-4 Example of U.S.-foreign technology transfer strategic alliance

Novozymes North America is an industrial enzyme manufacturer that has built a network of international R&D alliances. Its Denmark-based parent company has followed a strategy of establishing offices, then research organizations, and finally production facilities in countries with growing markets, such as Brazil, India, and China. Novozymes conducts R&D in partnerships with organizations like China Resources Alcohol Corporation (CRAC), which recently agreed to collaborate with Novozymes on cellulosic biofuels research. State-owned organizations like CRAC are attractive partners for multinational biotechnology firms because they cultivate R&D capacity and support collaborations between state-owned industrial biotech enterprises and research establishments, such as those at the Chinese Academy of Sciences' Institute of Microbiology, Southern Yangtze University, and Tsinghua University. While most IB R&D is still done in Europe and the United States, developing countries reportedly have fast-growing and competitively priced pools of scientific talent that are attracting investment and attention from firms like Novozymes.

Sources: Industry officials, telephone interviews by Commission staff, March 27, 2008; *Biopact*, "Novozymes Enters Development Cooperation," June 28, 2007; Chervanak, "Industrial Biotechnology in China," Fall 2006; Zhu, "CNPC, BP May Buy Stakes in Chinese Ethanol Producer," March 14, 2007; and OECD, Directorate for Science, Technology and Industry, Committee for Scientific and Technological Policy, Working Party on Biotechnology, Task Force on Biotechnology for Sustainable Industrial Development, *Globalisation of Industrial Biotechnology R&D*, February 14, 2008, 12.

For all companies, supply chain-based foreign alliances were less common but still significant; the total number of alliances with feedstock providers more than tripled from 2004 to 2007. Alliances with foreign feedstock providers and foreign enzyme and micro-organism developers were the most prevalent for bio-based chemical producers (box 3-5).

BOX 3-5 Examples of U.S.-foreign supply chain strategic alliances

Rising soybean and corn prices have recently made jatropha (a genus of succulent plants, shrubs, and trees native to Central America) more attractive as a liquid biofuel feedstock. Jatropha is drought tolerant and can be grown on land with little agricultural value; it is also insulated from price increases driven by food buyers because it is inedible. UK-based BP (parent company of BP America Inc.) recently formed a joint venture with UK-based D1 Oils to cultivate jatropha in Southeast Asia, Southern Africa, Central and South America, and India.

Similarly, ADM has been working with German automobile maker Daimler AG to develop jatropha. In the future, biofuels will increasingly come from plants like jatropha, as well as cellulosic materials such as agricultural residues, energy crops, and municipal waste, all of which potentially yield more energy per dollar invested.

Sources: D1 Oils plc, "Jatropha: A New Energy Crop," undated (accessed March 10, 2008); BP, "BP and D1 Oils Form Joint Venture," June 29, 2007; Nakanishi, "Jatropha Shines as Non-food Oil for Biodiesel," January 14, 2008; and Royal Society, "Sustainable Biofuels: Prospects and Challenges," 2008, 9.

For liquid biofuel producers, alliances with foreign feedstock producers are relatively infrequent because U.S. producers currently use domestically produced corn as their main input.[54] However, the recent increase in foreign alliances with feedstock providers indicates that firms are beginning to import feedstocks from developing countries that have acreage available for production of biodiesel feedstocks.[55] Biofuel firms can reduce the risk of excessive price fluctuations or crop failures by diversifying supply sources and ensuring year-round access to inputs. Additionally, a continuous flow of feedstocks (which eliminates the need for large and expensive inventory holdings) can be accomplished by importing feedstocks from geographically dispersed economies.[56] As global prices for agricultural commodities fluctuate, firms will adjust and relocate their supply sources, which are subject to change due to new technologies and regulations. Many large, IB-focused companies are multinational, which likely facilitates the creation of foreign strategic alliances.

Some firms are pursuing market opportunities by establishing partnerships with foreign retailers and producers, placing manufacturing and distribution centers in countries with strong consumer markets and optimizing supply chains in these countries to reduce the time between demand and production.[57] These strategies facilitate the early involvement of

---

[54] Runge and Senauer, "How Biofuels Could Starve the Poor," May-June 2007.

[55] De Marzio, "Addressing Global Misconceptions on Biodiesel," September 5–6, 2007. The complexity of globalized supply chains poses particular problems for organizations that try to determine the total environmental impact of biofuels, as each stage of the supply chain must be taken into account when assessing the total environmental footprint. For example, carbon dioxide is released into the atmosphere as a result of deforestation in Indonesia due to growing palm trees for palm oil, as well as in the clearing of land for soybean crops in Brazil. Many organizations indicate that an accurate accounting of the net environmental impact of palm oil- or soybean-derived biofuels includes these effects from cropland use. See Zah, et al., *Life Cycle Assessment of Energy Products,* May 22, 2007.

[56] Royal Society, "Sustainable Biofuels: Prospects and Challenges," 2008, 21.

[57] See Su and Shong-Iee, "The Emerging Global Direct Distribution Business Model," Fall 2007.

potential users and strengthen downstream innovation.[58] For example, U.S.-based biopolymer producer NatureWorks LLC has created strategic alliances with domestic and foreign compounders (i.e., companies that create new materials by combining multiple polymers) to extend its global market access. In Korea, NatureWorks products are delivered to the marketplace by a network of local plastics processors that supply packaging materials to supermarket chains like E-Mart.[59] The NatureWorks brand is also valuable to global businesses that rely on an environmentally friendly image, such as Green Mountain Coffee Roasters, which uses hot beverage cups coated with PLA.[60]

Intellectual Property

Patents, trademarks, and other types of IP protections are critical preconditions to the development and adoption of IB; without them, many firms would be unable or unwilling to invest the substantial funds required to bring IB products and processes to market. There has been a significant increase in patent and trademark filings, reflecting new discoveries in IB processes and products, new brands, and more IP transactions between firms (tables 3-14–3-17).

The growth in trademark registrations was especially strong, with bio-based chemical producers being particularly active in registering new trademarks to protect their bio-based inputs and final products. Patent applications also increased, driven by increased patenting by dedicated R&D firms.[61] Income from licensing and sales of IP by IB firms and costs attributable to licensing and purchases of IP also showed strong growth from 2004 to 2007.[62] Liquid biofuel producers, bio-based chemical producers, and dedicated R&D companies all increased their IP income and costs, with the transactions of bio-based chemical producers,

---

[58] OECD, Directorate for Science, Technology and Industry, Committee for Scientific and Technological Policy, Working Party on Biotechnology, Task Force on Biotechnology for Sustainable Industrial Development, *Globalisation of Industrial Biotechnology R&D*, February 14, 2008, 4.

[59] NatureWorks LLC, "NatureWorks PLA is Environmentally Friendly Alternative," March 22, 2006.

[60] NatureWorks LLC, "Green Mountain Coffee Roasters Launches First Hot Beverage Cups," August 14, 2006.

[61] Data on intellectual property activities should be interpreted with caution. Pharmaceutical companies, in particular, reported that it was extremely difficult to isolate IB patents from other types of biotechnology patents, especially given the varying definitions of IB within the industry and for purposes of this study. Moreover, enzymatic and genetic processes often are combined to produce an end product, making it difficult to categorize a particular discovery. Commission staff attempted to verify data through follow-up telephone interviews. Where it was possible for a company to estimate a ratio of IB patents to other patents, or to estimate that portion of licensing income attributable to IB, such ratios were applied to the data. Where not possible, a null value was reported. Not all responses could be verified.

[62] IP licensing refers to the transfer of a right to use a particular type of intellectual property, for example a trade secret or patent, and includes royalties and other types of payments for the right to use the property. IP purchases and sales refer to the transfer of all of the rights associated with the intellectual property from one firm to another, not just the transfer of a right to use the property.

TABLE 3-14
Intellectual property: Respondents' activity, 2004–07

Item	2004	2005	2006	2007	2004/07 percent change
	Number				
Patents and trademarks:					
New patent applications	797	793	806	939	17.8
New trademarks registered	197	633	767	1,027	421.3
	Value (*1,000 dollars*)				
Intellectual property income and costs:					
Income:					
Licensing	15,930	24,335	26,008	60,839	281.9
All other income	([1])	3,133	3,885	4,138	([1])
Total	15,930	27,468	29,893	64,977	307.9
Costs[2]	230,230	228,413	251,726	323,478	40.5

[1] Data withheld to avoid disclosure of confidential business information and not included in totals. However, these data are minor and do not appreciably affect trends.
[2] Detailed data aggregated to avoid disclosure of confidential business information.

Source: Compiled from data submitted in response to U.S. International Trade Commission questionnaire.

TABLE 3-15
Intellectual property: Respondents' patent applications and trademarks registered, by company groups, 2004–07
(*Number*)

Item	2004	2005	2006	2007	2004/07 percent change
Patents and trademarks:					
New patent applications:					
Liquid biofuel producers	122	123	119	125	2.5
Bio-based chemical producers:					
Pharmaceutical producers	117	113	106	145	23.9
All other producers	432	338	348	348	-19.4
Dedicated research and development companies:					
Pharmaceutical companies	67	81	95	80	19.4
All other companies	106	165	135	225	112.3
New trademarks registered:					
All producers[1]	139	([2])	701	800	475.5
Dedicated research and development companies[1]	42	19	29	168	300.0

[1] Detailed company group data aggregated to avoid disclosure of confidential business information.
[2] Data withheld to avoid disclosure of confidential business information.

Note.—Group data are not mutually exclusive in all cases. For example, some companies produce both liquid biofuels and bio-based chemicals, and are included in both groups. Therefore, the sum of these will not equal the total(s) shown elsewhere in this report.

Source: Compiled from data submitted in response to U.S. International Trade Commission questionnaire.

TABLE 3-16
Intellectual property: Respondents' income and costs, by company groups, 2004–07
(*1,000 dollars*)

Item	2004	2005	2006	2007	2004/07 percent change
Income:					
All producers[1]	([2])	15,858	17,440	33,498	([2])
Dedicated research and development companies:					
Pharmaceutical companies	([2])	10,793	9,964	28,871	([2])
All other companies	([2])	1,202	2,554	3,523	([2])
Costs:					
Liquid biofuel producers	([2])	([2])	([2])	([2])	625.7
Bio-based chemical producers:					
Pharmaceutical producers	([2])	([2])	([2])	([2])	16.2
All other producers	14,702	21,890	19,213	22,960	56.2
Dedicated research and development companies:					
Pharmaceutical companies	39,642	40,432	50,898	([2])	([2])
All other companies	([2])	663	1,733	3,547	([2])

[1] Detailed company group data aggregated to avoid disclosure of confidential business information.
[2] Data withheld to avoid disclosure of confidential business information.

Note.—Group data are not mutually exclusive in all cases. For example, some companies produce both liquid biofuels and bio-based chemicals, and are included in both groups. Therefore, the sum of these will not equal the total(s) shown elsewhere in this report.

Source: Compiled from data submitted in response to U.S. International Trade Commission questionnaire.

TABLE 3-17
Patents: Number granted to respondents, 1997–2007

Item	Number of patents
Domestic patents:	
All companies	3,628
By company groups:	
Liquid biofuel producers	211
Bio-based chemical producers:	
Pharmaceutical producers	997
All other producers	1,762
Dedicated research and development companies[1]	662
Foreign patents:	
All companies	9,899
By company groups:	
Liquid biofuel producers	399
Bio-based chemical producers:	
Pharmaceutical producers	677
All other producers	6,697
Dedicated research and development companies[1]	1,029

[1] Detailed data aggregated to avoid disclosure of confidential business information.

Note.—Group data are not mutually exclusive in all cases. For example, some companies produce both liquid biofuels and bio-based chemicals, and are included in both groups. Therefore, the sum of these will not equal the total(s) shown elsewhere in this report.

Source: Compiled from data submitted in response to U.S. International Trade Commission questionnaire.

and particularly IP expenditures by pharmaceutical companies, predominating.[63] Industry representatives confirm that IP protections of all types provide incentives to invest in innovation, facilitate the transfer of technology, and open doors to financing and capital markets by providing a basis for valuing the results of (often substantial) R&D investments.[64]

Patenting

Patents are an important underpinning for innovation in IB.[65] Industry representatives report that they are particularly important for firms seeking to protect R&D investments, secure venture financing, or enter into licensing agreements with other firms for the further development and commercialization of their inventions.[66] The financing opportunities and strategic alliances facilitated by patents allow dedicated R&D companies in particular to stay in business, notwithstanding cash-flow positions that are often negative, decades-long research and product development times, and complex regulatory processes.[67] Patents also serve to advance technical knowledge in the field, as the party seeking the patent must disclose the technology to the public, allowing it to be studied and improved upon.

Patent applications and patent grants are frequently cited as indicators of the inventiveness of countries and firms.[68] However, there are benefits and limitations to using the numbers of patent applications and grants as a measure of innovation. On the benefit side, these data are readily available through the U.S. Patent and Trademark Office (USPTO) and other patent offices and contain substantial detail about firms' activities; additionally, these data are historical, permitting the analysis of trends. Data limitations include the fact that not all inventions are patented, many patents are never commercialized or licensed, patent applications and granted patents substantially lag underlying inventions, and patent applications can overstate levels of successful innovation.[69] Despite these limitations, however, these data provide a useful window into firms' innovative activities.

---

[63] Pharmaceutical industry representatives reported that for many IP-related transactions it is not possible to apportion between the value of an IB platform technology and that of the pharmaceutical compound that is made by using the platform technology. Moreover, the value of the IP is largely driven by whether the compound is in early or late stages of clinical review and approval. Thus, the reported data may overstate the value of IB intellectual property in pharmaceutical transactions. Industry officials, telephone interviews by Commission staff, February 25 and 28, 2008.

[64] Industry officials, interviews by Commission staff, Washington, DC, January 11, 2007, March 20, 2007, and April 12, 2007, and Chicago, IL, May 9, 2007; and industry officials, telephone interviews by Commission staff, March 6, 2007, February 25, 28, and 29, 2008, and March 5, 2008.

[65] The U.S. Supreme Court greatly assisted in the growth of the biotechnology industry with its 1980 decision in Diamond v. Chakrabarty, 447 U.S. 303, 309 (1980), holding patentable a genetically-engineered oil-eating bacterium. That decision fueled industry investment and patenting. FTC, *To Promote Innovation*, 2003, 1718.

[66] Industry officials, interviews by Commission staff, Washington, DC, January 11, 2007, March 20, 2007, and April 12, 2007, and Chicago, IL, May 9, 2007; and industry officials, telephone interviews by Commission staff, March 6, 2007, February 25, 28, and 29, 2008, and March 5, 2008.

[67] BIO, statement submitted to the Senate Committee on the Judiciary, October 24, 2007, 1; and industry officials, interviews by Commission staff, Washington, DC, December 7, 2006, and March 20, 2007.

[68] See NSB, *Science and Engineering Indicators 2008*, 2008, 6-38; and ASTRA, *Innovation Indicators for Tomorrow*, 2008, 3.

[69] NAS, *Industrial Research and Innovation Indicators*, 1997, 24; NSB, *Science and Engineering Indicators 2008*, 2008, 6-38; ASTRA, *Innovation Indicators for Tomorrow*, 2008, 3; USPTO, *Performance and Accountability Report*, December 21, 2007; and Allison and Lemley, "Who's Patenting What?" 2000, 2099.

Patent Applications

There were 3,335 patent applications related to IB filed during the 2004–07 period (tables 3-14 and 3-15). IB patent application filings grew by 18 percent from 2004 to 2007, driven in large part by the increased activity of dedicated R&D companies, and particularly those conducting biofuel and bio-based chemical R&D unrelated to pharmaceuticals. The strong growth in patenting by R&D companies suggests that they are important contributors to the increasing level of innovation in IB. Dedicated R&D companies report that patents are often the most important part of their business; they are the most important product they generate, and are required by outside investors that often base financing decisions on a valuation of the patent portfolio.[70]

Bio-based chemical producers outside the pharmaceutical sector accounted for the largest share of patent applications, although their patenting declined from 2004 to 2007. Companies that identify the production of enzymes and micro-organisms as their main lines of business accounted for many of the innovations in the patent applications filed by bio-based chemical producers. These innovations often are relevant to liquid biofuels, e.g., enzymes used to produce cellulosic ethanol, as well as bio-based chemicals. The largest bio-based chemical producers (in terms of sales revenues) were responsible for most of the patent application activity. Liquid biofuel producers filed substantially fewer applications than bio-based chemical producers, and the number of filings remained relatively flat. Corn ethanol and biodiesel producers filed most of the liquid biofuel producers' patent applications, and again the largest producers were responsible for most of the patenting. Although small R&D firms focus on the discovery and patenting of new technologies, small producers of bio-based chemicals and liquid biofuels generally are not active in seeking patents.

Patents Granted

Bio-based chemical producers, and particularly companies specializing in the production of enzymes and micro-organisms, accounted for most of the 3,628 domestic and 9,899 foreign IB-related patents granted from 1997 through 2007. Most foreign patents are held by bio-based chemical producers; in general, chemical companies have operations that are more multinational in scope than the other bio-based sectors. Industry representatives report that decisions about where to patent are driven in large part by the importance of the technology to the firm's business, the strength of the patent claim, and the size and relative importance of the market.[71] For important technologies with strong claims, companies patent in their most important current and future markets. Less important patents or those with riskier claims are filed in fewer locations.[72] U.S. bio-based industries consider European countries and China their most important foreign filing locations, followed by India, Japan, Brazil,

[70] Industry officials, interviews by Commission staff, Chicago, IL, May 9, 2007; and industry officials, telephone interviews by Commission staff, February, 25, 28, and 29, 2008, and March 5, 2008. A number of studies have found that the value of biotechnology firms increases with the number of patents obtained, their content, and the breadth of their coverage. Lerner, "The Importance of Patent Scope," 1994, 320.

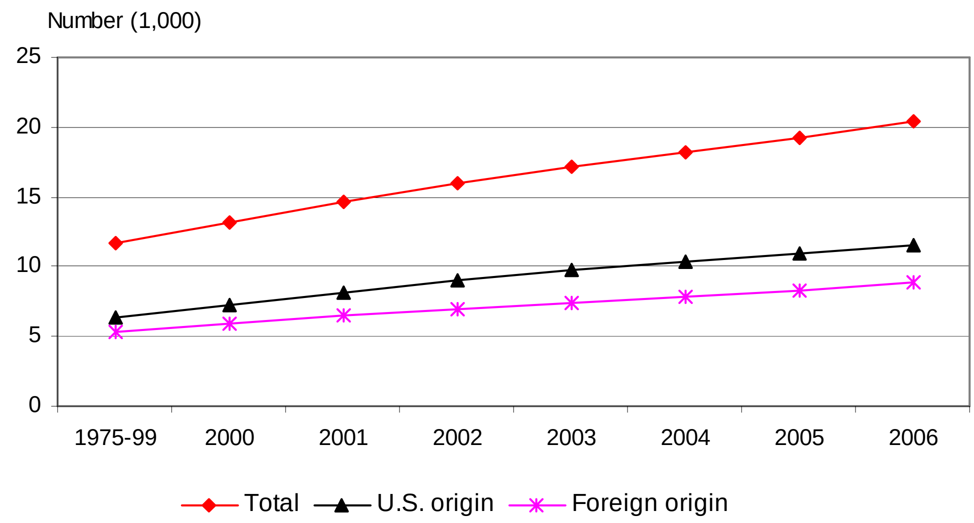
[71] Industry officials, telephone interviews by Commission staff, March 6, 2007, December 12, 2007, January 17, 2008, and February 11, 22, and 25, 2008. Foreign patenting is facilitated by the streamlined procedures of the Patent Cooperation Treaty (PCT), under which an applicant may file an international application in one jurisdiction and, after processing, seek national patents in the offices of PCT members.

[72] Industry officials, telephone interviews by Commission staff, March 6, 2007, December 12, 2007, January 17, 2008, and February 11, 22, and 25, 2008.

Canada, and Mexico. A number of firms reported increasing patent activity in China despite ongoing concerns about patent review, enforcement, and infringement.[73]

Although broader in scope than the Commission's inquiry, results of a USPTO search[74] also suggest substantial and growing levels of innovation in IB. The USPTO search showed increasing numbers of IB-related patents granted; 11,716 patents were granted during the 1975–2000 period, growing rapidly to 20,418 patents granted by 2006 (figure 3-3).[75] In 2006, 55 percent of the patents granted by the USPTO were to U.S. owners and 45 percent were to foreign owners. U.S. corporations were the largest source of inventions, followed by foreign corporations, U.S. and foreign individuals, the U.S. government, and foreign governments. In 2006, Japan was the top source of foreign-owned patents and California the top source of domestically-owned IB-related patents (figures 3-4 and 3-5).

FIGURE 3-3
Industrial biotechnology-related patents granted, U.S. and foreign origin, cumulative, 1975–2006



Source: U.S. Patent and Trademark Office.

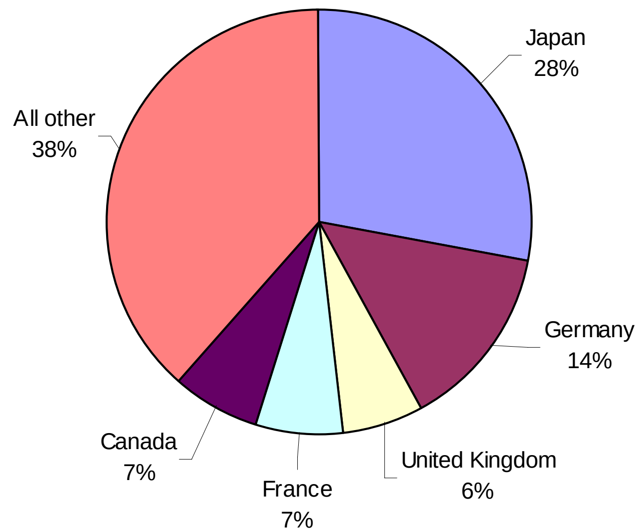
---

[73] Industry officials, interviews by Commission staff, Chicago, IL, May 9, 2007, Washington, DC, March 20, 2007, and Cedar Rapids, IA, May 21, 2007.

[74] To supplement the Commission's questionnaire, and with the assistance of the USPTO, the Commission searched patent grants in the area of IB for the period from January 1975 through December 2006. The USPTO search was class-based, relying on classes and subclasses of the U.S. Patent Classification System (USPC) identified from a set of model patents in the areas of biofuels, biopolymers, enzymes, chemical processes, and pharmaceuticals. The USPTO recommended class-based searching rather than text or key word searching, which is considered to generate unrefined results. Government official, e-mail message to Commission staff, April 25, 2007. The model patents identified subclasses within the following USPC classes: Chemistry: Molecular Biology and Microbiology (most subclasses were within this class); Organic Compounds; and Sugar, Starch and Carbohydrates. The results are broader in scope than those of the Commission's questionnaire in that they include all patents with the same classifications as the model patents. Moreover, unlike the questionnaire, which was limited to firms in the liquid fuel and chemical industries, the USPTO search included firms from all industries, individuals, government, and academic inventors, as well as applications filed by foreign inventors. The results thus illustrate trends and characteristics of inventors across a much broader field than the Commission's survey.

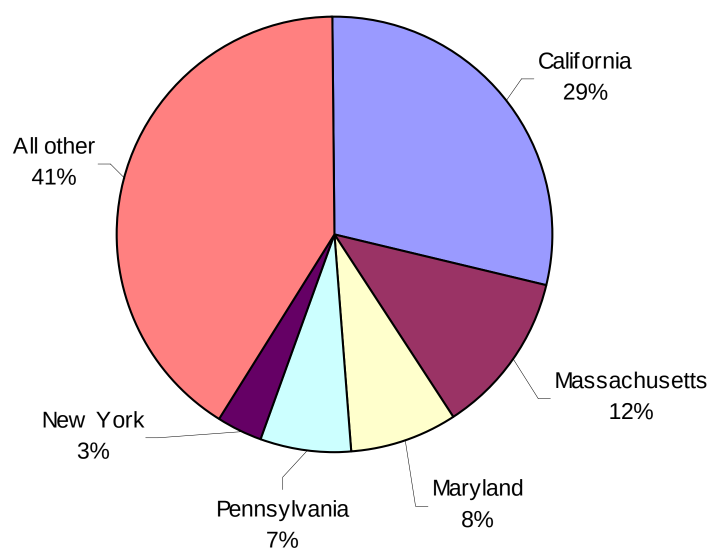
[75] To put these results into the context of the broader field of all biotechnology patenting, the USPTO reported a total of 112,360 patents granted in all biotechnology fields through 2005. USPTO, Electronic Information Products Division, Patent Technology Monitoring Branch, *Patent Technology Center Groups 1630-1660*, 2006.

FIGURE 3-4
Foreign-origin patents, by country, 2006



Source: U.S. Patent and Trademark Office.

FIGURE 3-5
Domestic-origin patents, by state, 2006



Source: U.S. Patent and Trademark Office.

Trademarks

Increased trademark activity in the field of IB is an indicator of substantial innovation and growth in the field.[76] Trademarks are distinctive signs used to uniquely identify the source of products or services; they protect business identity and reputation and foster product differentiation. The branding enabled by trademarks is an important part of firms' marketing of their innovations; the launch of a new product or service often is accompanied by a new trademark.

The strong growth in IB trademark registrations during the 2004–07 period was largely driven by significant increases in registrations by nonpharmaceutical bio-based chemical producers. Enzyme companies in particular identified large increases in trademark registrations. Dedicated R&D companies outside of the pharmaceuticals field also posted substantial percentage gains in trademark registrations, as did liquid biofuel producers. The large percentage increases in trademark registrations across almost all subgroups are particularly striking when compared to the smaller percentage increases in patent application filings.[77]

Industry representatives explain the trademark trends by noting that IB trademarks are gaining increasing importance as the field matures, moving from early discoveries to commercialization of innovative technologies and products.[78] They also note that increased consumer interest in the environment and in energy independence has spurred more bio-branding.[79] For example, trademark registrations in the energy field that include the word "green" have increased tenfold since 2004.[80] Moreover, trademarks are used to cover inputs as well as end products. Enzyme producers report that because their brands are associated with high quality and innovation, customers are using language indicating that a particular enzyme has been used in making an end product.[81]

Licensing and Purchases and Sales

IB companies are reportedly licensing out or selling technologies that are not within their core business areas and can be more effectively commercialized by others and obtaining licenses for or purchasing new technologies that provide a better fit with their missions. Industry representatives report that strong increases in licensing and purchase and sales transactions reflect an active market as new technologies and innovations are disseminated

---

[76] Mendonca, Pereira, and Goinho, "Trademarks as an Indicator of Innovation," 2004, 1385–1404. By contrast, trade secrets typically are not cited as an innovation indicator because they do not require any sort of application or registration that can be easily measured. They arise as a matter of law when a firm develops information of commercial value that is not generally known and takes reasonable steps to protect it. Trade secrets often are relied upon when the commercial value of an idea is unclear, when innovations are incremental and rapid and thus not practical to patent, and in strategic alliances. Industry officials, interviews by Commission staff, Chicago, IL, May 9, 2007, and Washington, DC, March 20, 2007.

[77] Trademarks generally are less costly and quicker to obtain than patents; the registration process takes about 15 months. USPTO, *Performance and Accountability Report*, December 21, 2007.

[78] Industry officials, telephone interviews by Commission staff, January 17, 2008, February 25 and 29, 2008, and March 3 and 5, 2008.

[79] Industry officials, interviews by Commission staff, Washington, DC, January 11, 2007, February 7, 2007, March 20, 2007, and April 12, 2007, Chicago, IL, May 9, 2007, and Cedar Rapids, IA, May 21, 2007.

[80] Fuierer, "The Growth of Green Trademarks," 2008.

[81] Industry official, telephone interview by Commission staff, January 17, 2008. Similarly, NatureWorks has noted that increasing numbers of consumer brand companies—for example in cosmetics and organic foods—are launching products using NatureWorks® polymer as a brand enhancer. NatureWorks LLC, "NatureWorks LLC Corporate Overview," April 2007.

across firms. New participants can become competitive more quickly through IP purchases and licensing. IP sales and licensing to other companies permit IB firms to recoup substantial investments in IB R&D and thus provide resources for ongoing activities. These revenues are particularly important for dedicated R&D companies that generally are not able to finance their ongoing operations with product sales.[82]

The liquid fuel and chemical industries registered strong growth in IP income and costs from 2004 to 2007 (tables 3-14 and 3-16). IP costs were substantially larger than IP income, although income grew at a much faster rate. The activities of pharmaceutical companies, both producers and dedicated R&D companies, substantially contributed to the large increases in IP income and costs; a small number of high-value transactions affected the results.

IP-related Impediments

IP-related impediments, such as patent barriers and high licensing costs, are generally not considered significant impediments to R&D or the commercialization of products by questionnaire respondents. In general, pharmaceutical companies, both those that produce bio-based chemicals and dedicated R&D companies, identified greater levels of concern with patent barriers and high licensing costs than other types of companies. This is not surprising given that their activities are more IP-intensive than those of liquid biofuel producers.

Representatives of smaller firms expressed concerns about the competitive disadvantage that results from the publishing of patent applications on the Internet 18 months after filing, despite the fact that the granting of the patent does not occur for years. This delay makes valuable details about the nature of the invention available to rivals without the full benefits and protections of a granted patent.[83] Smaller firms also identified patenting and enforcement costs as burdensome, noting that the funds for patenting can be difficult to obtain, especially because government grants often cannot be used for this purpose. IP litigation costs can also be burdensome, particularly for smaller firms.[84]

However, industry representatives reported that the opportunity to recoup R&D investments through the market exclusivity of a patent or trademark or to obtain financing based on a strong IP portfolio provides valuable competitive advantages to IB firms that far outweigh IP-related impediments.[85] Industry representatives noted that IP risks generally are considered to be unavoidable in a field characterized by rapid innovation and substantial IP activities; they are part of the calculations that firms regularly make in determining business strategy.

---

[82] Industry officials, telephone interviews by Commission staff, February 22, 25, and 28, 2008, and March 5, 2008.

[83] Industry officials, telephone interviews by Commission staff, February 28 and 29, 2008, and March 5, 2008.

[84] Industry officials, interviews by Commission staff, Washington, DC, February 7, 2007, March 20, 2007, and April 12, 2007, and Chicago, IL, May 9, 2007.

[85] Industry officials, telephone interviews by Commission staff, December 12, 2007, January 17, 2008, February 22, 25, 28, and 29, 2008, and March 5, 2008; and industry officials, interviews by Commission staff, Washington, DC, December 7, 2006, January 11, 2007, February 7, 2007, March 20, 2007, and April 12, 2007, and Chicago, IL, May 9, 2007.

CHAPTER 4
U.S. and Foreign Government Policies and Programs

This chapter identifies and examines pertinent government support policies in the United States and provides a comparative description of the policies in Brazil, Canada, China, the EU,[1] and Japan. These countries and the EU were selected for examination and comparison because questionnaire responses and independent research identified them as having the most extensive policies to support IB. A summary table describing the liquid biofuel and bio-based chemical activities in the United States, in other major producing countries, and in smaller scale producing countries is found in appendix C.

Governments choose to support early-stage, high-risk IB R&D for a variety of reasons, including to address the absence of market incentives, promote the potential public benefits in the areas of renewable, or bio-based, fuels and chemicals, increase national competitiveness, and create high-quality jobs. Further, governments may support commercialization to bring IB products to market and to gain market share against conventional products with which they may not initially be cost competitive. Countries have numerous approaches to supporting the development and adoption of IB by their liquid fuel and chemical industries. It is difficult, if not impossible, to quantitatively compare government policies across countries.

Targeted U.S. and foreign government support for the development and adoption of IB is much more extensive for the liquid fuel industry than for the chemical industry. Such targeted support is largely driven by energy security concerns, and to a lesser extent, interest in supporting agricultural activities.

Policies identified by questionnaire respondents that contribute to the development and adoption of IB by the liquid fuel and chemical industries include: (1) research, development, and commercialization (RD&C) support; (2) tax incentives; (3) mandatory use regulations; (4) loan guarantees; and (5) agricultural feedstock policies. The U.S. liquid biofuel and bio-based chemical industries rank federal tax incentives, mandatory use regulations for final products, and state or local tax incentives as the most important U.S. government policies supporting the development and adoption of IB (table 4-1). The policies of the United States, Brazil, Canada, China, the EU, and Japan are summarized in table 4-2, along with those of other countries that are active in IB.[2]

According to one source, over one-half of all U.S. government support for ethanol and nearly all government support for biodiesel, at the state and federal level, comes in the form of tax incentives.[3] Ethanol producers in particular highlighted the importance of the ethanol import

[1] The current 27 member states of the EU are: Austria, Belgium, Bulgaria, the Czech Republic, Cyprus, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovenia, Slovakia, Spain, Sweden, and the United Kingdom.

[2] The policies of these other countries are not expanded upon in the text.

[3] Koplow, *Biofuels—At What Cost?* 2006, 51.

tariff,[4] as well as government programs supporting agricultural feedstock supply and utilization. Following tax incentives, bio-based chemical producers indicated the importance of collaboration with government agencies and government procurement of bio-based products. Stand-alone research companies reported that government grants are an important form of support for their IB activities.

With respect to the United States, in a submission to the Commission, chemical and materials manufacturer Rohm and Haas stated that, “while bio-based fuels have benefitted and grown from substantial tax credits, no such credits are available for the chemical uses of these bio-based materials. The availability of a tax credit for bio-based chemicals could dramatically help the growth of their use in chemical manufacturing while helping to meet the same objectives of the fuel tax credit programs—reduced dependence on imported petroleum products and the stimulation of the US rural economy.”[5] Some industry officials further claim that U.S. government support for liquid biofuels may be having a detrimental effect on the chemical industry’s development and adoption of IB. According to the Soap and Detergent Association, “tax credits for the use of ‘animal fats’ as alternative fuels are threatening the viability of domestic oleochemical producers whose customers include cleaning products formulators, and plastic, tire and lubricant manufacturers. These credits, for the production of biodiesel, the direct burning of fats as fuel, and for ‘co-production of renewable diesel,’ are directly subsidizing the diversion of the oleochemical industry’s critical raw material, tallow, to non-oleochemical applications.” The association also noted that “ethanol subsidies are also depleting the tallow supply. Ironically, tallow-based, traditionally ‘green’ oleochemicals stand to be run over by subsidies for biofuels.”[6] Dow Chemical echoed these sentiments, stating that “renewable chemical production should not be disadvantaged vs. renewable fuel production by subsidies that apply only to biofuels.”[7]

[4] See chap. 2 for more information about the U.S. tariff treatment for ethanol.
[5] Rohm and Haas, written submission to the USITC, August 1, 2007.
[6] Soap and Detergent Association, written submission to the USITC, November 1, 2007.
[7] Dow, written submission to the USITC, April 10, 2007.

TABLE 4-1
Government programs: Respondents' indication of importance in supporting development or adoption of industrial biotechnology

Program	Total responses	Percentage indicating: Very important	Least important
All companies:			
Federal tax incentives	350	61	33
Mandatory use of final products	332	51	41
State or local tax incentives	340	46	42
U.S. government agricultural feedstock supply support	335	41	47
U.S. government agricultural feedstock utilization support	329	37	51
Government procurement of bio-based products	330	28	60
State or local government grants	326	28	63
Department of Energy grants	327	28	66
U.S. import tariff	328	27	60
Collaboration with government agencies	326	26	60
Other federal agency grants	328	26	66
Department of Agriculture grants	331	26	66
Mandatory use of intermediate products	319	18	67
Federal loan guarantees	327	17	73
State or local loan guarantees	319	16	73
By company groups:			
Dedicated research and development companies:			
Department of Energy grants	59	41	58
Other federal agency grants	62	40	53
Federal tax incentives	60	37	57
Collaboration with government agencies	56	30	61
Department of Agriculture grants	60	30	67
Mandatory use of final products	57	28	70
State or local government grants	59	27	66
State or local tax incentives	58	26	62
Federal loan guarantees	58	22	78
U.S. government agricultural feedstock utilization support	58	22	69
U.S. government agricultural feedstock supply support	58	21	71
Government procurement of bio-based products	59	20	73
State or local loan guarantees	55	20	78
Mandatory use of intermediate products	58	19	74
U.S. import tariff	55	15	76
Liquid biofuel producers:			
Federal tax incentives	176	89	7
Mandatory use of final products	165	73	15
State or local tax incentives	168	65	22
U.S. government agricultural feedstock supply support	167	62	23
U.S. government agricultural feedstock utilization support	163	55	31
U.S. import tariff	162	42	43
Government procurement of bio-based products	160	37	45
State or local government grants	158	36	51
Department of Agriculture grants	163	34	56
Collaboration with government agencies	160	31	53
Department of Energy grants	160	30	60

See source at end of table.

TABLE 4-1—*Continued*
Government programs: Respondents' indication of importance in supporting development or adoption of industrial biotechnology

Program	Total responses	Percentage indicating: Very important	Least important
By company groups—*Continued*			
Liquid biofuel producers—*Continued*			
Other federal agency grants	157	29	61
Mandatory use of intermediate products	152	25	55
Federal loan guarantees	159	23	62
State or local loan guarantees	155	21	63
Bio-based chemical producers:			
Federal tax incentives	59	27	63
Collaboration with government agencies	56	21	61
Government procurement of bio-based products	56	21	73
State or local tax incentives	58	21	69
Mandatory use of final products	55	16	78
Other federal agency grants	55	16	80
U.S. government agricultural feedstock supply support	55	16	75
State or local government grants	53	15	79
Department of Energy grants	54	15	83
Department of Agriculture grants	52	10	88
U.S. government agricultural feedstock utilization support	54	9	80
U.S. import tariff	55	9	87
State or local loan guarantees	52	6	92
Mandatory use of intermediate products	54	4	89
Federal loan guarantees	54	4	94

Note.—Group data are not mutually exclusive in all cases. For example, some companies produce both liquid biofuels and bio-based chemicals, and are included in both groups.

Source: Compiled from data submitted in response to U.S. International Trade Commission questionnaire.

TABLE 4-2
Government policies directly supporting development or adoption of industrial biotechnology by the liquid fuel and chemical industries in the United States and selected countries

Major countries		
United States	R&D and commercialization support	The USDOE's Biomass and Biorefinery Systems program provides R&D support for biomass and biorefineries. The Biomass Research and Development Initiative (BRDI), a multi-agency program established by the 2000 Biomass Research and Development Act (BRDA), coordinates federal R&D support for biofuels and bio-based products. Small Business Innovative Research (SBIR) and Small Business Technology Transfer (STTR) programs provide grants to qualified small business for research and commercialization of technology, respectively, including IB. Cooperative research and development agreements (CRADAs) negotiated between national research laboratories and outside organizations in industry, academia, etc., provide a contractual R&D framework delineating the partners' roles and contributions, business confidentiality, and intellectual property protection, among other concerns. The Federal Transfer Consortium (FTC) facilitates dissemination (technology transfer) of national laboratories' R&D findings to the private sector. Additional federal legislation that sets goals and provides funding for IB R&D includes the 2007 Energy Independence and Security Act of 2007 (EISA), Energy Policy Act of 2005 (EPAct 2005), and 2000 BRDA.
		State R&D support programs include various tax incentives, loan guarantees, and grants. Regional cooperation agreements exist among states with the common goal of developing regional biotechnology industries, but there are differences as to approaches and benefits.
	Tax incentives	The volumetric ethanol excise tax credit (VEETC) offers a federal blenders' credit of 51 cents per gallon of ethanol blended into gasoline, without limits to either production or blending volumes. The biodiesel volumetric excise tax credit is similar to the VEETC, but with a smaller credit amount and limits to eligible production and blending volumes. The federal producers' credit offers 10 cents per gallon for up to 30 million gallons of ethanol or biodiesel output.
		State sales tax exemptions range from 1 to 42 cents per gallon for blended fuels containing either ethanol or biodiesel. States also offer various production-linked tax credits, state blending credits, distributor tax incentives, sales and use tax credits for production equipment, or property tax exemptions for renewable fuels.

See source at end of table.

TABLE 4-2—*Continued*
Government policies directly supporting development or adoption of industrial biotechnology by the liquid fuel and chemical industries in the United States and selected countries

Major countries—*Continued*		
United States (*continued*)	Mandatory use regulations	The Renewable Fuel Standard (RFS) program, established by EPAct 2005 and amended by EISA, mandates successively greater quantities and shares of renewable fuels from 2008 (9 billion gallons) through 2022 (to 36 billion gallons), of advanced biofuels from 2009 (600 million gallons, 5.5 percent share) through 2022 (58.3 percent share), and of cellulosic ethanol from 2010 (10.5 percent share of advanced biofuels) through 2022 (76.2 percent share). The 1992 Energy Policy Act (EPAct 1992) directs federal, state, and local governments that operate diesel truck fleets to increase their biodiesel purchases to earn alternative fuel credits. The federal bio-preferred procurement program, created by the 2002 farm bill, requires all federal agencies to increase their purchases of bio-based products certified by the USDA.
		State RFS programs have requirements similar to those of the federal RFS program. State renewable portfolio standards (RPS) are flexible mandates directing electric power retailers to include renewable energy among their generating fuels. Several states have renewable fuel use directives for public agency vehicles.
	Loan guarantees	The USDA provides grants and loan guarantees for biofuel production facilities in rural areas. The USDOE Loan Guarantee Program focuses on innovative biomass projects.
	Agricultural feedstock programs	The USDA administers most federal support for agricultural biofuel feedstocks, as many of these crops receive support through the farm bill. Most significant farm bill funding in periods of low prices are marketing assistance loans, direct payments, and counter-cyclical payments. High prices for biofuel feedstocks are rendering USDA support programs less relevant because they represent declining shares of farm income. The USDA's Bioenergy and Energy Alternative National Program and its Quality and Utilization of Agricultural Products National Program administer feedstock R&D activities to raise crop output and develop new bio-based products. The USDA's new Feedstock Program (March 2008) initiates policies to develop 1) new markets for woody biomass culled from forests, and 2) conversion processes for switchgrass into biofuels. The USDOE has its Bioenergy Feedstock Development Program and similar programs, often with national laboratories, to more effectively convert cellulosic biomass into biofuels, and to develop a feedstock infrastructure for biofuel production. The joint USDA-USDOE National Biomass Initiative provides matching grants to R&D projects to make conversion of nontraditional biomass feedstocks into biofuels more efficient and cost effective.
		There are numerous state and local funding programs and regulatory structures to encourage agricultural production that includes feedstock crops for conversion into biofuels.
	Other	Duty-free entry for U.S. ethanol imports from U.S. insular possessions and CBERA beneficiary countries enables U.S. blenders to avoid offsetting the 51 cents per gallon income tax credit by the 54 cents per gallon import tariff.

See source at end of table.

TABLE 4-2—*Continued*
Government policies directly supporting development or adoption of industrial biotechnology by the liquid fuel and chemical industries in the United States and selected countries

Major countries—*Continued*		
Brazil	R&D and commercialization support	The 2006–11 Agroenergy Plan sets R&D goals, coordinates R&D efforts, and disseminates findings of ethanol and cogenerated power from sugarcane, biodiesel from animal and plant sources, forest biomass, and agricultural and agro-industry wastes. Biodiesel R&D priorities include diversifying feedstocks, commercializing ethanol transesterfication, and developing new uses for byproducts such as glycerin and oil cake. Brazilian Biodiesel Technology Network of major universities and research institutes was created by the Ministry of Science and Technology. Government-funded R&D projects beginning in the early 1990s to produce biopolymers from sugarcane and other bio-based sources, due in part to declining demand in the mid-1980s for ethanol and sugar. Several Brazilian federal government ministries and state agencies provide biofuel R&D funding.
	Tax incentives	The 2004 National Program for Production and Use of Biodiesel (PNPB) provides preferential tax and credit incentives for purchasing feedstocks from small family farms in disadvantaged regions. Reductions to or exemptions from taxes, imposed at both the federal and state levels, are available upon sales of ethanol, ethanol-blended fuels, and flexible-fuel vehicles.
	Mandatory use regulations	The *Proalcool* Program, dating from 1976, adjusts ethanol blending mandates, which range from 11 percent to 25 percent, depending on ethanol supply and demand; the current requirement is 20–25 percent ethanol in gasoline. 2004 PNPB mandates 2 percent biodiesel blending in 2008, rising to 5 percent by 2013.
	Loan guarantees	The National Bank of Economic and Social Development (BNDES) provides most public financing at favorable rates for ethanol production through several financing programs. Regional and state banks provide funding for ethanol production and administer BNDES financing. The 2004 PNPB provides participating biodiesel producers with more favorable loan terms. The Bank of Brazil's BB Biodiesel program provides credits, through programs administered by various banks, for the individual production stages from growing feedstocks to marketing biodiesel.
	Other	The National Agency for Petroleum, Gas, and Biocombustibles administers auctions, with voluntary participation by eligible biodiesel producers, that are intended to provide a floor price. The national petroleum company, Petrobras, and its subsidiaries, are required to purchase auctioned biodiesel.

See source at end of table.

TABLE 4-2—*Continued*
Government policies directly supporting development or adoption of industrial biotechnology by the liquid fuel and chemical industries in the United States and selected countries

Major countries—*Continued*		
Canada	R&D and commercialization support	The Scientific Research and Experimental Development program, the largest source of federal government support for industrial R&D, encourages Canadian firms to conduct industrial R&D in Canada by offering investment tax credits for capital, operating, and overhead expenditures. Federal-level R&D funding focuses on developing renewable fuels from nonfood feedstocks and on alternative markets for Canadian agricultural products through the Agricultural Bioproducts Innovation Program, Agricultural Biofuels Capital (ecoABC) Investment Program, Agri-Opportunities Program, Investments in Forest Innovation, ecoEnergy Renewals, ecoEnergy Efficiency, ecoEnergy Technologies, Bioproducts National Program, Energy Cogeneration from Agricultural and Municipal Wastes (EcoAMu), BIOCAP government-private sector partnership network (ceased operations March 2008), Environmental Technology Assessment for Agriculture, Sustainable Development Technology Canada (SD Tech Fund and NextGen Biofuels Fund), and Technology Partnerships Canada, among others.
		Ontario’s Biotechnology Cluster Innovation Program funds environmental biotechnology, among other fields. Some provinces also provide funding to support bio-based chemicals and materials R&D.
	Tax incentives	The Biofuels Opportunities for Producers Initiative provides financial assistance to agricultural producers in developing business proposals and feasibility studies for creating or expanding biofuel production capacity. The Co-operative Development Initiative partially finances the establishment of cooperative ventures for biofuels. The federal government announced in March 2007: (1) producer payments over seven years to ethanol and biodiesel producers, and (2) establishment of a fund to support commercialization of cellulosic ethanol and other next-generation biofuels. The ecoAgriculture biofuels Capital Initiative (2007–11) provides funding to construct and expand several ethanol production projects. The Ethanol Expansion Program (2003–05) preceded this initiative. Federal excise tax exemptions for retail sales of biofuels were in effect from the 1990s to April 2008 when they were replaced by production incentive programs.
		Some provinces provide funding for ethanol producers, ethanol production capacity construction, and bioenergy infrastructure improvements. Some provinces exempt retail sales of biofuels from excise taxes.
	Mandatory use regulations	Federal mandates (announced December 2006) are forthcoming that will specify an average renewable fuel content of 5 percent for all gasoline starting in 2010; and an average renewable fuel content of 2 percent for all diesel fuel and heating oil starting not later than 2012, but only upon successful performance demonstration across Canadian climatic conditions.
		Some provinces currently specify, or plan to specify, various minimum content or replacement shares of ethanol in gasoline supplies.
	Loan guarantees	Sustainable Development Technology Canada (SD Tech Fund and NextGen Biofuels Fund) provides for interest-free loans that are repayable at such time as the venture becomes profitable.

See source at end of table.

TABLE 4-2—*Continued*
Government policies directly supporting development or adoption of industrial biotechnology by the liquid fuel and chemical industries in the United States and selected countries

Major countries—*Continued*		
China	R&D and commercialization support	Chemical R&D industrial parks are being established to attract increased investment by both domestic and foreign firms. High-technology projects for liquid biofuels and bio-based products are funded by the National High-tech R&D Program, National Program on Key Basic Research Projects, and National Innovation Fund of China, among others. The Chinese Academy of Sciences funds R&D in biobutanol, micro-organisms, and energy crops. Government-initiated R&D programs focus on diversification, quality improvements, and lower biodiesel feedstock costs.
	Tax incentives	The central government regulates prices of corn, ethanol, gasoline, and diesel, reportedly holding them below international levels, and froze energy prices in January 2008 to offset inflation. State support for ethanol producers is generous in the industry's early years but declines as profitability improves. New laws require ethanol firms to establish risk reserves, modify financial incentives, and offer venture capital, all reportedly to encourage the ethanol industry to become more economically self-sufficient. As with ethanol, support for biodiesel includes tax benefits, preferential loans, and assistance to firms developing demonstration-scale production projects from nonfood feedstocks. Support for bio-based chemicals include numerous incentives for profitable and efficient producers, and preferential tax treatment for select firms in emerging industries.
	Mandatory use regulations	The central government passed successive laws to initiate trial ethanol-blended gasoline programs in several provinces in 2000–02 that were subsequently expanded, and established an administrative framework for domestic sales and pricing. E10 blends (10 percent ethanol) were mandated by the central government in 2005 for most vehicles in the nine eastern seaboard provinces, with a goal of expanding the E10 share from 20 percent of gasoline consumption in 2006 to 50 percent by 2010; the E10 requirement is anticipated to extend nationwide by 2020. Among the provisions of the 2005 Renewable Energy Law (implemented January 2006), renewable energy is to account for 10 percent of China's energy consumption by 2020, and gasoline marketers must also offer liquid biofuels. A 2005 program promotes production and consumption of biodegradable plastics.
	Agricultural feedstock programs	Economic incentives for biodiesel include financial assistance to farmers for producing nonfood feedstocks. To offset food security concerns, quantities of corn allowed for industrial uses were capped, limiting ethanol producers to amounts consumed by existing facilities, and prohibits grain feedstocks for new or expanded production. Projects focusing on nonfood inputs are now being developed and approved; funding is being made available for such projects. Large-scale cultivation initiatives were created for oil-bearing nut and fruit trees as biodiesel feedstocks by the central government agencies; some were created in partnership with state-owned petroleum firms.

See source at end of table.

TABLE 4-2—*Continued*
Government policies directly supporting development or adoption of industrial biotechnology by the liquid fuel and chemical industries in the United States and selected countries

Major countries—*Continued*		
EU	R&D and commercialization support	Nearly all major EU member states offer dedicated funding and engage in public-private collaborations to varying degrees for IB R&D; public sources fund the initial research of cellulosic ethanol whereas the private sector enters with matching public funding at the pilot and demonstration plant stage. The European Commission's (EC) Directorate General for Research, European Chemical Industry Council, and European Association for Bioindustries jointly launched the European Technology Platform on Sustainable Chemistry (SusChem TP) initiative in mid-2004, which is a long-term, public-private partnership to expand R&D investment and enhance European competitiveness in various industry sectors, including IB. The Seventh Framework Program (December 2007), the most recent multi-year R&D funding priorities plan, includes R&D and demonstration of renewable fuel production systems and conversion technologies.
	Tax incentives	The EU Energy Tax Directive (October 2003) allows favorable tax treatment for biofuels and biofuel blends, and allows individual member states to decide upon the level of partial or full exemptions from taxes levied on conventional fuels. Germany, the earliest promoter of biofuels through tax exemptions, scaled back the full tax relief for biofuel sales below quota levels introduced in January 2007, in part to alleviate budgetary constraints.
	Mandatory use regulations	The EU Biofuels Directive (May 2003) sets nonbinding targets for 2005 and 2010 for member states' biofuel shares of transport fuel consumption, but national targets were less ambitious and fulfillment uneven. EU-wide attainment (1 percent) was short of the 2 percent target for 2005 and considered highly unlikely to meet the 5.75 percent target for 2010. Subsequently, the EC Renewable Energy Road Map (January 2007) set binding targets of 20 percent renewable energy sources, including biofuels, and at least a 10 percent share in the transport sector by 2020. In April 2008, Germany cancelled the planned increase in the compulsory ethanol content of gasoline, from the current E5 to E10, due to corrosion concerns for older vehicles. The national vehicle testing organization and standards agency raised similar concerns about the planned increase in the compulsory biodiesel content in diesel fuel, from B5 to B7, but the government reportedly considers that stricter product standards address corrosion problems of B7.
	Agricultural feedstock programs	The June 2003 and April 2004 reforms to the EU Common Agricultural Policy (CAP) decoupled commodity-specific support requirements that rendered growers in member states eligible for credit payments for growing nonfood energy crops on food crop-growing lands. Among the July 2006 reforms to the November 2005 EU-25 Sugar Policy are production quota exemptions for sugar grown as feedstock for chemicals, pharmaceuticals, and ethanol and the extension of eligibility to sugarbeets grown as nonfood crops for the credit payments and energy crop assistance in the June 2003 CAP reforms. The December 2007 reforms to the Community Wine Management framework will phase out support for purchase and sale of surplus EU wine for distillation into industrial and fuel ethanol.

See source at end of table.

TABLE 4-2—*Continued*
Government policies directly supporting development or adoption of industrial biotechnology by the liquid fuel and chemical industries in the United States and selected countries

Major countries—*Continued*		
Japan	R&D and commercialization support	The National Biotechnology Strategy (December 2002), jointly formulated by government and industry, is the first comprehensive national strategy covering R&D through commercialization of biotechnology. Five government ministries, each for their own specific policy goals, provide most of the government funding for IB R&D, particularly for biofuel projects. Recently, public universities, research institutes, and funding agencies have become administratively independent from the government. They continue to receive most funding from their affiliated government ministries but are also encouraged to seek private funding. Several collaborations among government agencies, universities, and private firms are underway to develop and demonstrate new technologies for mass production of low-cost cellulosic ethanol, biodiesel, and bio-based chemicals from various domestic feedstocks. Tax credits are available for total R&D expenditures, for increased R&D expenditures, and for small and medium-sized enterprises.
		Prefecture and local governments have an important role in forming industrial clusters, establishing partnerships between government and businesses at the local level, and funding regional institutes.
	Tax incentives	Tax incentives for purchases of fuel-efficient or clean-energy vehicles were introduced in FY 2005, but there are currently no specific tax breaks for purchases of biofuels. A preferential tax system is proposed for FY 2008 that would exempt biofuel blends from fuel taxes in proportion to the biofuel content.
	Mandatory use regulations	Currently, there are no national biofuel mandatory use regulations in Japan, in part due to lack of consensus between the Environment Ministry's push for mainstream introduction of E3 blends and industry's support for ETBE-gasoline blends. The 1976 Quality Control Law sets an upper limit of 3 percent ethanol-equivalent in gasoline blends and the 2007 Quality Control Law sets an upper limit of 5 percent first-generation biodiesel (fatty acid methyl ester, or FAME) in diesel blends to ensure vehicle safety and control emissions. No upper limit is set for second-generation biodiesel (bio-hydrated diesel). All new registered gasoline-fueled vehicles must be capable of burning E10 blends starting in 2010; some localities are experimenting with direct ethanol blends or gasoline-ethyl tertiarty butyl ether blends. Bio-based chemicals (especially bioplastics) benefit from usage, waste management, and labeling legislation, such as the 2001 Law on Promoting Green Purchasing, revisions to the 1991 Law for the Promotion of Effective Utilization of Resources, 2000 Basic Law for the Recycling-based Society, and 2000 Biotechnology Strategic Scheme, among others.
	Agricultural feedstock programs	The sugar support system was adjusted in 2007 to favor sugarcane (considered the more efficient ethanol feedstock) with commodity-specific support, whereas sugarbeets will be covered by blanket direct payments.

See source at end of table.

TABLE 4-2—*Continued*
Government policies directly supporting development or adoption of industrial biotechnology by the liquid fuel and chemical industries in the United States and selected countries

Other countries		
Australia	R&D and commercialization support	Renewable Energy Development Initiative grants support for renewable energy innovation and commercialization, with funding to be allocated over seven years. Additional funding is available to qualifying projects for R&D, pilot or demonstration facilities, or early-stage commercialization.
	Tax incentives	From 2003 to July 2011, the excise tax on ethanol for transport fuel is eligible for rebates; during July 2011 to July 2015, the rebate will be phased down to an effective tax rate of one-half that of conventional fuel and one-half that of the tariff on imports. The Biofuels Capital Grants Program, announced in 2003, assists new entrants. In 2004, all funds were awarded to four biodiesel and three ethanol projects. Locally produced biofuels have an advantage over the imported product in terms of tax treatment.
	Mandatory use regulations	Biofuels targets have been set but not yet mandated; a couple of states have local mandates.
	Other	The Ethanol Distribution Program provides federal grants to retail service stations that sell E10, with some 700 stations anticipated to receive such conversion assistance.
India	R&D and commercialization support	The national government provides significant amounts of R&D funding for biotechnology, particularly in consultation with individual state governments, to promote the potential of the oil-seed jatropha plant as a nonfood feedstock for biofuels.
	Tax incentives	Biotechnology clusters established by states benefit from direct financial support, tax holidays, and other incentives.
	Mandatory use regulations	The national government mandates a 5 percent blend of ethanol in certain states and territories, which will increase to 10 percent nationwide, and possibly to 20 percent longer term. No biodiesel mandate is expected before 2010.
	Other	Import duties are considered important by the government to protect domestic ethanol producers, despite government support for consumption of traditional fossil fuels that decreases the relative competitiveness of biofuels.

See source at end of table.

TABLE 4-2—*Continued*
Government policies directly supporting development or adoption of industrial biotechnology by the liquid fuel and chemical industries in the United States and selected countries

Other countries—*Continued*		
Indonesia	R&D and commercialization support	There is limited government funding of IB R&D.
	Tax incentives	Accelerated assets depreciation, extended tax loss carried forward, and investment tax credits are available. A tax holiday for biofuels investors is currently under consideration.
	Mandatory use regulations	Current use requirements are set at 2.5 percent for ethanol and biodiesel, with plans to increase to 25 percent.
	Other	The government works with private sector banks to provide loans to finance the development of feedstocks and infrastructure for biofuels; the government is to contribute support for the 10 percent interest rate charged by the banks. The government is considering financial supports for biofuels to improve their competitiveness with fossil fuels that already benefit from government support.
Korea	R&D and commercialization support	The Next-generation Clean Energy Development Project will (1) invest in R&D for synthetic fuels derived from biomass, coal and natural gas, as well as biobutanol by 2010, and (2) provide funding for a two-year (2006–08) feasibility study on bioethanol as a transport fuel. Government-funded research institutes are developing technologies to (1) produce chemical raw materials and energy from biomass; (2) discover, improve, and synthesize biocatalysts; (3) produce functional polymers and monomers with biocatalysts; and (4) scale-up R&D for commercialization of biochemical and fine chemical production technologies. The government is establishing an inbound investment promotion program and an R&D complex exclusively for foreign biotechnology firms to attract foreign direct investment. The government is also establishing procedures for technology transfers from the educational institutions to the private sector.
	Tax incentives	Retail sales of biodiesel are tax exempt (except from VAT) based on the portion of biodiesel blended into the fuel.
	Mandatory use regulations	A 0.5 percent minimum biodiesel content was mandated in 2006; the minimum will rise to 3 percent by 2012. The government supports use of biodegradable materials in trash bags and fishing nets, one-time use products cannot be made from conventional plastics, and polystyrene is banned in food packaging.
	Other	National biodiesel standards were set in 2004. Government goals include exploring options for domestic biodiesel feedstock production, producing 186 million gallons of biodiesel by 2012; and increasing bioenergy utilization to 15 percent by 2010.

See source at end of table.

TABLE 4-2—*Continued*
Government policies directly supporting development or adoption of industrial biotechnology by the liquid fuel and chemical industries in the United States and selected countries

Other countries—*Continued*		
Malaysia	R&D and commercialization support	The Ninth Malaysia Plan (2006–10) allocates funds to develop the biotechnology industry, with significant portions devoted to agriculture and pharmaceuticals. Scholarships are available for students pursuing advanced degrees in biotechnology.
	Tax incentives	Ten-year tax-exempt status is available for biotechnology firms meeting certain conditions, a minimum 70 percent tax exemption is offered on income derived from biotechnology production for five years, and biotechnology plant equipment is exempt from import duties.
	Mandatory use regulations	Implementation of the mandated 5 percent biodiesel blend has been delayed pending establishment of feasibility. Nevertheless, several government ministries currently use a 5 percent blend in their fleet vehicles.
	Other	Government support for fossil fuels decreases the relative competitiveness of biofuels.
New Zealand	R&D and commercialization support	The government supports biotechnology R&D through Crown Research Institutions (CRIs), such as AgResearch and Scion. Scion launched its “Biomaterial Futures” strategy in 2003, and has a new mandate to create “plant-based bio-materials and new manufacturing processes as a basis for sustaining the consumer markets of the future.” The Bioenergy Knowledge Centre provides tools and information to those considering woody biomass as a renewable energy source. The Centre’s aim is to reduce technical, financial, and operational risks associated with investment in bioenergy projects. CRI Cawthron’s research into microbial enzymes for pharmaceuticals, rather than industrial process applications, could also find new applications in industrial technology.
	Tax incentives	The government-backed Venture Investment Fund focuses on the biotechnology sector, with the goals of attracting top biotechnology venture capital funds from around the globe and managing the investment of these funds in New Zealand’s biotechnology firms.
	Other	Genetically modified (GM) material can only be imported for research purposes, which could pose a problem for feedstock and biofuel that are derived from GM materials.
Philippines	R&D and commercialization support	The Philippines Biofuel Act sets guidelines for government engagement in and support of biofuels R&D. Several coconut-biodiesel research projects are underway.
	Tax incentives	Tax exemptions are provided for both domestically produced and imported biofuels and inputs.
	Mandatory use regulations	All gasoline sold must contain 5 percent ethanol by 2009, rising to 10 percent by 2011; diesel must contain 1 percent biodiesel and 2 percent by 2009.
	Other	Biofuels producers to receive direct financial support and preferable financing terms by state-owned financial institutions.

See source at end of table.

TABLE 4-2—*Continued*
Government policies directly supporting development or adoption of industrial biotechnology by the liquid fuel and chemical industries in the United States and selected countries

Other countries—*Continued*		
South Africa	R&D and commercialization support	The government provides little direct R&D support, but instead is investing, through two parastatal firms, in the construction of two ethanol plants that will begin operations in early 2009.
	Mandatory use regulations	The government mandated the gradual elimination of lead in gasoline and its replacement by ethanol, with a 2 percent mandatory blending targeted in the future.
Thailand	R&D and commercialization support	There is some state-funded R&D, but most biotechnology R&D focuses on pharmaceuticals and agriculture.
	Tax incentives	Firms in the IB sector are exempt from corporate taxes for eight years and their imported production machinery is exempt from import duties.
	Mandatory use regulations	As of 2007, a 5 percent biodiesel usage requirement is in effect for certain areas, to be extended nationwide by 2011. Usage mandates are 10 percent biodiesel blends by 2012 and 10 percent ethanol blends by 2011.
	Other	The government provides financial support for consumption of fossil fuels, and provides price supports for sugar production.

Source: Various U.S. and foreign industry and government publications.

Research, Development, and Commercialization Support

All of the countries examined in this chapter provide RD&C funding directly to the private sector and fund government-run research institutions that share their findings with the private sector. In contrast to R&D in the liquid biofuel sector, for which government funding is typically explicitly earmarked, bio-based chemical RD&C funding is typically part of larger, more general authorizations.

United States

RD&C is supported at the federal and state levels in several ways, such as direct grants, technology transfer, and cooperative research and development agreements (CRADAs). Moreover, federal legislation provides government agencies with guidance as to which types of research projects to support, from specific goals such as lowering the production cost of cellulosic ethanol, to general goals such as advancing the competitiveness of IB in general.

Federal Initiatives

Legislation that establishes goals and funding for R&D include the EISA,[8] EPAct 2005,[9] and the Biomass Research and Development Act (BRDA).[10] EISA establishes new funding or expands existing R&D funding by authorizing up to $25 million in funding for biofuels infrastructure development in states that have low rates of ethanol production,[11] up to $200 million in renewable fuel infrastructure grants for retailers to install, replace, or convert motor fuel storage and dispensing infrastructure,[12] and up to $500 million for advanced biofuels R&D.[13] EISA further increases the EPAct 2005 authorization level of grants to support cellulosic ethanol production.[14]

EPAct 2005 also provides R&D funding; including up to $200 million annually for direct support of biomass programs. Such funds are primarily made available through the USDOE with cooperative oversight arrangements with other federal agencies such as the USDA, the U.S. Environmental Protection Agency (EPA), and the National Science Foundation. These agencies also have their own independent mandates to further the development of the IB sector.

EPAct 2005 also directs the USDOE to establish a $250 million per-facility grant and loan guarantee program,[15] a $36 million grant program for converting sugarcane to ethanol,[16] and a $250 million loan guarantee program for establishing sugar-to-ethanol facilities.[17] In February 2007, the USDOE announced grants totaling $385 million over the next four years

---

[8] Energy Independence and Security Act, Pub. L. No. 110-140 (2007).
[9] Energy Policy Act of 2005, Pub. L. No. 109-58 (2005).
[10] Biomass Research and Development Act of 2000 7 USC 7624 Note.
[11] Energy Independence and Security Act, Pub. L. No. 110-140, § 223, 121 Stat. 1492, 1533 (2007); and Sissine, *Energy Independence and Security Act of 2007,* December 21, 2007, 6.
[12] Energy Independence and Security Act, Pub. L. No. 110-140, § 244, 121 Stat. 1492, 1541 (2007).
[13] Energy Independence and Security Act, Pub. L. No. 110-140, § 207, 121 Stat. 1492, 1531 (2007).
[14] Energy Policy Act of 2005, Pub. L. No. 109-58, §1501, 119 Stat. 594, 1069 (2005). Sissine, *Energy Independence and Security Act of 2007,* December 21, 2007, 6.
[15] Energy Policy Act of 2005, Pub. L. No. 109-58, §212, 119 Stat. 594, 1087 (2005).
[16] Energy Policy Act of 2005, Pub. L. No. 109-58, §1516, 119 Stat. 594, 1091 (2005).
[17] Energy Policy Act of 2005, Pub. L. No. 109-58, §1516, 119 Stat. 594, 1091 (2005).

to build six biorefineries, as well as $375 million to establish three new bioenergy research centers.[18]

BRDA also supports the development of IB by establishing oversight and technical advisory committees, and directing federal government agencies to cooperate and carry out policies that promote R&D, demonstration, and education and outreach activities leading to the production and consumption of bio-based fuels and products.[19] BRDA also established the Biomass Research and Development Initiative (BRDI) described below.

U.S. Department of Energy biomass and biorefinery R&D systems program

The USDOE provides significant support through its biomass and biorefinery systems program. Reported USDOE expenditures for this program were stable between 2003 and 2006, with expenditures increasing by over 60 percent in 2007, owing to a few major expenditures (table 4-3).

TABLE 4-3
U.S. Department of Energy expenditures for biomass and biorefinery systems research and development, 2003–07

(*1,000 dollars*)

Source	2003	2004	2005	2006	2007
Feedstock infrastructure	2,405	982	1,984	479	9,725
Platforms R&D	44,841	28,874	29,288	15,140	[1]49,306
Utilization of platform outputs	38,037	20,088	20,473	23,322	[2]89,190
Technical program management	811	396	394	([3])	([3])
Congressionally directed activities	([3])	41,234	35,332	51,777	([3])

[1] $16.9 million was allocated for R&D on the conversion of biomass residues from biochemical biorefineries to provide syngas.

[2] $54.4 million was allocated to fund three industrial scale demonstration cost-shared projects to validate integrated biorefinery designs. An additional $35.8 million was allocated for R&D of technologies for processing intermediate biorefinery product streams into ethanol and value-added products.

[3] Not available.

Note.—The Biomass and Biorefinery System R&D Program focuses on: (1) feedstock infrastructure, for reducing the cost of collecting and preparing raw biomass, and for the sustainable production and delivery of future energy crops; (2) platforms R&D, for reducing the cost of outputs and byproducts from bio-chemicals and thermochemical processes; and (3) utilization of platform outputs, for developing technologies and process that utilize intermediates such as sugars and syngas to co-produce fuels, value-added chemicals and materials, and heat and power.

Source: USDOE, EERE Web site. http://www1.eere.energy.gov/ba/pba/budget_archives.html (accessed February 12, 2008).

---

[18] USDOE, "DOE Selects Six Cellulosic Ethanol Plants," February 28, 2007; and GBEP, *A Review of the Current State of Bioenergy Development in G8 +5 Countries*, 2007, 223. Abengoa, Alico, Blue Fire, Broin, Iogen, and Range Fuels were listed as receiving between $33 and $80 million for construction of cellulosic biorefineries capable of producing between 11.4 and 125 million gallons of ethanol. Together, these plants are expected to be able to produce more than 130 million gallons of cellulosic ethanol. USDOE, "DOE Selects Six Cellulosic Ethanol Plants," February 28, 2007. See also USDOE, "Biorefinery Grant Announcement," February 28, 2007.

[19] Duncan, "U.S. Federal Initiatives to Support Biomass Research and Development," 2003, 193.

Biomass research and development initiative

The Biomass Research and Development Initiative (BRDI), established by the BRDA, has also provided a steady stream of R&D funding since 2002 (table 4-4). BRDI, cooperatively managed by the USDOE and the USDA, is a multi-agency effort to coordinate federal support for R&D of bioenergy (including biofuels) and bio-based products. It provides R&D support to private firms, national laboratories, universities, and other research institutions. Processing and conversion projects typically receive the most funding, followed by feedstock production.

TABLE 4-4
U.S. Department of Agriculture and U.S. Department of Energy: Biomass research and development awards by type of project, and company matches, 2002–06
(*1,000 dollars*)

Source	2002	2003	2004	2005	2006
Feedstock production:					
Grant	0	2,000	2,717	3,283	3,909
Match	([1])	701	1,420	868	1,326
Preprocessing and conversion:					
Grant	0	0	0	0	1,922
Match	([1])	0	0	0	245
Processing and conversion:					
Grant	[2]76,650	19,804	11,211	0	7,589
Match	([1])	19,869	4,139	0	2,804
Product uses and distribution:					
Grant	0	2,000	6,481	7,246	1,855
Match	([1])	936	2,499	4,668	512
Public policy:					
Grant	0	0	5,393	2,098	2,217
Match	([1])	0	2,118	799	3,675
Cross cutting:					
Grant	2,700	0	553	0	0
Match	([1])	0	198	0	0
Total federal grants	79,350	23,804	26,355	12,627	17,492
Total company match	([1])	21,506	10,374	6,335	8,562
Total project investment	79,350	45,310	36,729	18,962	26,054

[1] Data not available.
[2] Three firms, Abengoa ($17.7 million), Cargill ($32.8 million), and Dupont ($18.2 million), received 86.6 percent of the grant funds for R&D of advanced biorefinery systems in 2002.

Note.—Data reported in year of award. Funding, however, is provided to companies for discrete projects, over time, not in lump sum amounts.

Source: Compiled from USDA and USDOE, “Annual Report to Congress on the Biomass Research and Development Initiative,” FY2002 through 2006; and USDA, BRDI, “Matrix of Projects Awarded under the Joint Solicitation, 2002–2005,” undated (accessed February 13, 2008).

Small business innovative research and small business technology transfer programs

The Small Business Innovative Research (SBIR) program and the Small Business Technology Transfer (STTR) program, both administered by the SBA, can support the development of IB by the liquid fuel and chemical industries; however, grants for biotechnology research have been limited. The SBIR is a three-phase award system that provides qualified small businesses with opportunities to propose innovative ideas that meet specific R&D needs of the federal government.[20] The STTR awards funds to small businesses in partnership with nonprofit research institutions. The program goals include moving ideas from the laboratory to the marketplace and fostering high-tech economic development.[21]

In total, over 30,000 programs, with grants totaling nearly $10 billion, have been supported by SBIR and STTR since 2000.[22] However, only 255 of these programs, totaling $56 million, involved IB.[23] Ownership requirements preclude grants to firms that are majority owned by venture capital firms, thereby disqualifying many small biotechnology firms.[24] California and Massachusetts are the leading states, ranked by aggregated grants, receiving SBIR and or STTR funds for IB R&D (table 4-5).

TABLE 4-5
Small Business Innovative Research (SBIR) and Small Business Technology Transfer (STTR) program grants, by state, 2000–2007

Item	Total		Industrial biotechnology		
	Number of grants	Grant value	Number of grants	Grant value	Share of total grant value
		$1,000		*$1,000*	*Percent*
California	5,943	2,060,088	44	12,038	0.6
Massachusetts	4,095	1,404,253	27	5,300	0.4
Texas	1,324	416,214	20	4,042	1.0
New York	1,242	450,963	12	3,779	0.8
Montana	169	46,977	15	2,462	5.2
All other	17,385	5,610,362	137	28,622	0.5
Total	30,158	9,988,857	255	56,243	0.6

Note.—States shown are based on total estimated biotechnology award value. For example, while Montana ranked 28th for total awards, it received the fifth largest amount for biotech research in SBIR and STTR grants.

Source: Compiled by Commission staff from Small Business Administration, Technology Resource Network, SBIR Web site. http://tech-net.sba.gov/index.cfm (accessed February 7, 2008).

State Programs

State programs and regional cooperation agreements to support IB R&D have also proliferated. State funding, much like federal funding, is provided through a complex package of individual tax incentives, loan guarantees, and grants. Pennsylvania, for example, provides grants through its Opportunity Grant Program, Redevelopment Assistance Capital Program, and Infrastructure Development Program. Colorado provides grants of $2 million for biosciences research into new products and discoveries. Other state investments include Florida's $510 million investment in the Scripps Florida Biotechnology Research Institute, and Arizona's $440 million investment in its Arizona State University bioscience facilities.[25]

[20] Small Business Administration Web site. http://www.sba.gov/SBIR/indexwhatwedo.html (accessed February 12, 2008)
[21] Schacht, *Small Business Innovation Research Program,* December 4, 2006, 6.
[22] Small Business Administration, Technology Resource Network, SBIR Web site. http://tech-net.sba.gov/index.cfm (accessed February 7, 2008).
[23] Ibid.
[24] Schacht, *Small Business Innovation Research Program,* December 4, 2006, 6.
[25] Battelle, "State Profiles," 2006, Arizona-1.

Some states have used tobacco settlement funds for bioscience research in general.[26] For example, Arkansas transfers up to 23 percent or $13 million of its yearly tobacco settlement trust payments to the Arkansas Bioscience Institute for research on agricultural, bioengineering, and biomedical topics.[27] The Indiana Economic Development Corporation, through the Certified Technology Park program, provides up to $5 million a year to invest in business incubators.[28]

Regional Programs

A number of neighboring states have joined to develop regional biotechnology industries. Prominent regional groups are the Great Lakes Biomass State-Regional Partnership (GLBSRP),[29] Northeast Regional Biomass Partnership,[30] Pacific Regional Biomass Energy Partnership,[31] Southeastern Regional Biomass Partnership,[32] and Western Regional Energy Biomass Partnership.[33] These regional groups were originally sponsored by the USDOE and were designed to encourage greater production and use of biomass for energy generation.

Although most regional groups have similar goals, they differ in how they operate and provide benefits. For example, the GLBSRP provides three main components—state grants, regionwide demonstration and technology transfer, and in-house management and support—to universities and industries from throughout its region. Grants are awarded annually; state offices perform resource assessment, demonstration projects, and provide technical assistance; and the GLBSRP manages projects with regionwide benefits. All demonstration and development projects must address commercially viable technologies and include substantial cost sharing.[34]

Another regional group, the Coalition of Western Governors, has established a Biomass Task Force as part of its Clean and Diversified Energy Initiative for the West to identify and develop its biotechnology industries. To date, four states have provided $250,000 in grants for education, policy development, outreach, and process development. A second round of grants worth $450,000 is anticipated for programs in California to evaluate current biofuels, identify future candidate technologies, and develop an effective course for future development, and to programs in California, Nevada, North Dakota, Utah, and Wyoming to increase bioenergy awareness through outreach. Programs in Nebraska are also anticipated to receive funding to develop life cycle bioenergy and environmental impact software.[35]

---

[26] Battelle, *Growing the Nation's Bioscience Sector*, 2006, 4.
[27] Battelle, "State Profiles," 2006, Arkansas-1.
[28] Ibid., Indiana-4.
[29] Great Lakes Biomass State-Regional Partnership Web site. http://www.cglg.org/biomass (accessed February 12, 2008).
[30] Northeast Regional Biomass Program Web site. http://www.nrbp.org/index.htm (accessed February 12, 2008).
[31] Pacific Regional Biomass Energy Partnership Web site. http://www.pacificbiomass.org/ (accessed February 12, 2008).
[32] Southeastern Regional Biomass Energy Program Web site. http://www.serbep.org/ (accessed February 12, 2008).
[33] Western Governors' Association Working Groups Web site. http://www.westgov.org/wga/initiatives/biomass/ (accessed February 12, 2008).
[34] Great Lakes Biomass State-Regional Partnership Web site. http://www.cglg.org/biomass (accessed February 12, 2008).
[35] Western Governors' Association Web site. http://www.westgov.org/ (accessed February 12, 2008).

Foreign Country Comparison

In contrast to the strong U.S. government support for RD&C, the bulk of Brazil's biofuels RD&C funding is from private sector sources,[36] although public funding is available from various federal ministries[37] and state agencies.[38] Under the current (2006–11) National Agro-energy Plan,[39] Brazil's RD&C efforts for ethanol focus on improving sugarcane varieties and cultivation processes and developing new products and processes based on sugarcane feedstocks.[40] Biodiesel research focuses on diversifying feedstocks into areas such as forest biomass and developing technologies to utilize co-products, residues, and wastes such as agricultural and urban wastes.[41]

Canada reportedly has the lowest R&D costs per researcher among G-7 countries and the most advantageous R&D tax treatment among OECD members.[42] Federal government R&D funding focuses on developing renewable fuels from second-generation (nonfood) feedstocks,[43] and promoting commercialization of readily marketable new agricultural products, processes, and services.[44] Several provinces fund RD&C for biofuels and bio-based chemicals as well.[45]

China funds R&D in IB,[46] including government-sponsored research funding for small enterprises. The central government also supports RD&C of high-technology projects.[47] China has initiated and is funding several government research programs related to feedstock diversification and lowering feedstock costs (e.g., breeding higher oil content rapeseed plants for biodiesel development).[48]

The EU has relatively low overall R&D funding levels, lagging those of the United States and other major global competitors.[49] However, nearly all the major EU economies offer dedicated funding for various types and stages of IB R&D, implemented especially through public-private collaborations.[50] Public funding supports the initial research, and private sector involvement commences, with matching government funding, at the development

---

[36] Garten Rothkopf LLC, *A Blueprint for Green Energy in the Americas*, undated (accessed December 18, 2007), 456.

[37] Ibid., 455.

[38] São Paulo is especially prominent among Brazilian states for funding ethanol research through its São Paulo Biofuels Chamber and São Paulo Agency for Agribusiness Technology (APTA). APTA, "Apresentação," undated (accessed March 2, 2008).

[39] MAPA, *Plano Nacional de Agroenergia 2006–2011*, 2006.

[40] Ibid., 21.

[41] Ibid., 21–23.

[42] CCPA, "Canada's Chemical Industry Advanced Materials," undated (accessed February 29, 2008).

[43] STDC Web site. http://www.sdtc.ca/en/about/index.htm (accessed March 5, 2008); and Clark, "Canadian Government Invests Can$500m in New Biofuels Fund," September 12, 2007.

[44] Agriculture and Agri-Food Canada, "Agri-Opportunities Program," January 4, 2008.

[45] Sarnia-Lambton Economic Partnership, "Profile: Industrial Bio-Products," undated (accessed February 29, 2008); and University of Alberta, "$25-million Research Centre to Cultivate Growth," June 23, 2006.

[46] Jiang, DSM (China) Ltd., "China: To Capture the Future of White Biotechnology," April 29, 2008; and industry official, e-mail message to Commission staff, May 28, 2008.

[47] Cao and Liu, "Industrial Biotechnology and Bioenergy in China," January 2006.

[48] Worldwatch Institute, "Used Cooking Oil to Fuel China's Expanding Car Fleet," October 12, 2006; and *Xinhua News Agency*, "China Breeds Rapeseed of Record High Oil Content," August 29, 2006.

[49] EuropaBio and ESAB, *Industrial or White Biotechnology*, November 2006, 12; Carrez, Lindroos, and Soetaert, "Biotech Industry Publishes New Policy Agenda for Europe," December 27, 2006; and DECHEMA e.V., "White Biotechnology," January 2006, 6.

[50] Ambikapathy, *Status and Comparative Study*, October 2006, 26 and 28.

phases for pilot or demonstration plants and for supporting infrastructure. Pre-pilot development is primarily undertaken by academic institutions and government research facilities.[51]

The Japanese government provides significant funding for IB generally, and for specific liquid biofuel projects in particular. As in the United States, there are many Japanese ministries, research institutes, and funding agencies involved in supporting IB R&D.[52] Public sector support by prefectural and local governments is also important, particularly in the formation of industrial clusters, the establishment of partnerships between local governments and businesses, and funding of regional institutes.[53] This type of support is also evident in the United States and Canada, where states, provinces, and municipalities are involved in localized development and commercialization of bio-based products.

Tax Incentives

Tax incentives are an important form of support for the development and adoption of IB for liquid fuel and chemical companies. The countries examined herein offer a variety of tax incentives to producers, R&D groups, intermediate consumers such as blenders and gas stations, and end-use consumers to encourage investment, research, development, and adoption of IB. R&D tax credits are the most commonly employed incentive in the major IB countries (table 4-6).

TABLE 4-6
Comparison of U.S. and foreign tax incentives for industrial biotechnology

Countries	R&D tax credits	Investment tax credits	Federal excise tax	Flex-fuel vehicle tax credits
United States	✓	✓	✓	✓
EU	✓	✓	✓	✓
Brazil	✓		✓	✓
Canada	✓	✓	✓	✓
China	✓	✓	✓	
Japan	✓	✓		✓

Source: Various U.S. and foreign industry and government publications.

United States

U.S. liquid fuel and chemical industry producers identified federal and state tax incentives as very important in supporting the development and adoption of IB. One industry participant characterized federal tax incentives as “crucial to the success to the industry.”[54] This type of response was most prevalent among liquid biofuel producers, particularly biodiesel producers. However, firms report that current policies support a select few traditional technologies for producing biofuels from traditional feedstocks, and claim that such policies discourage innovation and the introduction of new biofuels to the marketplace. These firms contend that federal policies should recognize other technologies and be feedstock neutral. An overview of major federal biofuel tax incentives is presented in table 4-7.

---

[51] Ibid.
[52] Fuyuno, *Japan’s Scientific Public Research Structure*, July 2007, 7.
[53] Ibid.
[54] Based on Commission questionnaire responses.

TABLE 4-7
Major U.S. federal government biofuel tax incentives

Title	Fuel Type	Incentive	Expiration	Note
Volumetric ethanol excise tax credit	Ethanol of 190 proof or greater from biomass[1]	$0.51 per pure gal. of ethanol used or blended.	December 2010	Available to blenders/retailers.
Volumetric biodiesel excise tax credit	Agri-biodiesel; waste grease biodiesel; and renewable diesel[2]	$1.00 per pure gal. of agri-biodiesel; $0.50 per pure gal. of waste-grease biodiesel; $1.00 per gal of renewable diesel fuel used or blended.	December 2008	Available to blenders/retailers.
Small ethanol producer credit	Ethanol from biomass	$0.10 per gal. of ethanol produced up to 30 million gallons.	December 2008	Up to 60 million gallons per year capacity. Cap at $1.5 million per year per producer.
Small biodiesel producer credit	Agri-biodiesel	$0.10 per gal. of biodiesel produced up to 15 million gallons.	December 2008	Up to 60 million gallons per year (mgy) production capacity. Cap at $1.5 million per year per producer.
Income tax credit for E85 and B20 infrastructure	Ethanol or biodiesel	Permits taxpayers to claim a 30 percent credit for cost of installing clean-fuel vehicle refueling facilities at business or residence.	December 2008	$30,000 limit on tax credit.
Tax credit on unconventional fuels	Gas from biomass and synthetic fuels	$6.40 per barrel of liquid fuels or $1.13 per thousand cubic feet of gas.	December 2007	Expanded under the Omnibus Reconciliation Act of 1990.
Tax exempt interest on Industrial Development Bonds	Fuel from solid waste	Facilities that produce fuel from solid waste are exempt from taxes on industrial development bond interest.	December 2010	

[1] Biomass includes grain based biomass.
[2] Agri-biodiesel is biodiesel produced from soybeans, waste grease biodiesel is biodiesel produced from recycled vegetable oil, and renewable biodiesel is biodiesel produced from other renewable sources such as animal fats.

Note.–Liquid biofuel blends are denoted with a B for biodiesel and an E for ethanol. For example, B20 is conventional diesel blended with 20 percent biodiesel, and E85 is gasoline blended with 85 percent ethanol.

Source: Lazzari, *Energy Tax Policy*, April 22, 2005; Schnepf, *Agriculture-Based Renewable Energy Production*, May 18, 2006; Joint Committee on Taxation, “List of Expiring Federal Tax Provisions 2007–2020,” January 11, 2008, 8–9; and Renewable Fuels Association Web site. http://www.ethanolrfa.org/policy/regulations/federal/standard (accessed February 15, 2008).

Federal Programs

The largest tax credit is the volumetric ethanol excise tax credit, commonly referred to as the blenders' credit, which provides blenders with a credit of 51 cents per gallon of ethanol used or blended. This credit is used to offset the 18.4 cents per gallon federal excise tax on gasoline. In a gallon of E10 gasoline, for example, the blender would receive a 5.1 cents credit against the gasoline tax, 16.6 cents in this example, reducing it to 11.5 cents. The blenders' credit is awarded without limit and regardless of the price of gasoline, and cost the federal government an estimated $3.7 billion in lost tax revenue in 2007.[55] Although the volumetric biodiesel excise tax credit is similar to the blenders' credit for ethanol, production and blending volumes are much smaller. The blenders' credit for biodiesel cost the federal government an estimated $100 million in lost tax revenue in 2007.[56] The American Jobs Creation Act extends the ethanol blenders' credit until 2010.

Small ethanol and biodiesel producers—defined as those with production capacity of less than 60 million gallons per year—are also supported by producer credits of 10 cents per gallon up to 30 million gallons produced. Industry representatives, however, claim that this credit provides a disincentive to build larger, more integrated biorefineries and that, to encourage plants to reach efficient scales of production, the limit on qualifying facilities should be expanded beyond 60 million gallons.[57]

State Programs

Several states also provided tax incentives to attract investment, ranging from production-linked tax credits (PTC) to state blending credits (table 4-8). Sales tax exemptions for blended fuels were found in 19 states, ranging from 1 cent per gallon (cpg) to 42 cpg on ethanol and biodiesel blended fuels. PTCs and distributor tax incentives were identified in 23 states. PTCs were granted to companies for a range of activities such as a continued production of renewable fuels or for increasing production or production capacity of renewable fuels. Distributor tax incentives are generally tied to offering renewable fuels for sale or conversion, or for installation of equipment necessary for producing renewable fuels.

[55] Joint Committee on Taxation, "Estimates of Federal Tax Expenditures," April 25, 2006, 25.
[56] Ibid.
[57] Based on Commission questionnaire responses.

TABLE 4-8
U.S. state tax incentives for industrial biotechnology

State	Incentive	Fuel	Note
Arkansas	50 cents per gallon (cpg) B1; $1.00/gal B2 and higher. Supplier refund.	Biodiesel	
Arkansas	50 cpg of B100 used in blending.	Biodiesel	Applies only to first 2% of gallons blended within the state.
Arkansas	9.8 cpg for E85.	Ethanol	State tax exemption.
Arizona	Angel investor tax credits.		Provides tax credits for biotech investments by angel investors.
California	40 cpg producer-linked tax credit (PTC).	Ethanol and biodiesel	Never funded.
California	9.8 cpg for E85.	Ethanol	State tax exemption.
Colorado	Sales and use tax recovery.		Allows biotechnology firms to recover the sales and use taxes paid in the preceding year on purchases of equipment and supplies for research and development.
Florida	20 cpg for E85.	Ethanol	
Hawaii	30 cpg PTC.	Ethanol	State-wide cap of $12m/yr.
Hawaii	Sales tax exemption for E10, E85, B2 and above.	Renewable fuels	The 4 percent sales tax exemption was equivalent to approximately 12.5 cpg in 2005.
Illinois	5 cpg grant for retrofitting or expanding existing biofuels production facilities; 10 cpg grant for new facilities.	Ethanol and biodiesel	Max. grant of $6.5m per facility.
Illinois	Sales tax exemption for E70 and above, B10 and above.	Ethanol and biodiesel	Pay only 80 percent of sales tax on proceeds for lower blends.
Indiana	2 cpg blenders' credit, B2 and higher.	Biodiesel	Requires use of in-state feedstocks.
Indiana	$1/gal PTC of B2 or higher.	Biodiesel	Only IN biodiesel eligible; per facility cap of $3–5m.
Indiana	1 cpg retailer tax credit, B2 or higher.	Biodiesel	$1m statewide limit.
Indiana	12.5 cpg PTC for increasing ethanol production capacity.	Ethanol	Increase must be 40 million gallons per year (mgy) or higher. Plant lifetime cap of $2m for 40-60 mgy; $3m if >60 mgy.
Iowa	3 cpg to distributors of B2 if 50% of sales are B2 or higher.	Biodiesel	
Iowa	25 cpg E85 retailer tax credit.	Ethanol	
Iowa	2.5 cpg incremental tax credit to retailers selling >60% of volume blended ethanol.	Ethanol	Credit applies only to sales in excess of 60% threshold.
Iowa	2 cpg for E10, 4 cpg for E85, 8.4 cpg for B2 and 42 cpg for B100.	Ethanol and biodiesel	4 cpg E85 credit up to $700,000; otherwise, 2 cpg.

See source at end of table.

TABLE 4-8—*Continued*
U.S. state tax incentives for industrial biotechnology

State	Incentive	Fuel	Note
Kansas	30 cpg PTC for biodiesel producers.	Biodiesel	
Kansas	5 cpg PTC for pre-existing ethanol production capacity; 7.5 cpg for new capacity or expansions.	Ethanol	Max. credits of $750k/plants up to 10 mgy; $1.125m on plants up to 15 mgy.
Kentucky	$1/gallon producer or blenders' tax credit.	Biodiesel	Statewide cap of $1.5m/year.
Maine	5 cpg PTC for ethanol and biodiesel producers.	Ethanol and biodiesel	
Maine	2 cpg for E10, 7.6 cpg for E85.	Ethanol	State tax exemption.
Maryland	20 cpg PTC for ethanol produced from small grains; 5 cpg PTC for other feedstocks such as corn.	Ethanol	Credit limited to 15 mgy, of which 10 mgy must be small grains.
Maryland	20 cpg PTC for biodiesel from soybeans in new production capacity; 5 cpg PTC if from other feedstocks or soy from pre-existing plant.	Biodiesel	Annual cap on 2 mgy of new soy capacity; 3 mgy from other capacity.
Maryland	R&D tax credits.		Tax credits for individuals, corporations, and VC firms that invest in biotechnology firms.
Minnesota	20 cpg PTC for ethanol production. New enrollments ceased in 2004.	Ethanol	Payments capped at $3m 20.8 per producer per year since 2004.
Minnesota	5.8 cpg for E85.	Ethanol	Blending tax credit.
Mississippi	20 cpg PTC for ethanol producers.	Ethanol	Cap of $6m/year per producer, $37m statewide.
Mississippi	Jobs tax credit, Advantage jobs program, Rural economic development corporate income tax credit.		Technology-intensive companies are now eligible.
Missouri	20 cpg PTC for first 12.5 mgy of ethanol production; 5 cpg on next 12.5 mgy.	Ethanol	Plants must be majority-owned by local agricultural producers.
Missouri	30 cpg PTC to biodiesel producers on first 15 mgy of production; 10 cpg on next 15 mgy.	Biodiesel	
Montana	2 cpg distributor tax rebate on B2 or higher.	Biodiesel	Must be sourced entirely from MT feedstocks.
Montana	10 cpg PTC for increases in biodiesel production over the prior year.	Biodiesel	
Montana	20 cpg PTC for ethanol production containing 100% MT feedstocks. Credit declines as local content falls.	Ethanol	$2m/yr per producer; $6m/year per state.
Montana	4.1 cpg PTC for E10 and E85	Ethanol	State tax exemption.

See source at end of table.

TABLE 4-8—*Continued*
U.S. state tax incentives for industrial biotechnology

State	Incentive	Fuel	Note
Nebraska	18.5 cpg PTC for ethanol production up to 15.6 mgy.	Ethanol	$2.8m per plant per year.
Nebraska	R&D tax credit.		Recently created R&D tax credit for start-up and early stage commercialization projects.
New York	Qualified emerging technology company tax credit.		Refundable tax credits up to $250,000 a year per firm for R&D expenses and other costs such as fundraising, commercialization, facilities, and training.
New York	42 cpg PTC for E85, 8.4 cpg for B20, and 42 cpg for B100.	Ethanol and biodiesel	State tax exemption.
North Carolina	20.2 cpg for E85 and B2.	Ethanol and biodiesel	State tax exemption.
North Dakota	5 cpg blender tax credit for B5 and higher.	Biodiesel	
North Dakota	40 cpg PTC for ethanol produced and sold in ND.	Ethanol	Plant built prior to 1995; plant cap at $900k/2 yrs if >15 mgy; at $450k/2 yrs if <15 mgy.
North Dakota	6.6 cpg for B2.	Biodiesel	State tax exemption.
North Dakota	Producer payments tied to price of corn for increasing capacity by 50% of 10 mgy.	Ethanol	State cap of $1.6m; plant lifetime cap of 10m.
North Dakota	Consumer, investment, and income tax incentives.		Committed $4.6 million in 2005 for consumer tax incentives for E85, investment tax credits for ethanol and biodiesel producers, and income tax credits for biodiesel producers.
Oklahoma	20 cpg PTC for new capacity up to 25 mgy prior to 2012, 10 mgy thereafter.	Biodiesel	Per plant lifetime cap of $25m prior to 2012; $6m/plant after.
Oklahoma	20 cpg PTC for new ethanol capacity.	Ethanol	
Oregon	Business energy tax credit.	Electricity	Exempt 50 percent of the real market value of property used to make electricity with renewable resources.
Oregon	Ethanol production facility tax exemption.	Ethanol	Exempt 50 percent of the real market value of property used to make electricity with renewable resources.
Pennsylvania	5 cpg producer grant for ethanol producers up to 12.5 mgy.	Ethanol	
Pennsylvania	9.3 cpg for E85.	Ethanol	State tax exemption.
South Dakota	20 cpg PTC.	Ethanol	State-wide cap of $7m/year.

See source at end of table.

TABLE 4-8—*Continued*
U.S. state tax incentives for industrial biotechnology

State	Incentive	Fuel	Note
South Dakota	2 cpg for E10 and 12 cpg for E85.	Ethanol	State tax exemption.
Texas	16.8 cpg PTC (net of fees) on first 18 mgy each of ethanol and biodiesel per plant.	Ethanol and biodiesel	
Virginia	10 cpg production grants for new plants or expansions of Biodiesel 10 mgy or more of ethanol or biodiesel.	Ethanol and biodiesel	
Wisconsin	20 cpg PTC on first 15 mgy of ethanol production.	Ethanol	Requires use of in-state feedstocks.
Wyoming	40 cpg PTC for new or expanded ethanol production facilities.	Ethanol	Caps of $2m/year for a single plant and $4m/year for the entire state.

Note.—Information is from 2006 and 2007 sources and may not be current in all cases. Liquid biofuel blends are denoted with a B for biodiesel and an E for ethanol. For example, B20 is conventional diesel blended with 20 percent biodiesel, and E85 is gasoline blended with 85 percent ethanol.

Sources: Koplow, *Biofuels—At What Cost?* "Table 4.2: Summary of Production-linked Incentives at the State Level," 2006, 28; Koplow, *Biofuels—At What Cost?* "Table 4.1: State Motor Fuel Tax Preferences for Biofuels, 2006," 2006, 27; Battelle, *Growing the Nation's Bioscience Sector*, 2006, 4; Battelle, "State Profiles," 2006, Arizona -1; Martinot, *2006 Update*, 2006, 10; Kojima, Mitchell, and Ward, *Considering Trade Policies*, 2007, 50; GBEP, *A Review of the Current State of Bioenergy Development in G8 +5 Countries*, 2007, 221; and Oregon Department of Energy Incentives Web site. http://www.oregon.gov/energy/renew/biomass/incentive.shtml#betc (accessed February 12, 2007).

States also provide sales and use tax credits on equipment purchases or property tax exemptions that specifically target IB in order to increase local development of IB R&D parks. Some industry representatives state that individual state mandates for biofuel content are narrowly focused, favoring particular feedstock and process technologies, and that this "picking of 'winners and losers' stifles innovation and creates uncertainty in the development of advanced biofuels."[58]

Foreign Country Comparison

In contrast with the United States, tax incentives for producers are not a predominant form of IB support in Brazil. An incentive program exists for biodiesel producers whereby they receive preferential tax rates and financing terms in exchange for purchasing feedstocks from, and providing technical assistance and training to, small family farmers.[59] Consumers benefit from tax incentives on purchases of flex-fuel vehicles,[60] as well as the ethanol to fuel those vehicles. Several preferential tax rates at the federal and state levels are applied to sales of fuel ethanol.[61]

Canada offers a number of tax and investment incentives. The Scientific Research and Experimental Development program is the largest single source of federal government

[58] Based on Commission questionnaire responses.
[59] MDA, "Selo Combustível Social," February 8, 2006.
[60] Ethanol Statistics Ltd., *The Brazilian Ethanol Market 2007*, September 2007, 17.
[61] MF, "Taxes on Consumption of Goods and Services in Brazil," November 2006; Decreto nº 5.060, de 30 de abril de 2004; MME, ANP, "Preços Médios Ponderados Semenais 2008," undated (accessed February 12, 2008); and Ethanol Statistics Ltd., *The Brazilian Ethanol Market 2007*, September 2007, 43.

support for industrial R&D conducted by Canadian firms.[62] There are also various investment incentives directed to the biofuel sector that support the construction and expansion of production facilities.[63] The federal government's excise tax exemptions for retail sales of biofuels[64] were replaced in April 2008 with the ecoEnergy for Biofuels incentive program to promote ethanol production.[65] Nevertheless, provincial governments still provide excise tax exemptions at the consumer level for biofuels.[66]

China has implemented numerous economic measures to promote ethanol supply and demand that include monetary support to producers, guaranteed profit levels, tax exemptions, financial incentives related to grain reserves, a fixed level of government compensation for losses through the sale of E10, and interest support for loans.[67] More recently, China promulgated new laws (e.g., for the creation of risk reserves, changes in financial incentives, and availability of venture capital)[68] that are reportedly intended to help the fuel ethanol industry become more economically self-sufficient.[69]

The EU also offers favorable tax treatment for biofuels and conventional fuels blended with biofuels; however, the appropriate level of taxation for conventional fuels and biofuels is left to the individual member states.[70] Member states offer a wide variety of either partial or full exemptions for biodiesel and ethanol blends from the various excise tax rates levied on conventional diesel and gasoline.[71]

In Japan, IB firms benefit from a number of R&D tax incentives that are available to all industries, including tax credits for R&D expenditures, increased R&D expenditures, and for small- to medium-sized enterprises.[72] Tax incentives relating to the purchase of fuel efficient or clean-energy vehicles exist,[73] and a preferential tax system is currently under consideration to promote the use of biofuels in motor vehicles.[74]

[62] Canada Revenue Agency, "What is the SR&ED Program?" December 21, 2004.

[63] Agriculture and Agri-Food Canada, "Minister Stah Announces Cash for Biofuels Farming Opportunities," July 17, 2006; CRFA, "Biofuels Get Big Boost in 2007 Budget," March 19, 2007; Government of Canada, "Five Ethanol Plants Receive $46 Million," July 6, 2005; and Agriculture and Agri-Food Canada, "ecoAgriculture Biofuels Capital Initiative: Program Overview," April 23, 2007.

[64] Dessureault, *Bio Fuels Canada*, August 17, 2007.

[65] Natural Resources Canada, "ecoEnergy for Biofuels," November 29, 2007.

[66] Dessureault, *Bio Fuels Canada*, August 17, 2007.

[67] Latner, O'Kray, and Jiang, *China, People's Republic of: Bio-Fuels*, August 8, 2006; Latner, Wagner, and Junyang, *China, People's Republic of: Biofuels Annual 2007*, June 1, 2007; Chervenak, "Industrial Biotechnology in China," Fall 2006, 175; ABARE, *Report of the Biofuels Taskforce*, 2005, 68; Bilin, "Development of Biofuels in China," August 20–21, 2007; and Kojima, Mitchell, and Ward, *Considering Trade Policies for Liquid Biofuels*, 2007, 94.

[68] The availability of private equity and venture capital has increased in recent year. Chervenak, "Industrial Biotechnology in China," Fall 2006, 176.

[69] The Jilin Fuel Ethanol Company reportedly loses € 0.42 per gallon (about $0.50) of fuel ethanol. Gehua, et al., *Liquid Biofuels for Transportation*, February 2006, 9, 17, and 103.

[70] GBEP, "Annex II—The Regional Dimension, European Union," 2007, 246.

[71] Kutas, Lindberg, and Steenblik, *Biofuels—At What Cost?* October 2007, 33–36, and 41; Steenblik, *Biofuels—At What Cost?* September 2007, 63–64; and Makowski, *Poland Bio-Fuels Update 2007*, July 27, 2007, 2.

[72] Tanaka, "Tax Incentives for Research and Development in Japan," April 27, 2006.

[73] Fukuda, Kingsbury, and Obara, *Japan: Bio-Fuels*, May 26, 2006, 3.

[74] Environment Monthly Digest, "Japan: Government Plans Preferential Tax in 2008," September 2007, 25.

Mandatory Use Regulations

Liquid fuel companies ranked mandatory use regulations as the second most important and effective support program after federal tax incentives.[75] Chemical companies, on the other hand, indicated that mandatory use of final products was one of the least effective government support programs. Mandatory use regulations raise demand to support commercialization until the targeted industry is economically viable. All of the countries examined in this chapter have either adopted or are moving toward the adoption of mandatory use regulations for biofuels (table 4-9), and some also have mandatory use policies for bio-based plastics.

TABLE 4-9
Comparison of U.S. and foreign mandatory use regulations for blended fuels

	Ethanol		Biodiesel	
Countries	**Federal**	**State[1]**	**Federal**	**State**
United States	✓	✓	✓	✓
Brazil	✓		✓[2]	
Canada		✓		
China	✓[3]			
European Union[4]	✓		✓	
Japan	([5])	([5])	([5])	([5])

[1] Indicates that regulations are in effect in some, but not necessarily all, states/provinces.
[2] As of 2008.
[3] Federal mandate in effect in 9 provinces.
[4] Member states have enacted their own national mandates.
[5] None.

Source: Various industry and government publications.

United States

The United States has the most comprehensive federally mandated biofuel requirements in the world, with an annually rising minimum level of renewable fuels in the nation's fuel supply,[76] along with requirements for advanced biofuel usage.[77] Firms cite the RFS, federal preferred procurement, and fleet fuel procurement requirements as the prominent programs supporting the commercialization of liquid biofuels.[78]

Federal Programs

Pertinent legislation establishing mandatory use programs are identified in EPAct 2005 (amended by EISA), EPAct 1992, and the Farm Security and Rural Investment Act of 2002 (2002 farm bill). They include the RFS, fleet fuel usage requirements, and the federal bio-preferred procurement program.

[75] Based on Commission questionnaire responses.
[76] EPA, "Regulation of Fuels and Fuel Additives," May 2007; and EPA, "Revised Renewable Fuel Standard for 2008," February 2008.
[77] EPA Web site. http://epa.gov/otaq/renewablefuels/index.htm#comp (accessed February 25, 2008); and 72 Fed. Reg. 23991 (May 1, 2007).
[78] Based on Commission questionnaire responses.

The RFS, established by EPAct 2005 and amended by EISA, currently requires the U.S. fuel supply to include at least 9 billion gallons of renewable fuel in 2008. This amount increases annually to 36 billion gallons by 2022. Furthermore, by 2009, 600 million gallons of advanced biofuels must also be included in that year's RFS requirement. By 2010, nearly 11 percent of the advanced biofuel requirement must be met with cellulosic ethanol production. Moreover, the share of advanced biofuels required to meet the RFS grows from 5.5 percent in 2009 to 58.3 percent in 2022. The share of cellulosic ethanol that must be included in the advanced biofuel requirement similarly expands from 10.5 percent in 2010 to 76.2 percent in 2022. In February 2008, the EPA announced that the minimum level of renewable fuels required in the total fuel supply for 2008 is 7.72 percent,[79] and the level is set to increase annually.[80]

EPAct 1992 directs federal, state, and local governments that operate fleets of diesel trucks to earn alternative fuel vehicle credits by increasing their purchases of biodiesel. The National Biodiesel Board (NBB) estimates that federal fleets increased their usage of biodiesel from approximately 500,000 gallons in 2000 to approximately 30 million gallons in 2004. Furthermore, according to the NBB, there are more than 400 major government fleets using biodiesel, including all branches of the U.S. military, state departments of transportation, and major public utility fleets.[81] School districts have also begun using biodiesel in their bus fleets.

U.S. chemical producers ranked government procurement of bio-based products as an important mechanism for supporting the development and adoption of IB, and government procurement of bio-based products was addressed in the 2002 farm bill. The 2002 farm bill created the federal bio-preferred procurement program, which directs the USDA to create and maintain a list of certified bio-based products and requires all federal agencies to increase their purchases of these products.[82] However, due to the complicated means in which products are registered and certified as bio-preferred, some industry representatives find this program "less than effective."[83]

State Programs

States have similar RFS requirements, and some even have renewable portfolio standards (RPS). RPS requirements are flexible mandates that require power retailers to include renewable energy in the mix of fuels they use to generate electricity. To date, 21 states and the District of Columbia have RPS requirements in place.[84] In each instance, biomass is included by definition to qualify as a renewable energy resource. However, most mandates were approved in 2006 and some are dependent on state production of inputs or biofuels.

---

[79] EPA annually establishes an obligated renewable fuel use level based on expected consumption for that year. Obligated parties, firms that produce and/or import more than 75,000 gallons of gasoline a year, must annually report to EPA the quantity of renewable fuels purchased or produced as a percent of its production. Any firm not meeting the EPA blending regulation may be liable for a civil penalty of up to $32,500 per day per violation. EPA Web site. http://epa.gov/otaq/renewablefuels/index.htm#comp (accessed February 25, 2008); and 72 Fed. Reg. 23991 (May 1, 2007).

[80] EPA, "Regulation of Fuels and Fuel Additives," May 2007; and EPA, "Revised Renewable Fuel Standard for 2008," February 2008.

[81] Momentum Biofuels, Inc. Web site. http://www.momentumbiofuels.com/_news.php (accessed February 12, 2008)

[82] The 2008 farm bill continues the federal procurement program for bio-based products. Food, Conservation, and Energy Act of 2008, Pub. L. No. 110-246, § 9002, 122 Stat. 1651.

[83] Industry official, interview by Commission staff, Ames, IA, May 22, 2006.

[84] DeCesaro and Brown, *Bioenergy*, 2006, 32.

Minnesota, for example, was the first state to implement minimum ethanol content standards, currently set at 10 percent, and the first state to set minimum biodiesel content levels, in place since 2005. Minnesota has further strengthened its ethanol mandate by approving legislation requiring 20 percent by 2013.[85] Hawaii requires that 85 percent of the gasoline sold in the state contain 10 percent ethanol. The state of Washington has legislated a minimum content of 2 percent ethanol in gasoline and 2 percent biodiesel in diesel fuel. Montana has approved legislation requiring a minimum of 10 percent ethanol in gasoline when in-state ethanol production surpasses 40 million gallons.[86]

States also rely on their vehicle fleets to increase the use of, or enhance public awareness of, liquid biofuels. For example, Wisconsin requires state agencies to use E10, E85, or biodiesel in their vehicle fleets as much as possible to reduce gasoline consumption by 20 percent by 2010 and 50 percent by 2015.[87] The order also mandates a reduction in the use of diesel fuel by 10 percent by 2010 and 25 percent by 2015. California has passed laws directing public agencies to use vehicles that run on biodiesel and biodiesel blends,[88] and Indiana requires renewable fuels, such as gasohol and ethanol, to be used in state-owned vehicles as much as possible.[89]

Foreign Country Comparison

Some foreign countries such as Brazil and China mandate the use of biofuels, and others are working toward establishing mandates. Brazil was the first country to establish a national ethanol blending requirement for gasoline, which started in 1976. In 2004, the requirement was changed to vary according to ethanol supply and demand conditions.[90] Brazil mandated the use of biodiesel blends beginning in 2008, with increasing annual percentages through 2013.[91] China initiated national usage requirements for ethanol blends in nine participating provinces, with a goal that these blends account for 50 percent of all gasoline consumption in these provinces by 2010;[92] this blending requirement is anticipated to be implemented nationwide by 2020.[93]

The EU approach tends to set targets rather than mandatory use regulations. The EU 2003 Biofuel Directive established rising biofuel use targets for member states to meet by 2005 and 2010;[94] however, member states have generally not met these targets.[95] Hence, the 2007 Renewable Energy Road Map set a new legally binding minimum target share for biofuels

[85] GBEP, *A Review of the Current State of Bioenergy Development in G8 +5 Countries*, 2007, 220.
[86] Kojima, Mitchell, and Ward, *Considering Trade Policies*, 2007, 89.
[87] USDOE, EERE Web site. http://www.eere.energy.gov/afdc/progs/view_all.php/WI/0 (accessed February 15, 2008).
[88] California South Coast Air Quality Management District Web site. http://www.aqmd.gov/Default.htm (accessed February 15, 2008).
[89] Koplow, *Biofuels—At What Cost?* 2006, 69.
[90] MAPA, "Mistura Carburante," June 29, 2007.
[91] Law No. 11.097 of January 13, 2005.
[92] Latner, Wagner, and Junyang, *China, People's Republic of: Biofuels Annual 2007*, June 1, 2007, 4; Ke, "China to Boost Bio-Energy Use," November 21, 2006; Kojima, Mitchell, and Ward, *Considering Trade Policies for Biofuels*, 2007, 93; and Wang, et al., "Biofuels in China," July 12–13, 2007.
[93] Speckman, "Biofuel Industry Faces Feedstock Uncertainty," February 12, 2008.
[94] European Parliament and European Council, *On The Promotion of the Use of Biofuels*, May 8, 2003.
[95] GBEP, "Annex II—The Regional Dimension, European Union," 2007, 247; EC, *Biofuels Progress Report*, January 10, 2007, 15–16; and Kutas, Lindberg, and Steenblik, *Biofuels—At What Cost?* October 2007, 18–19.

in the EU transport sector.[96] In April 2008, Germany cancelled its planned increase in the compulsory ethanol content of gasoline, from the current E5 to E10, due to corrosion concerns for older vehicles.[97] In contrast, the planned increase in the compulsory biodiesel content in diesel fuel, from B5 to B7, was not cancelled despite similar corrosion concerns; the government reportedly considers these concerns to be manageable through stricter product standards.[98]

Canada and Japan have not yet implemented biofuel use regulations. The Canadian government announced that it would develop a mandate that would require 5 percent of the domestic gasoline pool to be renewable fuel each year starting in 2010.[99] The mandate would also require an average 2 percent of all diesel fuel and heating oil to be renewable fuel.[100] The mandate for diesel fuel and heating oil would become effective no later than 2012 only if renewable diesel fuel demonstrates its effectiveness under the range of Canadian climatic conditions.[101]

Japan does not have a national usage mandate, but has announced that all newly registered motor vehicles must be capable of burning ethanol blends starting in 2010.[102] Despite the lack of national mandates, some Canadian provinces have their own mandates[103] and some Japanese localities have begun limited vehicle testing of biofuels.[104]

China and Japan are also promoting the commercialization of bio-based chemical products through various usage programs and waste management laws. For example, the Chinese government established a program in 2005 to promote biodegradable plastics—specifically, the production and consumption of polylactic acid—with specific market targets out to 2020.[105]

Loan Guarantees

Nearly 58 percent of respondents characterized federal loan guarantees as very important. Because of the innovative and risky nature of many industrial biotechnologies, traditional lenders are likely to decline to extend credit or to offer limited credit with extremely high risk premiums. Loan guarantees bridge this gap by securing the banks against the risk associated with "first adopter" lending. One industry representative stated that banks have said that they "would be happy to provide commercial loans for [later stage] projects . . . , but would be unable, without a loan guarantee, to provide funding for the initial startup."[106]

---

[96] EC, *Renewable Energy Road Map*, January 10, 2007.

[97] Just-auto.com editorial team, "Germany: Government Scraps Compulsory Biofuel Blending Plans," April 4, 2008.

[98] Just-auto.com editorial team, "Germany: Concerns Raised Over Compulsory Blending of Biodiesel," April 21, 2008.

[99] Canadian Gazette, part I, December 30, 2006, Vol. 140, no. 52.

[100] Ibid.

[101] Ibid.

[102] Bunting, "New Renewable Fuels Standard Demands Ethanol Compatibility," August 2006, 1.

[103] Manitoba Science, Technology, Energy, and Mines Web site. http://www.gov.mb.ca/stem/energy/ethanol/ (accessed February 14, 2008); and Dessureault, *Bio Fuels Canada*, August 17, 2007.

[104] *Asahi Shimbun*, "Test Sales of Biofuel to Start in the Tokyo Area," April 27, 2007; and Masaki, "Japan Steps Up Its Biofuel Drive," December 13, 2007.

[105] DECHEMA e.V., "China's Biotechnology Industry on the Upswing," January 2007, 4.

[106] Industry official, telephone interview by Commission staff, February 29, 2008.

Many of the countries examined in this chapter have some type of loan guarantee mechanism. Some countries provide financial support through national banks that are directed to support specific programs, and others provide loan guarantees to specific companies in targeted industries.

United States

The U.S. liquid fuel and chemical industries consider federal and state loan guarantees to be ineffective in supporting the IB industry. Over 60 percent of questionnaire respondents expressed dissatisfaction with loan guarantees. One reason cited was the allegedly cumbersome application and qualification process. Industry sources further reported that the "lack of guaranteed loan programs impedes" the expansion of their operations.[107] Others claim that USDA grants and loan guarantees require applicants to meet strict rural definitions, which disqualifies projects sited in certain areas considered appropriate for liquid biofuel production, such as those with adequate inbound and outbound transportation infrastructure.[108]

However, some industry representatives report that loan guarantees are a crucial form of support for commercializing innovative technologies, such as cellulosic ethanol. Industry representatives further reported that only the federal government has the capacity to take on the financial needs of commercializing innovative technologies such as building cellulosic ethanol production facilities.[109]

The USDOE provides loan guarantees for commercialization and demonstration projects under EPAct 2005 and recently announced $2 billion in loan guarantees for the commercialization of alternative energy technologies from the R&D stage. EPAct 2005 also established grant and loan guarantee programs targeting cellulosic ethanol and ethanol produced from sugar. To date, $36 million has been transferred to projects in Hawaii, Florida, Louisiana, and Texas to convert sugarcane to ethanol, a $250 million loan guarantee program was established for sugar-to-ethanol conversion facilities, and another $50 million loan guarantee program was established for sugarcane-to-ethanol facilities.[110]

Six companies—Alico, BlueFire, Choren, Endicott Biofuels, Iogen Biorefinery Partners, and Voyager—have been invited to submit full applications and begin negotiations to obtain USDOE loan guarantees for the development of innovative biomass projects. Iogen has further reported in its public comments to the USDOE that the "President's '20 in Ten' initiative[111] depends on the widespread deployment of advanced biofuels refineries, and the

[107] Based on Commission questionnaire responses; and industry official, telephone interview by Commission staff, February 28, 2008.

[108] Based on Commission questionnaire responses; and industry official, telephone interview by Commission staff, February 28, 2008.

[109] Industry official, telephone interview by Commission staff, February 29, 2008.

[110] USDOE, "DOE Selects Six Cellulosic Ethanol Plants," February 28, 2007; USDOE, "Biorefinery Grant Announcement," February 28, 2007; and RFA, "Summary RFS and Renewable Tax Provisions," undated (accessed April 21, 2008).

[111] The goal of reducing U.S. gasoline usage by 20 percent in the next 10 years—"Twenty In Ten"—is to be reached by increasing the supply of renewable and alternative fuels by setting a mandatory fuels standard to require 35 billion gallons of renewable and alternative fuels in 2017.

Title 17[112] loan guarantee program is a key element in facilitating that deployment."[113] The importance of the timely implementation of the loan guarantee program, as well as the magnitude of the guarantees, was emphasized in May 2008 when Iogen announced that it would delay its cellulosic ethanol plant in Idaho, proceeding first with a plant in Saskatchewan, Canada.[114] Moreover, Eastman Chemical, a manufacturer and marketer of chemicals, fibers, and plastic worldwide, noted that without the "necessary incentives and framework to attract 'first adopter' projects," the deployment of innovative technologies will not occur. Incentives such as "Title XVII are necessary to encourage commercialization" of innovative technologies.[115]

Foreign Country Comparison

Some of the countries examined in this chapter offer loan guarantee programs for further development of liquid biofuels. Loan guarantees are a prominent form of government support in Brazil, where the National Economic and Social Development Bank administers several financing programs that are available to ethanol producers, generally at favorable interest rates compared with those available from commercial banks. In addition, regional and state-owned banks provide funding to the Brazilian ethanol sector as well as administer funds from the national bank.[116] China reportedly provides loan assistance through state-owned banks to firms in this sector.[117] In contrast to the United States, EU member states and the European Commission provide matching funds,[118] rather than loan guarantees, to industry partners for liquid biofuel R&D. In Canada, the Sustainable Development Technology Canada program provides interest-free loans that are repayable at such time as the venture becomes profitable.

---

[112] The USDOE's loan guarantee program was authorized by Title XVII of EPAct 2005. It "aims to encourage early commercial use of new or significantly improved technologies in energy projects. Loan guarantees issued by DOE, and backed by the full faith and credit of the United States government, will encourage the development of projects that employ new technologies that avoid, reduce, or sequester air pollutants and greenhouse gases. Projects supported by loan guarantees will help fulfill President Bush's goal of reducing our reliance on imported sources of energy by diversifying our nation's energy mix and increasing energy efficiency." USDOE, "DOE Announces Plans for Future Loan Guarantee Solicitations," April 11, 2008.

[113] Iogen Corporation, written submission to the U.S. Department of Energy, public comment period May 16–July 2, 2007, 3.

[114] Iogen had been planning to bring onstream a commercial-scale plant in Idaho possibly as early as 2009 pending approval of the loan guarantees. However, in the intervening time, it became apparent that parallel Canadian government support would possibly be available 6–9 months ahead of the U.S. loan guarantee. An earlier start in Canada is expected to enhance Iogen's intention to have a multi-plant rollout in the United States as early as possible to meet the annually increasing RFS mandate. Existing supply chain agreements negotiated with farmers and other entities remain viable. Industry official, e-mail message to Commission staff, May 28, 2008.

[115] Eastman Chemical Company, written submission to the U.S. Department of Energy, public comment period May 16–July 2, 2007, 2–3.

[116] Garten Rothkopf LLC, *A Blueprint for Green Energy in the Americas*, undated (accessed December 18, 2007), 520.

[117] Latner, O'Kray, and Jiang, *China, Peoples Republic of: Bio-Fuels*, August 8, 2006; Latner, Wagner, and Junyang, *China, People's Republic of: Biofuels Annual 2007*, June 1, 2007; Chervenak, "Industrial Biotechnology in China," Fall 2006, 175; ABARE, *Report of the Biofuels Taskforce*, 2005, 68; Bilin, "Development of Biofuels in China," August 20–21, 2007; and Kojima, Mitchell, and Ward, *Considering Trade Policies for Liquid Biofuels*, 2007, 94.

[118] Ambikapathy, *Status and Comparative Study*, October 2006, 26 and 28.

Agricultural Feedstock Programs

Agricultural feedstocks are the major input for all liquid biofuels and many bio-based chemicals; the cost of feedstocks is estimated to constitute more than one-half of the production costs for ethanol and biodiesel.[119] As such, programs that support the supply and utilization of agricultural feedstocks are important to liquid biofuel producers.

Agricultural feedstocks, used in the liquid biofuel and bio-based chemical industries, consist of grain and oilseed crops and their field residues (primarily corn, sorghum, soybeans, and wheat, but also barley and rice); switchgrass and other forage crops; animal fats; potatoes; recycled cooking oils; and sugar and molasses derived from sugarcane and sugarbeets.

United States

Agricultural programs that specifically support biofuels consist of R&D projects that improve enzymatic processes, a necessary step for converting biomass into ethanol and other bio-based products. These programs also target technologies that integrate feedstock pretreatment, biological conversion, and product recovery processes.

Federal Programs

Federal programs affecting agricultural crops, including agricultural crops that can be used as feedstocks for biofuels and bio-based chemicals, are administered by the USDA and the USDOE. The programs involve a wide range of activities, including direct support for farmers, R&D projects at universities and in the private sector, and research in government laboratories.

U.S. Department of Agriculture programs

The USDA administers most of the federal funding related to agricultural crops used as feedstocks because many of these crops receive support through the 2002 farm bill. Other legislation targeting agriculture also applies; some of the programs fund only feedstocks or feedstock projects.

Farm bill provisions

Under the 2002 farm bill,[120] the federal government provides financial support for certain crops, including corn, grain sorghum, soybeans, other oilseeds, rice, wheat, barley, oats, and sugarcane and sugarbeets.[121] Many of these programs focus on providing federal funding during periods when farm prices are low and include programs in the form of (1) marketing assistance loans and related programs, (2) direct payments, and (3) counter-cyclical payments. USDA programs provided production support for U.S. corn and sorghum totaling

---

[119] Kojima, *Support for Biofuels,* August 21, 2007.

[120] On June 18, 2008, the United States Senate and the U.S. House of Representatives passed the Food Conservation, and Energy Act of 2008 (Pub. L. No. 110-246, 122 Stat. 1651), overriding President Bush's veto of this legislation. The 2008 farm bill left provisions affecting feedstocks fundamentally unchanged from the 2002 farm bill. Wyant, *Agri-Pulse Update*, May 28, 2008, 1–5.

[121] These support programs do not provide for grasses, hay, forage crops, or animal fats.

$9.4 billion in FY 2006.[122] On an estimated pro rata basis of the total U.S. corn and sorghum crop, production payments provided to producers of corn and sorghum feedstocks consumed in the U.S. ethanol industry are estimated to have been $510 million in 2006 and $640 million in 2007.[123] Payments for crude soybean oil (derived from soybeans) used in the U.S. biodiesel industry were estimated at $20 million annually in 2006–07.[124] Total production support for U.S. soybean production in FY 2006 under USDA programs was $591 million.[125]

Marketing assistance loans provide farmers with cash flow without having to sell their commodities at harvest time, when market prices are typically the lowest.[126] According to the USDA, under current market price conditions for feedstock commodities, in which prices are far above loan rates, the marketing loan program has little impact on planting decisions.[127]

Direct payments are available through USDA's Direct and Counter-cyclical Program. These payments are tied to historical acreage and yields, rather than a farm's current production.[128] Feedstock commodities eligible for direct payments include corn, grain sorghum, soybeans, other oilseeds (canola, crambe, flaxseed, mustard seed, rapeseed, safflower, sesame, sunflower), rice, and wheat. Like marketing assistance loans, direct payments do not have a significant impact on planting decisions by farmers.

Farmers receive counter-cyclical payments when prices for eligible commodities are less than target prices specified in the 2002 farm bill. Counter-cyclical payments were not granted in crop year 2006 and may not be granted in crop year 2007, as target prices continue to be much lower than market prices. The USDA estimates that corn prices are 70 percent higher than the price that would trigger payments, and grain sorghum and soybeans are 76 percent and 94 percent higher, respectively.[129]

Research and development programs

USDA R&D activities for crops, including crops used as feedstocks for biofuels, are administered through the Agricultural Research Service (ARS) and focus on increasing corn and soybean production, as well as researching new bio-based products. The ARS has two separate programs: the Bioenergy and Energy Alternative National Program, and the Quality and Utilization of Agricultural Products National Program. Total ARS expenditures for these programs were included under the category "value-adding crop" research, and amounted to about $100 million in FY 2006, although not all of the funding was used for projects related to feedstocks. Projects funded through the Bioenergy and Energy Alternative National Program will likely result in a reduction in capital and processing costs associated with biofuel production. Projects funded through the Quality and Utilization of Agricultural Products National Program attempt, among other goals, to understand the structure,

[122] USDA, FSA, "CCC Net Outlays by Commodity and Function, Table 35," February 5, 2007; and Schnepf and Womach, *Potential Challenges to U.S. Farm Subsidies in the WTO,* April 26, 2007, 27–31.

[123] Koplow, *Biofuels at What Cost?* October 2007, 25 and 29.

[124] Ibid.

[125] USDA, FSA, "CCC Net Outlays by Commodity and Function Table 35," February 5, 2007.

[126] Loan rates are fixed under the 2002 farm bill and are currently $2.75 per bushel for wheat, $1.95 per bushel for corn and grain sorghum, $5.00 per bushel for soybeans, $0.093 per pound for other oilseeds. USDA, FSA, "2007 National Average Loan Rates." 2007.

[127] USDA, FSA, "Current Loan Deficiency Rates," undated (accessed March 10, 2008).

[128] USDA, FSA, "USDA Issues Final 2007 Direct Payments," September 25, 2007.

[129] USDA, FSA, "USDA Announces No Partial 2007-crop-year Counter-cyclical Payments," March 4, 2008.

properties, metabolism, and function of various crop and animal components, particularly carbohydrates, proteins, and lipids, in order to generate the development of new food, feed, and industrial products.[130]

Bioenergy program

The USDA's Bioenergy Program, administered by the Farm Service Agency, provided direct support to U.S. ethanol and biodiesel producers from 2001 to 2006 for eligible feedstocks[131] used in fuel production. The program ended in June 2006. The goal of the program was to encourage increased purchases of agricultural feedstocks for ethanol and biodiesel. The total annual payments averaged $75 million to ethanol producers and $20 million to biodiesel producers.[132] For biodiesel, the program primarily supported the purchase of soybean oil and animal fats, whereas for ethanol, corn and sorghum were the main feedstocks supported.[133]

Feedstock program

In March 2008, USDA pledged to implement policies that encourage the use of feedstocks and other biomass. Particular policies would (1) develop new markets for woody biomass culled from the nation's forests; and (2) foster the development of switchgrass.[134] USDA officials then announced federal grants under a woody biomass utilization program of approximately $4.1 million to 17 small business and community groups to find renewable energy and other uses for woody biomass harvested from national forests.[135]

U.S. Department of Energy programs

The Bioenergy Feedstock Development Program at USDOE's Oak Ridge National Laboratory (ORNL) focuses on new crops and cropping systems R&D.[136] In June 2007, the USDOE awarded $125 million for projects at a new bioenergy research center located at ORNL. The goal of the center is to develop processes for converting plants such as switchgrass and poplar trees into biofuels. The facility will be funded by the state of Tennessee and owned by the University of Tennessee.[137]

Significant federal government funds are also being granted to private corporations for conversion research. For example, Mascoma Corporation secured $4.9 million from the USDOE in March 2007 to develop fermentative organisms that speed the conversion of various types of cellulosic biomass into ethanol.[138] Other companies that received funding

---

[130] USDA, BRDI, *Biobased Fuels, Power and Products Newsletter*, December 2003.

[131] Eligible commodities are barley; corn; grain sorghum; oats; rice; wheat; soybeans; cottonseed; sunflower seed; canola; crambe; rapeseed; safflower; sesame seed; flaxseed; mustard seed; cellulosic crops such as switchgrass and hybrid poplars; fats, oils, and greases (including recycled fats, oils and greases) derived from an agricultural product; and any animal byproduct (in addition to oils, fats and greases) that may be used to produce bioenergy, as determined by the Secretary of Agriculture.

[132] Koplow, *Biofuels at What Cost?* 2006, 26.

[133] Ash, Livezey, and Dohlman, *Soybean Backgrounder*, April 2006, 18; and Yacobucci, *Biofuels Incentives*, July 25, 2006, 3–4.

[134] USDA, "USDA Rural Development Invites Applications," March 6, 2008.

[135] USDA, "Agriculture Secretary Schafer Awards More than $4.1 Million," March 10, 2008.

[136] Schnepf, *Agriculture-Based Renewable Energy Production*, May 18, 2006, 14.

[137] USDOE, ORNL, "ORNL-led Team Wins DOE Bioenergy Center," June 26, 2007.

[138] *AmericanVentureMagazine.com*, "Mascoma Secures $4.9 Million in Funding," March 29, 2007.

for similar research include Cargill ($4.4 million), Celunol Corporation ($5.3 million), Dupont ($3.7 million), and Purdue University ($5.0 million).[139]

The USDOE and the USDA also jointly administer the National Biomass Initiative. This program falls under the section 941 of the EPAct 2005,[140] and provides funds for R&D projects that encourage production and use of nontraditional biomass feedstocks. In both FY 2006 and FY 2007, the section 941 program was appropriated $14 million.[141] The USDA and the USDOE recently announced the awarding of grants totaling $18.4 million over three years for 19 biomass R&D projects and 2 biofuel demonstration projects under this initiative.[142] The projects are designed to make the production of biomass more efficient and cost effective (table 4-10). Grant recipients are required to raise a minimum of 20 percent matching funds for each project.[143]

The USDOE is also responsible for programs that develop feedstock infrastructure for biofuel production. The goal is to provide feedstock assembly and delivery operations that supply a consistent quantity of low-cost, high-quality, lignocellulosic biomass for conversion into biofuels.[144] Research focuses on three areas: (1) downstream costs associated with sustainable harvest practices, (2) engineered systems for mechanical preprocessing of feedstocks, and (3) dry and wet in-storage preprocessing costs. Active projects include multi-component harvesting of wheat straw and feedstock supply logistics.[145] The USDOE's Idaho National Laboratory and ORNL are heading up these efforts. In FY 2007 and FY 2008, the USDOE was appropriated $9.7 million and $12.3 million, respectively, for feedstock infrastructure projects. The budget request for FY 2009 is $15.5 million.[146]

---

[139] *Farm Industry News*, "Suitable Cellulose," September 1, 2007.

[140] Section 941 of EPAct was formerly authorized under the Biomass Research and Development Act of 2000. Within EPAct, it is authorized at $200 million, but these are discretionary funds, which were zeroed out of the FY 2009 budget, and as noted above, were only appropriated at $14 million for FY 2007 and FY 2008.

[141] EESI, "Administration Proposes Disappointing Renewable Energy Agriculture and DOE Biomass Budgets," February 5, 2008.

[142] USDA, "USDA, DOE to Invest up to $18.4 Million," March 4, 2008.

[143] Ibid.

[144] USDOE, EERE, "Biomass Program, Feedstock Infrastructure," June 2006.

[145] USDOE, EERE, "Biomass Program, Feedstock Research Projects," undated (accessed March 13, 2008).

[146] EESI, "Administration Proposes Disappointing Renewable Energy Agriculture and DOE Biomass Budgets," February 5, 2008.

TABLE 4-10
U.S. Department of Agriculture and U.S. Department of Energy: 2008 biomass research and development grants

Recipient	Grant	Purpose
	Dollars	
Battelle Memorial Institute	1,000,000	Address catalytic conversion of biomass to fuels and chemicals using ionic liquids
Packer Engineering	1,000,000	Research and develop on-farm conversion of biomass to synthetic gas, combined heat and electric power, and fertilizer
Purdue University	1,000,000	Develop low-cost, high-yield process for direct production of high energy density liquid fuel from biomass
University of Colorado	1,000,000	Develop rapid solar-thermal chemical systems for conversion of biomass to synthesis gas
University of Kentucky Research Foundation	999,964	Develop advanced ceramic materials for the separation and recovery of high-value pentose derivatives from cellulosic biomass using molecular imprinting
North Carolina State University	999,889	Develop advanced technology for low-cost ethanol from engineered cellulosic biomass
Cornell University	998,943	Develop more effective enzymatic conversion processes through nano-scale elucidation of molecular mechanisms and kinetic modeling
Agrivida, Inc.	982,589	Study altered plant compositions for improved biofuel production (rice straw, sorghum, and switchgrass)
University of Minnesota	975,676	Develop microwave-assisted pyrolysis system for conversion of cellulosic biomass to bio-oils
Rutgers University	971,799	Breed U.S. native grass
Iowa State University	944,899	Develop catalytic production of ethanol from biomass-derived synthesis gas
Ceres, Inc.	883,290	Evaluate herbaceous and woody crops for use in thermochemical processing, specifically willow and switchgrass species
University of Florida	866,576	Address genetic engineering of sugarcane for increased fermentable sugar yield
Ceres, Inc.	839,909	Identify and characterize plant genes involved in biosynthesis, with a focus on switchgrass
GE Global Research	820,035	Integrate biomass gasification with catalytic partial oxidation for tar conversion
University of Akron	743,904	Research and develop supercritical methods for biorefinery of rubber-bearing guayule biomass
University of Minnesota	715,340	Develop pathways to achieving U.S. bioenergy policy goals, assess economic costs and environmental impacts, and identify potential technological bottlenecks
Kansas State University	690,000	Demonstrate pelletizing forage crops and perennial grasses in the field to increase cellulosic ethanol production
University of Minnesota	576,368	Research and analyze lignin as a facilitator during saccharification by brown rot fungi

Source: U.S. Department of Agriculture.

State Programs

Funding to encourage the production and development of feedstocks is also occurring at the state and local levels. Although a comprehensive list of such programs is not available, many state and local government programs directed at feedstocks for liquid biofuels take the form of reduced taxes, grants, and regulations that encourage the use of feedstocks in downstream biofuel production or financial support for plant construction.[147] Arkansas offers an income tax credit of $15 per ton of rice straw (in excess of 500 tons) used to produce ethanol, effective January 1, 2006.[148] In 2007, Texas enacted legislation that authorizes $30 million annually for grants from the Texas Department of Agriculture to farmers, loggers, and others that provide agricultural biomass, wood waste, or storm-generated biomass debris to facilities that use biomass to generate electrical power.[149] New York provided small-scale, one time grants in 2006 to start feedstock farms within the state. Examples include $60,000 to the SUNY College of Environmental Science and Forestry in order to develop the first commercial willow plantation, and $22,385 for Cornell University Cooperative Extension Dutchess County to begin 15-acre growing trials of switchgrass.[150] As noted above, Tennessee is funding part of a multi-million dollar project to construct a 5 million gallon-per-year demonstration plant to convert switchgrass to ethanol, based on research at the USDOE Bioenergy Science Center in Oak Ridge, TN.[151]

Other states, such as Iowa, provide grants to local universities for R&D into feedstocks that produce larger volumes of ethanol per production unit or reduce the cost of converting the feedstock into ethanol. For example, a large ethanol producer, Poet LLC (previously known as Broin Companies), based in Sioux Falls, SD, has teamed up with researchers at Iowa State University to study differences in starches found in several varieties of corn. The goal is to identify strains of corn starches that are more readily broken down into glucose during conversion into ethanol. The two-year project is co-funded by Poet and an Iowa state economic development fund, the "Grow Iowa Values Fund."[152]

Several states have created regulatory regimes that directly encourage increased production of cellulosic feedstocks in their states. In Washington state, for example, legislation was passed in 2007 that created a position for a state employee responsible for coordinating efforts to develop both a biofuel market and a plan for a complete biofuel infrastructure supply chain in the state. In addition, conservation districts, public development authorities, and electric utilities are given direct authority to "enter into crop purchase contracts for dedicated energy crops used for the production, selling, or distributing of biodiesel produced from Washington feedstock, cellulosic ethanol, and cellulosic ethanol blends."[153]

---

[147] Koplow, *Biofuels at What Cost?* 2006, 38 and 51; and Koplow, *Biofuels at What Cost?* October 2007, 17–18.

[148] Arkansas Department of Finance and Administration, Tax Credits and Special Refunds Section, "Rice Straw Income Tax Credit," 2005.

[149] State of Texas, State Energy Conservation Office, "Cellulosic Ethanol," 2006.

[150] New York Forest Owners Association, "Position Statement," undated (accessed March 7, 2008).

[151] USDOE, ORNL, "ORNL-led Team Wins DOE Bioenergy Center," June 26, 2007; and ORNL, "DOE Bioenergy Science Center," June 26, 2007. Funding partners for the center include the USDOE's ORNL, the USDOE's NREL in Colorado, University of Tennessee, University of Georgia, Dartmouth College, Georgia Tech, the ArborGen, Diversa Corporation (now Verenium Corp.), and Mascoma Corporation.

[152] Lammers, "Iowa Researcher Works on Ethanol Project," February 21, 2008.

[153] BioEnergy Washington, "BioFuel Incentives," undated (accessed March 8, 2008).

Foreign Country Comparison

In contrast with the policy approach of the U.S. government, foreign governments focus their policy on specific crops for the end product. In December 2004, the Brazilian government passed legislation which allowed tax exemptions for biodiesel producers that utilize castor oil and palm oil as feedstock. These incentives are designed to benefit rural communities in Brazil's northeastern states, which are some of the poorest in the country.[154]

In line with restrictions on industrial usage of grains amid efforts to offset food security concerns, China announced the large-scale cultivation of bioenergy forests as feedstocks for biodiesel production.[155] The Ministry of Agriculture also announced new plans for growing sugarcane, sweet sorghum, and cassava for the production of ethanol, and rapeseed for the production of biodiesel.[156]

The European Commission is considering mandatory targets to boost the use of biofuels throughout the EU. To meet these targets, the European Commission is encouraging EU members to produce 50 percent of the feedstock for biofuels produced domestically. The EU has a special aid program for energy crops grown on non-set-aside land. These crops are eligible for €45 per hectare (about $22.60 per acre), with a maximum guaranteed area of 1.5 million hectares (3.7 million acres). Feedstocks used for ethanol production in the EU are primarily cereals and sugarbeets; the main biodiesel feedstock is rapeseed.[157]

According to the 2006 EU-25 sugar policy, sugar grown as feedstock for manufacturing chemicals, pharmaceuticals, and ethanol is exempt from production quotas; sugarbeets grown as nonfood crops qualify for set-aside payments; and sugarbeets are eligible for energy crop assistance.[158]

In Japan, a change to the sugar support program in 2007 favored sugarcane, as an ethanol feedstock, to receive commodity-specific support, whereas sugarbeets continue to fall under the blanket direct payment.[159]

---

[154] UNCTAD, *The Emerging Biofuels Market*, 2006, 14.

[155] *Bloomberg News*, "China to Develop Bio-Fuel Forests as Big as England," February 8, 2007; and Liang, "China Resorts to Biodiesel Projects," January 17, 2008.

[156] Jiao, "Crop Bases to Feed Biofuel Production," July 4, 2007.

[157] UNCTAD, *The Emerging Biofuels Market*, 2006, 10.

[158] Haley, Kelch, and Jeraldo, "European Union-25 Sugar Policy," January 31, 2006, 24.

[159] Fukuda, Kingsbury, and Obara, *Japan: Bio-Fuels*, May 26, 2006, 4–5.

Bibliography

Aberle, Randy. AgCountry Farm Credit Services. "Attracting Senior Debt to the Cellulosic Ethanol Industry." Presented at Cellulosic Ethanol Conference. Washington, DC, November 14, 2006.

Agência Paulista de Tecnologia dos Agronegócios (APTA). "Apresentação," undated. http://www.apta.sp.gov.br/ (accessed March 2, 2008).

Agriculture and Agri-Food Canada. "Agri-Opportunities Program," January 4, 2008. http://www.agr.gc.ca /index_e.php?s1=prog&s2=aop&page=intro.

———. "ecoAgriculture Biofuels Capital Initiative (ecoABC): Program Overview," April 23, 2007. http://www.agr.gc.ca/index_e.php?s1=prog&s2=ecoabc-iieb&page=what-quoi.

———. "Minister Stah Announces Cash for Biofuels Farming Opportunities." News release, July 17, 2006. http://www.agr.gc.ca/cb/index_e.php?page=n60717&s1=n&s2=2006.

Ahmann, Dianne, and John R. Dorgan. *Bioengineering for Pollution Prevention through Development of Biobased Energy and Materials: State of the Science Report*. Washington, DC: EPA, 2007. http://es.epa.gov/ncer/publications/statesci/bioengineering.pdf.

Alliance for Science & Technology Research in America (ASTRA). *Innovation Indicators for Tomorrow: Innovation Vital Signs Project "Candidates"; By Framework Category, A Better Taxonomy and Nomenclature for the Innovation Process?* 2008. http://www.usinnovation.org/files/Innovation_Indicators807.pdf (accessed February 22, 2008).

Allison, John R., and Mark A. Lemley. "Who's Patenting What? An Empirical Exploration of Patent Prosecution." *Vanderbilt L. Rev.* 53 (2000): 2099.

Altman, Ira, Chris R. Boessen, and Dwight R. Sanders. "Contracting for Biomass: Supply Chain Strategies for Renewable Energies." Selected Paper for Presentation at the Southern Agricultural Economics Association Annual Meeting, 2006. http://ageconsearch.umn.edu/bitstream/123456789/763/1/sp07al01.pdf.

Ambikapathy, J. *Status and Comparative Study, Cellulosic Bioethanol Production in the US, EU and China*. Brussels: European Association for Bioindustries (EuropaBio), October 2006.

AmericanVentureMagazine.com. "Mascoma Secures $4.9 Million in Funding," March 29, 2007. http://www.americanventuremagazine.com/news.php?newsid=2664/.

APM Health Europe. "Acquisition vs. Academia." *Biotech Focus Report*, June 15, 2007. http://focus.apmhealtheurope.com/freestory.php?bulletin=27.

Archer Daniels Midland Company (ADM). "Metabolix and ADM to Produce Mirel™, the World's First Biobased and Fully Biodegradable Plastic." News release, April 23, 2007. http://ir.metabolix.com/releasedetail.cfm?ReleaseID=239056.

Arkansas Department of Finance and Administration. Tax Credits and Special Refunds Section. "Rice Straw Income Tax Credit," 2005. http://www.arkansas.gov/dfa/excise_tax_v2/et_tc_incentives.html.

Asahi Shimbun. “Test Sales of Biofuel to Start in the Tokyo Area,” April 27, 2007. http://www.asahi.com/english/Herald-asahi/TKY200704270100.html.

Ash, Mark, Janet Livezey, and Erik Dohlman. *Soybean Backgrounder*. U.S. Department of Agriculture, Economic Research Service, April 2006. http://www.ers.usda.gov.

Askren, Hana, and Heather West. “Tremors in the Biodiesel Industry Could Force Consolidation, Bankruptcies.” *Financial Times*, February 19, 2008. http://www.ft.com/cms/s/2/a6193be8-df31-11dc-91d4-0000779fd2ac,dwp_uuid=e8477cc4-c820-11db-b0dc-000b5df10621.html.

Australian Bureau of Agricultural and Resource Economics (ABARE). *Report of the Biofuels Taskforce to the Prime Minister*. Canberra: ABARE, 2005.

Battelle. *Growing the Nation's Bioscience Sector: State Bioscience Initiatives 2006*. Arlington, VA: Battelle Technology Partnership Practice and SSTI, 2006.

———. “State Profiles.” In *Growing the Nation's Bioscience Sector: State Bioscience Initiatives 2006*. Arlington, VA: Battelle Technology Partnership Practice and SSTI, 2006.

Bilin, Xiong. “Development of Biofuels in China and Related Policies and Measures.” Presented at U.S. Department of Agriculture's Global Conference on Agricultural Biofuels: Research and Economics, Minneapolis, MN, August 20–21, 2007. http://www.ars.usda.gov/meetings/Biofuel2007/presentations/.

BIO. “Achieving Sustainable Production of Agricultural Biomass for Biorefinery Feedstock,” November 21, 2006. http://bio.org/ind/biofuel/SustainableBiomassReport.pdf.

———. Statement submitted to the Senate Committee on the Judiciary on the Role of Federally-Funded University Research in the Patent System, October 24, 2007.

BioEnergy Washington. “BioFuel Incentives,” undated. http://www.bioenergy.wa.gov/BiofuelIncentives.aspx (accessed March 8, 2008).

Biopact. “Novozymes Enters Development Cooperation on Cellulosic Ethanol in China,” June 28, 2007. http://biopact.com/2007/06/novozymes-enters-development.html.

Bloomberg News. “China to Develop Bio-Fuel Forests as Big as England.” *The Financial Express*, February 8, 2007. http://www.financialexpress.com/print.php?content_id=154224.

Bozeman, Barry. “Technology Transfer and Public Policy: A Review of Research and Theory.” *Research Policy* 29 (2000): 627–55.

British Petroleum (BP). “BP and D1 Oils Form Joint Venture to Develop Jatropha Biodiesel Feedstock.” News release, June 29, 2007. http://www.bp.com/genericarticle.do?categoryId=2012.

Bunting, Alan. “New Renewable Fuels Standard Demands Ethanol Compatibility.” *Automotive Environment Analyst*. AWKnowledge, August 2006.

Bureau van Dijk. Zephyr Mergers and Acquisitions database (accessed March 17, 2008).

Caesar, William K., Jens Riese, and Thomas Seitz. “Betting on Biofuels.” *The McKinsey Quarterly* 2 (2007): 53–62.

Canada’s Chemical Producers Association (CCPA). “Canada's Chemical Industry Advanced Materials: The Bridge to High Technology Products,” undated. http://www.ccpa.ca/files/Library/Reports/AdvancedOverview.doc (accessed February 29, 2008).

Canada Revenue Agency. “What is the SR&ED Program?” December 21, 2004. http://www.cra-arc.gc.ca/taxcredit/sred/aboutus-e.html.

Canadian Renewable Fuels Association (CRFA). “Biofuels Get Big Boost in 2007 Budget.” News release, March 19, 2007.

Cao, Zhuan, and Ming Liu. Chinese Society of Biotechnology. Tsinghua University. “Industrial Biotechnology and Bioenergy in China.” Presented at BIO’s Pacific Rim Summit, Honolulu, HI, January 2006.

Cargill. “Cargill Introduces BiOH ™ Brand Polyols.” News release, December 11, 2006. http://www.cargill.com/news/news_releases/2006/061211_bioh.htm#TopOfPage.

———. “Cargill’s BiOH™ Polyols Business Expands to Third Continent with Latin American Manufacturing Site.” News release, September 18, 2007. http://www.cargill.com/news/news_releases/2007/070918_biohbrazil.htm.

Carrez, D., P. Lindroos, and W. Soetaert. “Biotech Industry Publishes New Policy Agenda for Europe.” *Medical News Today*, December 27, 2006. http://www.medicalnewstoday.com/articles/59138.php.

Carriquiry, Miguel. “U.S. Biodiesel Production: Recent Developments and Prospects.” *Iowa Ag Review* 13, no. 2 (Spring 2007). http://www.card.iastate.edu/iowa_ag_review/spring_07/article4.aspx.

Carriquiry, Miguel, and Bruce A. Babcock. “A Billion Gallons of Biodiesel: Who Benefits?” *Iowa Ag Review* 14, no. 1 (Winter 2008). http://www.card.iastate.edu/iowa_ag_review/winter_08/IAR.pdf.

CEBC. “CEBC News.” Summer 2007. http://www.cebc.ku.edu/news/newsletters/cebc-news-v3-web.pdf.

Centre for Sustainable Engineering. “Biocatalysis: Overview,” 2005. http://www.cseng.org.uk/pdf/Biocatalysis%20-%20Overview%20PDF.prn.pdf (accessed January 11, 2007).

Ceres Inc. “Ceres and Rohm & Haas to Study Plant-Based Bioproducts.” News release, April 30, 2007. http://www.ceres.net/News/NewsReleases/2007/04-30-.

Chemical & Engineering News (*C&E News*). “Japan's Unique Perspective: Several Japanese Firms Have Parlayed a Rich History of Fermentation into Strong Biocatalysis Businesses,” May 21, 2001. http://pubs.acs.org/cen/coverstory/7921/7921biocatalysis3.html.

Chervenak, Matthew. “Industrial Biotechnology in China.” *Industrial Biotechnology* 2, no. 3 (Fall 2006): 174–76.

Clark, Giles. “Canadian Government Invests Can$500m in New Biofuels Fund.” *Biofuels Review*, September 12, 2007. http://www.biofuelreview.com/content/view/1192/.

Collins, Keith. Office of the Chief Economist, U.S. Department of Agriculture. Statement before the U.S. Senate Committee on Environment and Public Works, September 6, 2006. www.usda.gov/oce/newsroom.

D1 Oils plc. "Jatropha: A New Energy Crop," undated. http://www.d1plc.com/agronomyEnergy.php (accessed March 10, 2008).

De Cesaro, Jennifer A. and Mathew H. Brown. *Bioenergy: Power, Fuels and Products*. Washington, DC: National Conference of State Legislatures, 2006.

DECHEMA e.V. "China's Biotechnology Industry on the Upswing." *China's Biotechnology Industry*. Trend Report no. 8, January 2007.

———. "White Biotechnology, A Promising Tool for the Chemical Industry." *Industrial Biotechnology*. Trend Report no. 16, January 2006.

De Marzio, Graciela. "Addressing Global Misconceptions on Biodiesel." Presented at Second Annual Texas Biodiesel Conference and Expo. Austin, September 5–6, 2007. http://www.tecnon.co.uk/gen/uploads//5s3wod2f5qoizx55lmyrxhup17102007162352.pdf.

Dessureault, Darlene. *Bio Fuels Canada*. U.S. Department of Agriculture, Foreign Agricultural Service. GAIN Report no. CA7041, August 17, 2007. http://www.fas.usda.gov/gainfiles/200708/146292128.pdf.

Dorgan, John, Birgit Braun, and Margaret Sobkowicz, Colorado School of Mines, and Laura Hollingsworth, Richard Lucas, and Rudy Sossa, PolyNEW Inc. "Ecobionanocomposites: A New Class of Green Materials." Presented at the ACS Green Chemistry Forum, Washington, DC, June 2007.

Dow Chemical Co. (Dow). Written submission to the U.S. International Trade Commission in connection with inv. no. 332-481, *Industrial Biotechnology: Development and Adoption by the U.S. Chemical and Biofuel Industries*, April 10, 2007.

Duffield, James, Hosein Shapouri, Michael Graboski, Robert McCormick, and Richard Wilson. *U.S. Biodiesel Development: New Markets for Conventional and Genetically Modified Agricultural Products*. U.S. Department of Agriculture, Economic Research Service, September 1998.

Duke University. "North Carolina and the Global Economy: Dimensions of Globalization," Spring 2004. http://www.duke.edu/web/mms190/biotech/dimensions.html.

Duncan, Marvin. "U.S. Federal Initiatives to Support Biomass Research and Development." *Journal of Industrial Ecology* 7, no. 3/4 (2003): 193–201.

Dunn, Peter J. Pfizer. "Green Chemistry in Process Development." Presented at the University of California San Diego, San Diego, CA, December 5, 2007.

DuPont. "DuPont Engineering Polymers Previews Plans to Produce a New Family of High-Performance Polymers Made with Renewable Resources," June 20, 2006. http://plastics.dupont.com/myplastics/Mediator?id=671&locale=en_US.

——. "DuPont Launches DuPont™ Cerenol™: Its Newest Renewably Sourced Polymer Family," June 4, 2007. http://duponttateandlyle.com/news_060407.html.

——. "Fact Sheet: The DuPont™ Sorona® Polymer Sustainability Story," November 2006. http://www.prnewswire.com/mnr/dupont/26198/docs/Fact_Sheet_Sorona_LCA.doc.

——. "Fermentation: A New Take on Old Technology," 2007. www2.dupont.com/Renewably_Sourced_Materials/en_US/proc-buildingblocks.html (accessed February 29, 2008).

——. "Sorona® Renewably-Sourced Polymers," 2007. http://www2.dupont.com/Renewably_Sourced_Materials/en_US/sorona.html (accessed February 26, 2008).

Eastman Chemical Company. Written submission to the U.S. Department of Energy, Loan Guarantee Program, public comment period May 16–July 2, 2007. http://lgprogram.energy.gov/nopr-pc.html.

Environment Monthly Digest. "Japan: Government Plans Preferential Tax in 2008 to Encourage Biofuels." AWKnowledge, September 2007.

Environmental and Energy Study Institute (EESI). "Administration Proposes Disappointing Renewable Energy Agriculture and DOE Biomass Budgets for Fiscal Year 2009." February 5, 2008. http://www.eesi.org/publications/Press%20Releases/2008/fy09_adminbudget_biomass_020408.pdf.

Ernst and Young LLP. *The Economic Contributions of the Biotechnology Industry to the U.S. Economy*, May 2000. http://bio.org/speeches/pubs/ernstyoung.pdf.

Ethanol & Biodiesel News. "Special Report: Capacity Glut Crimps New Ethanol Plants," February 19, 2008.

Ethanol Producer Magazine. "East Coast Ethanol, LLC to Build Four 100-Million Gallon Per Year Ethanol Plants in the Southeast," September 14, 2007. http://www.ethanolproducer.com/press-release.jsp?press_release_id=122.

Ethanol Statistics Ltd. *The Brazilian Ethanol Market 2007*. Dordrecht, The Netherlands: Ethanol Statistics, Ltd., September 2007.

European Association for Bioindustries (EuropaBio) and European Federation of Biotechnology, Section on Applied Biocatalysts (ESAB). *Industrial or White Biotechnology: A Policy Agenda for Europe*. Brussels and Ghent: EuropaBio and ESAB, November 2006.

European Commission (EC). *Biofuels Progress Report: Report on the Progress Made in the Use of Biofuels and Other Renewable Fuels in the Member States of the European Union*. COM(2008) 845 final. Brussels: European Commission, January 10, 2007.

———. *Renewable Energy Road Map, Renewable Energies in the 21st Century, Building a More Sustainable Future*. COM(2006) 848 final. Brussels: European Commission, January 10, 2007.

European Parliament and European Council. *On The Promotion of the Use of Biofuels or Other Renewable Fuels for Transport*. EU Directive 2003/30/EC. Brussels, May 8, 2003.

Farm Industry News. "Suitable Cellulose," September 1, 2007. http://www.farmindustrynews.com.

Farrell, Alexander E., Richard J. Plevin, Brian T. Turner, Andrew D. Jones, Michael O'Hare, and Daniel M. Kammen. "Ethanol Can Contribute to Energy and Environmental Goals." *Science* 311 (January 27, 2006): 506–08.

Federal Trade Commission (FTC). *To Promote Innovation: The Proper Balance of Competition and Patent Law Policy*. Washington, DC: FTC, 2003. http://www.ftc.gov/os/2003/10/innovationrpt.pdf.

———. *2007 Report on Ethanol Market Concentration*, undated. http://www.ftc.gov/reports/ethanol/2007ethanol.pdf (accessed March 21, 2008).

———. *2006 Report on Ethanol Market Concentration*, December 1, 2006.

———. *2005 Report on Ethanol Market Concentration*, December 1, 2005.

Fisher, Lawrence M. "How Strategic Alliances Work in Biotech," January 1, 1996. http://www.strategy-business.com/.

Food and Agriculture Policy Research Institute (FAPRI). *2008 US Baseline Briefing Book*. FAPRI-MU Report no. 03-08, March 2008. http://www.fapri.missouri.edu/outreach/publications/2008/FAPRI_MU_Report_03_08.pdf.

Fraser, James. "Diversa, Celunol Merger Creates Cellulosic Ethanol Powerhouse." *Seeking Alpha*, February 15, 2007. http://seekingalpha.com/article/27144-diversa-celunol-merger-creates-cellulosic-ethanol-powerhouse.

Fuierer, Alana M. "The Growth of Green Trademarks," 2008. http://www.hrfmlaw.com/img/articles/article_464915.pdf (accessed February 21, 2008).

Fukuda, Hisao, Aaron Kingsbury, and Kakayu Obara. *Japan: Bio-Fuels; Bio-Fuels Production Report 2006*. U.S. Department of Agriculture, Foreign Agricultural Service. GAIN Report no. JA6024, May 26, 2006.

Fuyuno, Ichiko. *Japan's Scientific Public Research Structure at a Glance*. British Embassy Tokyo, July 2007. http://www.uknow.or.jp/be_e/science/reports/Policy/Japan_scientific_public_research_structure.pdf.

Garten Rothkopf LLC. *A Blueprint for Green Energy in the Americas*, undated. Prepared for the Inter-American Development Bank. http://www.iadb.org/biofuels (accessed various dates).

Gehua, Wang, Zhao Lixin, Zhang Yanli, Fu Yujie, Elisabeth-Maria Huba, Liu Dongsheng, Li Shizhong, Liu Dehua, and Heinz-Peter Mang. *Liquid Biofuels for Transportation: Chinese Potential and Implications for Sustainable Agriculture and Energy in the 21st Century Assessment Study*. Funded by German Ministry for Food, Agriculture, and Consumer Protection (BMELV) through German Agency for Renewable Resources (FNR), February 2006.

Genencor. "DuPont and Genencor Create World-Leading Cellulosic Ethanol Company." News release, May 14, 2008. http://www.genencor.com/cms/connect/genencor/media_relations/news/frontpage/investor_257_en.htm.

Genome News Network. "A Talk with Microbe Hunter Karl Stetter," October 1, 2004. http://www.genomenewsnetwork.org/articles/2004/10/01/stetter.php.

Global Bioenergy Partnership (GBEP). "Annex II—The Regional Dimension, European Union." In *A Review of the Current State of Bioenergy Development in G8 +5 Countries*, 240–56. Rome: Food and Agriculture Organization of the United Nations, 2007.

———. *A Review of the Current State of Bioenergy Development in G8 +5 Countries*. Rome: Food and Agriculture Organization of the United Nations, 2007.

Goodman, Barbara. National Renewable Energy Laboratory (NREL). "The Road Ahead: Advanced Powertrain Forum; Alternative Fuel Partnerships." Presented at Management Briefing Seminar, Ann Arbor, MI, August 10, 2007. http://www.cargroup.org/mbs2006/documents/GoodmanBarbara_000.pdf.

Government of Canada. "Five Ethanol Plants Receive $46 Million in Government of Canada Funding." News release, July 6, 2005. http://www.nrcan-rncan.gc.ca/media/newsreleases/2005/200550_e.htm.

Graff, Gordon. "Biofuel Bonanza Could Create Specialty Chemical Fountainhead." *Purchasing*, December 13, 2007. http://www.purchasing.com/article/CA6511685.html.

Greenbiz.com. "BP Funds $500 Million in Biofuels Research at Berkeley," February 2, 2007. http://www.greenbiz.com/news/news_third.cfm?NewsID=34558.

Haley, S., D. Kelch, and A. Jeraldo. "European Union-25 Sugar Policy." In *Sugar and Sweeteners Outlook*, SSS-245. Washington, DC: U.S. Department of Agriculture, Economic Research Service, January 31, 2006.

Hill, Jason, Erik Nelson, David Tilman, Stephen Polasky, and Douglas Tiffany. "Environmental, Economic, and Energetic Costs and Benefits of Biodiesel and Ethanol Biofuels." *Proceedings of the National Academy of Sciences of the United States of America* 103, no. 30 (July 25, 2006): 11206–9.

Hochhauser, Albert M. "Fats and Fatty Oils." *Kirk-Othmer Encyclopedia of Chemical Technology*. Hoboken, NJ: John Wiley & Sons, 2005.

Hoffman, William. "Select Global Biotechnology and Bioscience Clusters," March 5, 2008. http://www.mbbnet.umn.edu/scmap/biotechmap.html.

Hurt, Chris, Wally Tyner, and Otto Doering. *Economics of Ethanol*. Department of Agricultural Economics, Purdue University, December 2006.

ICMR. "NatureWorks: Market Development for Bioplastics," 2007. http://www.icmrindia.org/casestudies/catalogue/Marketing/Natureworks-Market%20 Development%20for%20Bioplastics.htm (accessed April 1, 2008).

Idaho State Journal. "Progress Slow on Shelley Ethanol Plant," May 17, 2007. http://www.pocatelloshops.com/blogs/ag.php?id=2934.

Iogen Corporation. Written submission to the U.S. Department of Energy, Loan Guarantee Program, public comment period May 16–July 2, 2007. http://www.lgprogram.energy.gov/nopr-pc.html.

Jiang, Wei-Ming. DSM (China) Ltd. "China: To Capture the Future of White Biotechnology." Presented at BIO 2008 World Congress on Industrial Biotechnology and Bioproceesing, Chicago, IL, April 29, 2008.

Jiao, Wu. "Crop Bases to Feed Biofuel Production." *China Daily*, July 4, 2007. http://www.chinadaily.com/bizchina/2007-07/04/cont.

Joint Committee on Taxation. "Estimates of Federal Tax Expenditures for Fiscal Years 2007–2011." Prepared for the House Committee on Ways and Means and the Senate Committee on Finance. Washington, DC, April 25, 2006.

———. "List of Expiring Federal Tax Provisions 2007–2020 (JCX-1-08)." Washington, DC, January 11, 2008.

Just-auto.com editorial team. "Germany: Government Scraps Compulsory Biofuel Blending Plans," April 4, 2008. http://www.just-auto.com/articleprint.aspx?ID-94375.

———. "Germany: Concerns Raised Over Compulsory Blending of Biodiesel," April 21, 2008. http://www.just-auto.com/articleprint.aspx?ID=94556.

Ke, Ren. "China to Boost Bio-Energy Use." *Xinhuanet*, November 21, 2006. http://www.ccchina.gov.cn/en/NewsInfo.asp?NewsId=6435.

Kojima, Masami. *Support for Biofuels: Considerations for Policymakers*. USDA Global Conference on Agricultural Biofuels: Research and Economics, Minneapolis, MN, August 21, 2007.

Kojima, Masami, Donald Mitchell, and William Ward. *Considering Trade Policies for Liquid Biofuels*. Energy Sector Management Assistance Program Special Report 004/07. Washington, DC: International Bank for Reconstruction and Development, 2007.

Koplow, Doug. *Biofuels—At What Cost? Government Support for Ethanol and Biodiesel in the United States*. Geneva, Switzerland: Global Subsidies Initiative, International Institute for Sustainable Development, 2006.

———. *Biofuels—At What Cost? Government Support for Ethanol and Biodiesel in the United States: 2007 Update.* Geneva, Switzerland: Global Subsidies Initiative, International Institute for Sustainable Development, October 2007.

Kourtz, Lauralynn, Kevin Dillon, Sean Daughtry, Oliver P. Peoples, and Kristi D. Snell. "Chemically Inducible Expression of the PHB Biosynthetic Pathway in *Arabidopsis*." *Transgenic Research* 6, no. 6 (December 2007): 759–69.

Krivda, Cheryl. "The Global Supply Chain: Discovering New Opportunity Across the 'Flat World'." *BusinessWeek*, 2005. http://www.businessweek.com/adsections/2005/pdf/0535_supplychain.pdf.

Kutas, G., C. Lindberg, and R. Steenblik. *Biofuels—At What Cost? Government Support for Ethanol and Biodiesel in the European Union*. Paris: OECD, October 2007.

Laane, Colja, and Feike Sijbesma. "Industrial Biotech at DSM: From Concept to Customer." In *Value Creation: Strategies for the Chemical Industry, 2nd Edition*, edited by F. Budde, U.-H. Felcht, and H. Frankemölle, 389–402. Weinheim: Wiley-VCH Verlag GmbH & Co., 2006.

Lammers, Dirk. "Iowa Researcher Works on Ethanol Project." *The News & Observer* (Raleigh, NC), February 21, 2008.

Latner, Kevin, Caleb O'Kray, and Junyang Jiang. *China, Peoples Republic of: Bio-Fuels An Alternative Future for Agriculture 2006.* U.S. Department of Agriculture, Foreign Agricultural Service. GAIN Report no. CH6049, August 8, 2006. http://www.fas.usda.gov/gainfiles/200608/146208611.pdf.

Latner, Kevin, Owen Wagner, and Jiang Junyang. *China, People's Republic of: Biofuels Annual 2007.* U.S. Department of Agriculture, Foreign Agricultural Service. GAIN Report no. CH7039, June 1, 2007. http://www.fas.usda.gov/gainfiles/200706/146291348.pdf.

Lauritzen, Clark. "Consolidation & Strategic Alternatives for Ethanol Producers." Presented at the Third Annual Platts Ethanol Finance & Investment Conference, Chicago, IL, May 10, 2007.

Lazzari, Salvatore. *Energy Tax Policy*. CRS Report for Congress IB10054. Washington DC: Congressional Research Service, April 22, 2005.

Lerner, Joshua. "The Importance of Patent Scope: an Empirical Analysis." *RAND Journal of Economics* 25, no. 2 (1994): 319–33.

Liang, Yan. "China Resorts to Biodiesel Projects to Solve Energy Shortage." *Xinhua*, January 17, 2008. http://news.xinhuanet.com/english/2008-01/16/content_7433384.htm.

LMC International. *Ethanol Quarterly*. Oxford, England and New York: LMC International, December 2007.

Makowski, W. *Poland Bio-Fuels Update 2007*. U.S. Department of Agriculture, Foreign Agricultural Service. GAIN Report no. PL7044, July 27, 2007.

Martinot, Eric. *2006 Update: Renewables Global Status Report*. Paris, France: Renewable Energy Policy Network for the 21st Century, 2006.

Masaki, Hisane. "Japan Steps Up Its Biofuel Drive." *Asia Times Online*, December 13, 2007. http://www.atimes.com/atimes/Japan/IL13Dh01.html.

Mendonca, Sandro, Tiago Santos Pereira, and Manuel Mira Goinho. "Trademarks as an Indicator of Innovation and Industrial Change." *Research Policy* 33 (2004): 1385–1404.

Metabolix, Inc. "About Telles," 2006. http://www.metabolix.com/natures%20plastic/mirel.html (accessed February 22, 2008).

———. "Form 10-K: Annual Report Pursuant to Section 13 or 15(d) of the Securities Exchange Act of 1934 for the Fiscal Year Ended December 31, 2006." U.S. Securities and Exchange Commission. http://www.secinfo.com/d11MXs.uN5b.htm.

———. "Metabolix Announces Results of Life Cycle Assessment for Mirel™ Bioplastics." News release, October 12, 2007.

Ministério de Agricultura, Pecuaria, e Abastecimento (MAPA). "Mistura Carburante (Álcool Anidro–Gasolina) Cronologia," June 29, 2007. http://www.agricultura.gov.br/pls/portal/docs/PAGE/MAPA/SERVICOS/USINAS_DESTILARIAS/MISTURA_CARBURANTE/MISTURA_COMBUST%CDVEL_25%25.PDF.

———. *Plano Nacional de Agroenergia 2006–2011*, 2006. http://www.agricultura.gov.br/pls/portal/docs/PAGE/MAPA/PLANOS/PNA_2006_2011/PLANO%20NACIONAL%20DE%20AGROENERGIA%202006%20-%202011-%20PORTUGUES.PDF (accessed March 2, 2008).

Ministério do Desenvolvimento Agrário (MDA). "Selo Combustível Social," February 8, 2006. http://www.mda.gov.br/saf/index.php?sccid=362.

Ministério de Fazenda (MF). "Taxes on Consumption of Goods and Services in Brazil," November 2006. http://www.receita.fazenda.gov.br/publico/estudotributarios/Eventos/EspecialistasPoliticaTributaria/Taxes%20on%20Consumption%20of%20Goods%20and%20Services%20in%20Brazil%20-%20Raimundo%20Carvalho.pdf.

Ministério di Minas y Energia (MME). Agencia Nacional de Petroleo, Gas, e Biocombustieis (ANP). "Preços Médios Ponderados Semenais 2008," undated. http://www.anp.gov.br/doc/petroleo/2008/comerc_gasolina08.pdf (accessed Feburary 12, 2008).

Nakanishi, Nao. "Jatropha Shines as Non-food Oil for Biodiesel." *Reuters*, January 14, 2008. http://www.reuters.com/article/GlobalAgricultureandBiofuels08/idUSHKG28600520080115?pageNumber=2&virtualBrandChannel=0&sp=true.

National Academy of Sciences (NAS). *Industrial Research and Innovation Indicators: Report of a Workshop*. Washington, DC: NAS, 1997.

National Agricultural Biotechnology Council. Fourth Annual World Congress on Industrial Biotechnology and Bioprocessing (2007). Summary Proceedings, March 21–24, 2007. http://nabc.cals.cornell.edu/pubs/WCIBB2007_proc.pdf.

National Biodiesel Board (NBB). "Commercial Biodiesel Production Plants," January 25, 2008. http://www.biodiesel.org/pdf_files/fuelfactsheets/Producers%20Map%20-%20existing.pdf.

———. "Energy Content," undated. http://www.biodiesel.org/pdf_files/fuelfactsheets/BTU_Content_Final_Oct2005.pdf (accessed May 29, 2008).

National Corn Growers Association (NCGA). "U.S. Corn Growers: Producing Food and Fuel," November 2006. http://www.ncga.com/news/OurViews/pdf/2006/FoodANDFuel.pdf.

National Science Board (NSB). *Science and Engineering Indicators 2008*. Arlington, VA: National Science Foundation, 2008.

Natural Resources Canada. "ecoEnergy for Biofuels: About the Program," November 29, 2007. http://oee.nrcan.gc.ca/transportation/ecoenergy-biofuels/about.cfm?attr=16.

NatureWorks LLC. "Green Mountain Coffee Roasters Launches First Hot Beverage Cups Coated with NatureWorks PLA," August 14, 2006. http://www.natureworksllc.com/news-and-events/press-releases/2006/8-14-06-green-mountain-coffee-roasters.aspx.

———. "Life Cycle Assessment," undated. http://www.natureworksllc.com (accessed February 7, 2008).

———. "NatureWorks LLC Corporate Overview," April 2007. http://www.natureworksllc.com/earth-month-2007/press-materials/corporate-overview.aspx (accessed April 1, 2008).

———. "NatureWorks PLA is Environmentally Friendly Alternative for Korean Customers," March 22, 2006. http://www.natureworksllc.com/news-and-events/press-releases/2006/3-22-06-natureworkspla-is-environmentally-friendly-alternative-for-korean-customers.aspx.

New Energy Finance, *Monthly Briefing* V, no. 9 (January 2008).

New York Forest Owners Association. "Position Statement: Policy on Woody Biomass Energy," undated. http://www.nyfoa.org/docs/PositionStatment-WoodyBiomassEnergyPolicy.pdf (accessed March 7, 2008).

Novozymes, Inc. "Cargill and Novozymes to Enable Production of Acrylic Acid via 3HPA from Renewable Raw Materials." News release, January 14, 2008. http://www.cargill.com/news/news_releases/080114_novozymes.htm.

OECD. *The Application of Biotechnology to Industrial Sustainability*. Paris: OECD, 2001.

———. Directorate for Science, Technology and Industry. Committee for Scientific and Technological Policy. Working Party on Biotechnology. Task Force on Biotechnology for Sustainable Industrial Development. *Globalisation of Industrial Biotechnology R&D*. DSTI/STP/BIO(2008)13, February 14, 2008. http://www.olis.oecd.org/olis/2008doc.nsf/NEWRMSFREDAT/NT00000AD6/$FILE/JT03240092.PDF.

Passmore, Jeff. Iogen Corporation. "The Developer Community's Perspectives on the Value Chain." Panel discussion at the Cellulosic Ethanol Conference, Washington, DC, November 14, 2006.

Paulson, Nick D. and Roger G. Ginder. "The Growth and Direction of the Biodiesel Industry in the United States." Iowa State University. Center for Agricultural and Rural Development Working Paper 07-WP 448, May 2007.

Pollard, David J., and John M. Woodley. "Biocatalysis for Pharmaceutical Intermediates: The Future is Now." *Trends in Biotechnology* 25, no. 2 (December 20, 2006): 66–73.

Port Import Export Reporting Service. PIERS Database. http://www.piers.com (accessed May 5, 2008).

Price Waterhouse Coopers and National Venture Capital Association (PWC/NVCA). *Moneytree Report.* http://www.pwcmoneytree.com.

Ran, Ningqing, Lishan Zhao, Zhenming Chen, and Junhua Tao. "Recent Applications of Biocatalysis in Developing Green Chemistry for Chemical Synthesis at the Industrial Scale." *Green Chemistry*, December 4, 2007.

Range Fuels. "U.S. Department of Energy Awards Range Fuels up to $76 million Grant," February 28, 2007. http://www.rangefuels.com/US-Department-of-Energy-Awards-Range-Fuels-up-to-76-million-Grant.

Renewable Fuels Association (RFA). *Changing the Climate: Ethanol Industry Outlook 2008*. Washington, DC: RFA, February 2008. http://www.ethanolrfa.org/objects/pdf/outlook/RFA_Outlook_2008.pdf.

———. Ethanol Facts: Food Vs. Fuel," undated. http://www.ethanolrfa.org/resource/facts/food/ (accessed May 5, 2008).

———. *Industry Statistics, 2005*, undated. http://www.ethanolrfa.org/industry/statistics/#EIO (accessed March 27, 2008).

———. "Summary RFS and Renewable Tax Provisions: The Energy Policy Act of 2005; Conference Report, HR 6." Issue Brief, undated. http://www.ethanolrfa.org/objects/pdf/PublicPolicy/Regulations/RFAIssueBrief-SummaryofFinalEnergyBill.pdf (accessed April 21, 2008).

Rohm and Haas. Written submission to the U.S. International Trade Commission in connection with inv. no. 332-481, *Industrial Biotechnology: Development and Adoption by the U.S. Chemical and Biofuel Industries*, August 1, 2007.

Rosenwald, Michael S. "The Rising Tide of Corn: Ethanol-Driven Demand Felt Across the Market." *Washington Post*, June 15, 2007.

Royal Society. *Sustainable Biofuels: Prospects and Challenges*. London: The Royal Society, 2008. http://image.guardian.co.uk/sys-files/Environment/documents/2008/01/14/RoyalSociety.pdf.

Runge, C. Ford, and Benjamin Senauer. "How Biofuels Could Starve the Poor." *Foreign Affairs* 86, no. 3 (May-June 2007): 41–53

Sarnia-Lambton Economic Partnership. "Profile: Industrial Bio-Products," undated. http://www.sarnialambton.on.ca (accessed February 29, 2008).

Schacht, Wendy. *Small Business Innovation Research Program*. CRS Report for Congress 96-402-SPR. Washington DC: Congressional Research Service, December 4, 2006.

Schnepf, Randy. *Agriculture-Based Renewable Energy Production*. CRS Report for Congress RL32712. Washington DC: Congressional Research Service, May 18, 2006.

Schnepf, Randy, and Jasper Womach. *Potential Challenges to U.S. Farm Subsidies in the WTO*. CRS Report for Congress 33697. Washington, DC: Congressional Research Service, April 26, 2007.

Schwartz, Sandi, Tina Masciangioli, and Boonchai Boonyaratanakornit. Rapporteurs. "Bioinspired Chemistry for Energy: A Workshop Summary to the Chemical Sciences Roundtable." Pre-publication copy, 2008. http://www.nap.edu/catalog/12068.html (accessed March 23, 2008).

Shapouri, Hossein, and Michael Salassi. *The Economic Feasibility of Ethanol Production From Sugar in the United States*. Washington, DC: USDA, July 2006.

Shapouri, Hossein, and Paul Gallagher. *USDA's 2002 Ethanol Cost-of-Production Survey*. USDA, Agricultural Economic Report no. 841, July 2005.

Shinn, Peter. "Ethanol Industry Consolidation Likely, Normal." *Primary Investment Management*, October 2, 2007. http://www.primary-im.eu/nieuws_item?item_id=51&previus_page=/nieuws.

Simonite, Tom. "GM Bacteria Churn Out 'Microdiesel' Fuel." *NewScientist.com*, September 19, 2006. http://technology.newscientist.com/article/dn10116-gm-bacteria-churn-out-microdiesel-fuel.html.

Sissine, Fred. *Energy Independence and Security Act of 2007: A Summary of Major Provisions*. CRS Report for Congress RL34294. Washington DC: Congressional Research Service, December 21, 2007.

Soap and Detergent Association. Written submission to the U.S. International Trade Commission in connection with inv. no. 332-481, *Industrial Biotechnology: Development and Adoption by the U.S. Chemical and Biofuel Industries*, November 1, 2007.

Society for General Microbiology. "New Fuels from Bacteria." *ScienceDaily*, September 26, 2006. http://www.sciencedaily.com/releases/2006/09/060925083802.htm.

Speckman, Joshua. "Biofuel Industry Faces Feedstock Uncertainty." *Bioenergy Business*, February 12, 2008. http://www.bioenergy-business.com/index.cfm?

State of Texas. State Energy Conservation Office. "Cellulosic Ethanol," 2006. http://www.seco.cpa.state.tx.us/re_ethanol_cellulosic.htm.

Steenblik, R. *Biofuels—At What Cost? Government Support for Ethanol and Biodiesel in Selected OECD Countries*. Paris: OECD, September 2007.

Su, Ivan, and Shong-Iee. "The Emerging Global Direct Distribution Business Model: Industry and Research Opportunities." *Transportation Journal* 46, no. 4 (Fall 2007): 42–57. http://www.entrepreneur.com/tradejournals/article/171140043.html.

Swift, Thomas Kevin, Emily Myers Levi, and Martha Gilchrist Moore. *Guide to the Business of Chemistry 2007*. Washington, DC: American Chemistry Council, 2007.

Tanaka, Ryozo. "Tax Incentives for Research and Development in Japan," April 27, 2006. http://www.uknow.or.jp/be_e/science/reports/Policy/36565X.pdf.

Tao, Junhua, Lishan Zhao, and Ningqing Ran. Bioverdant. "Recent Advances in Developing Chemoenzymatic Processes for Active Pharmaceutical Ingredients." *Organic Process Research & Development*, November 2007: 259–67.

Thum, Oliver. "Biocatalysis: A Sustainable Method for the Production of Emollient Esters." Published in the Proceedings of the 54th SEPAWA Congress and 3rd European Detergents Conference. Wurzburg, Germany, October 10–12, 2007.

———. "Enzymatic Production of Care Specialities Based on Fatty Acid Esters." *Tenside Surfactants Detergents: Journal for Theory, Technology and Application of Surfactants* 41, no. 6 (2004): 287–90.

Thum, Oliver, and Karen Margrethe Oxenbøll. "Biocatalysis: A Sustainable Process for Production of Cosmetic Ingredients." *SÖFW Journal : International Journal for Applied Science (English edition)* 134 (January-February 2008). http://www.novozymes.com/NR/rdonlyres/C23C3F09-CAA4-40DC-A0A9-E8E0262ACDDC/4851/Thum.pdf .

Tokgoz, Simla, Amani Elobid, Jacinto Fabiosa, Dermot J. Hayes, Bruce A. Babcock, Tun-Tsian (Edward) Yu, Fengxia Dong, Chad E. Hart, and John C. Beghin. *Emerging Biofuels: Outlook on U.S. Grain, Oilseed, and Livestock Markets.* Iowa State University, Center for Agricultural and Rural Development, May 2007. http://www.card.iastate.edu.

Truesdell, Susan. Pfizer. "Biotransformations for a Green Future." *Chemical Engineering Progress*, October 2005.

UNCTAD. *The Emerging Biofuels Market: Regulatory, Trade and Development Implications*. New York and Geneva: United Nations, 2006.

U.S. Department of Agriculture (USDA). "Agriculture Secretary Schafer Awards More Than $4.1 Million for Use in Woody Biomass Development." News release, March 10, 2008.

———. "USDA, DOE to Invest up to $18.4 Million for Biomass Research, Development and Demonstration Projects." News release, March 4, 2008.

———. "USDA Rural Development Invites Applications for Renewable Energy Loans and Grants." News release, March 6, 2008.

———. Agricultural Marketing Service (AMS). "National Weekly Ag Energy Round-up," December 2007.

———. AMS. Transportation and Marketing Programs. *Ethanol Transportation Backgrounder,* September 2007.

———. Agricultural Research Service (ARS). "Bioenergy and Energy Alternatives National Program Significant Accomplishments," August 2007. http://www.ars.usda.gov/SP2UserFiles/Program/307/BioenergyAccomplishments.pdf.

———. Biomass Research and Development Initiative (BRDI). *Biobased Fuels, Power and Products Newsletter*, December 2003. http://http://www.brdisolutions.com/news/NewsletterArchive/Dec2003.asp.

———. BRDI. "Matrix of Projects Awarded under the Joint Solicitation, 2002–2005," undated. http://www.brdisolutions.com (accessed February 13, 2008).

———. Farm Service Agency (FSA). "CCC Net Outlays by Commodity and Function Table 35," February 5, 2007. http://www.fsa.usda.gov/FSA/webapp?area=about&subject=landing&topic=bap-bu-ce.

———. FSA. "Current Loan Deficiency Rates," undated. http://www.fsa.usda.gov/FSA/searchLDPRates (accessed March 10, 2008).

———. FSA. "2007 National Average Loan Rates," 2007. http://www.fsa.usda.gov/FSA/webapp?area=home&subject=prsu&topic=lor.

———. FSA. "USDA Announces No Partial 2007-crop-year Counter-cyclical Payments for Corn, Grain Sorghum, and Soybeans," March 4, 2008.

———. FSA. "USDA Issues Final 2007 Direct Payments," September 25, 2007.

———. Office of Chief Economist. *USDA Agricultural Projections to 2016*, February 2007.

USDA and U.S. Department of Energy (USDOE). "Annual Report to Congress on the Biomass Research and Development Initiative for FY 2002," January 2003. http://www.brdisolutions.com.

———. "Annual Report to Congress on the Biomass Research and Development Initiative for FY 2003," February 2005. http://www.brdisolutions.com.

———. "Annual Report to Congress on the Biomass Research and Development Initiative for FY 2004," July 2005. http://www.brdisolutions.com.

———. "Annual Report to Congress on the Biomass Research and Development Initiative for FY 2005," undated. http://www.brdisolutions.com(accessed February 13, 2008).

———. "Annual Report to Congress on the Biomass Research and Development Initiative for FY 2006," undated. http://www.brdisolutions.com(accessed February 13, 2008).

———. *Biomass as Feedstock for a Bioenergy and Bioproducts Industry*, April 2005.

U.S. Department of Energy (USDOE). "Biorefinery Grant Announcement." News release, February 28, 2007.

———. "DOE Announces Plans for Future Loan Guarantee Solicitations." News release, April 11, 2008. http://www.lgprogram.energy.gov/press/041108.pdf.

———. "DOE Selects Six Cellulosic Ethanol Plants for Up to $385 Million in Federal Funding." News release, February 28 2007. http://www.doe.gov/news/4827.htm.

———. Energy Efficiency and Renewable Energy (EERE). "Biomass Program, Feedstock Infrastructure," June 2006. http://www1.eere.energy.gov/biomass/pdfs/feedstock_infrastructure.pdf.

———. EERE. "Biomass Program, Feedstock Research Projects," undated. http://www1.eere.energy.gov/biomass/project_factsheets.html#feedstocks (accessed March 13, 2008).

———. EERE. "Energy Policy Act of 2005," January 24, 2008. http://www.eere.energy.gov/afdc/incentives_laws_epact.html.

———. EERE. "Wal-Mart Launches Second Energy-Saving Store in Colorado." *EERE News*, November 16, 2005. http://www.eere.energy.gov/news/news_detail.cfm/news_id=9533.

———. Energy Information Administration (EIA). "American Jobs Creation Act of 2004," 2005. http://www.eia.doe.gov/oiaf/aeo/otheranalysis/aeo_2005analysispapers/ajca.html.

———. EIA. *Biofuels in the U.S. Transportation Sector*, February 2007, and errata October 2007. http://www.eia.doe.gov/oiaf/analysispaper/biomass.html.

———. EIA. "Status and Impact of State MTBE Bans," March 27, 2003. http://www.eia.doe.gov/oiaf/servicerpt/mtbeban/table1.html.

———. EIA. "U.S. Fuel Ethanol Oxygenate Production at Oxy Plant," February 29, 2008. http://tonto.eia.doe.gov/dnav/pet/hist/m_epooxe_yop_nus_1m.htm.

———. Oak Ridge National Laboratory (ORNL). "DOE Bioenergy Science Center." Fact sheet, June 26, 2007. http://www.science.doe.gov/News_Information/News_Room/2007/Bioenergy_Research_Centers/DOE%20BRC%20fact%20sheet%20final%206-26-07.pdf.

———. ORNL. "ORNL-led Team Wins DOE Bioenergy Center." News release, June 26, 2007. http://www.ornl.gov/info/press_releases/get_press_release.cfm?ReleaseNumber=mr20070626-00.

———. National Renewable Energy Laboratory (NREL). "Biochemical Conversion Technologies–Projects," November 6, 2007. http://www.nrel.gov/biomass/proj_biochemical_conversion.html.

———. NREL. "NREL Technology Partnerships," January 10, 2007. http://www.nrel.gov/technologytransfer/tech_partnership_agreements.html.

———. Pacific Northwest Laboratory. "Bio-based Products," undated. http://readthis.pnl.gov/MarketSource/ReadThis/B3_not_print_quality.pdf (accessed May 12, 2008).

U.S. Environmental Protection Agency (EPA). "Contaminant Focus: Methyl Tertiary Butyl Ether (MTBE); Overview," November 30, 2007. http://www.clu-in.org/contaminantfocus/default.focus/sec/Methyl_Tertiary_Butyl_Ether_(MTBE)/cat/Overview/.

———. "Methyl Tertiary Butyl Ether (MTBE): Gasoline," September 13, 2007. http://www.epa.gov/MTBE/gas.htm.

———. “Regulation of Fuels and Fuel Additives: Renewable Fuel Standard Program,” May 2007. http://www.epa.gov/EPA-AIR/2007/May/Day-01/a7140a.htm.

———. “Revised Renewable Fuel Standard for 2008, Issued Pursuant to Section 211(o) of the Clean Air Act as Amended by the Energy Independence and Security Act of 2007,” February 2008. http://epa.gov/otaq/renewablefuels/rfs0108.pdf.

———. “State Actions Banning MTBE (Statewide).” EPA420-B-07–013, August 2007. http://www.epa.gov/mtbe/420b07013.pdf.

U.S. International Trade Commission (USITC). *Harmonized Tariff Schedule of the United States (2008) Revision 1*. Washington, DC: USITC, 2008.

U.S. Patent and Trademark Office (USPTO). *Performance and Accountability Report Fiscal Year 2007*, December 21, 2007. http://www.uspto.gov/web/offices/com/annual/2007/index.html (accessed February 11, 2008).

———. Electronic Information Products Division. Patent Technology Monitoring Branch. *Patent Technology Center Groups 1630-1660, Biotechnology: All Classified Patents.* Washington, DC: USPTO, 2006.

University of Alberta. “$25-million Research Centre to Cultivate Growth in Value-added Agriculture.” News release, June 23, 2006. http://www.expressnews.ualberta.ca/article.cfm?id=7679.

Verenium Corporation. “Cellulosic Technology,” 2007. http://www.verenium.com/Pages/Technology/Cellulosic%20Tech/TechCellTechOvw.html (accessed March 5, 2008).

———. “Diversa and Celunol Complete Merger to Create Verenium Corporation, a Leader in the Emerging Biofuels Industry.” News release, June 20, 2007. http://www.verenium.com/PDFs/Merger%20Press%20Release.pdf.

Walt, Vivienne. “The World's Growing Food-Price Crisis.” *Time*, February 27, 2008. http://www.time.com/time/world/article/0,8599,1717572,00.html.

Wang, Xiaoyang, Tiesheng Wang, William Meyers, and Seth Meyer. “Biofuels in China: Market Impacts, Growth Prospects and Policy Dilemmas.” Presented at the WERA-101 Conference, Shanghai, China, July 12–13, 2007.

Washer, Stewart. Phylogica. Presentation at Pacific Rim Summit on Industrial Biotechnology & Bioenergy. Honolulu, HI, November 14, 2007.

Weintraub, Arlene. “Biotech Heads for the Factory Floor.” *BusinessWeek*, August 2, 2004. http://www.businessweek.com/magazine/content/04_31/b3894014_mz022.htm.

Whelan, Jason. NatureWorks LLC. “Bio-Polymers Markets.” Presented at BIOPolymers Markets 2007 Conference, Hong Kong, May 15–16, 2008.

Worldwatch Institute. “Used Cooking Oil to Fuel China’s Expanding Car Fleet,” October 12, 2006. http://www.renewableenergyworld.com/rea/news/story?id=46210.

WTO. "Understanding on the Interpretation of Article II:1(b) of the General Agreement on Tariffs and Trade 1994," undated. http://www.wto.org/english/docs_e/legal_e/07-2-1-b_e.htm (accessed March 21, 2008).

Wyant, Sara. *Agri-Pulse Update*, May 28, 2008. http://www.agri-pulse.com.

Xinhua News Agency. "China Breeds Rapeseed of Record High Oil Content for Biodiesel Development," August 29, 2006. http://www.uofaweb.ualberta.ca/CMS/printpage.cfm?ID=49652.

Yacobucci, Brent. *Biofuels Incentives: A Summary of Federal Programs*. CRS Report for Congress RL33572. Washington, DC: Congressional Research Service, July 25, 2006.

Yacobucci, Brent D., and Jasper Womach. *Fuel Ethanol: Background and Public Policy Issues*. CRS Report for Congress RL30369. Washington, DC: Congressional Research Service, 2004.

Zah, Rainer, Heinz Böni, Marcel Gauch, Roland Hischier, Martin Lehmann, and Patrick Wäger. *Life Cycle Assessment of Energy Products: Environmental Impact Assessment of Biofuels*. St. Gallen, Switzerland: Federal Office for Energy, Federal Office for the Environment, and Federal Office for Agriculture, May 22, 2007. http://www.bfe.admin.ch/php/modules/publikationen/stream.php?extlang=en&name=en_667574407.pdf.

Zhu, Winnie. "CNPC, BP May Buy Stakes in Chinese Ethanol Producer." *Bloomberg*, March 14, 2007. http://www.bloomberg.com/apps/news?pid=20601089&sid=azBsPeFNAzoY&refer=china.

APPENDIX A
REQUEST LETTER FROM THE SENATE FINANCE COMMITTEE

United States Senate

COMMITTEE ON FINANCE
WASHINGTON, DC 20510-6200

November 1, 2006

ER - NOV 2 2006 - 108

The Honorable Daniel R. Pearson
Chairman
U.S. International Trade Commission
500 E Street, S.W.
Washington, D.C. 20436

Dear Chairman Pearson:

Numerous entities in the United States consider the application of industrial biotechnology key to improving process efficiency and developing new products. The current impact of industrial biotechnology on the U.S. economy, however, is not well understood. For this reason, pursuant to section 332(g) of the Tariff Act of 1930 (19 U.S.C. § 1332(g)), I am requesting that the Commission institute a fact-finding investigation of the competitive conditions affecting certain industries that are developing and adopting new biotechnology processes and products.

The Committee requests that the Commission's investigation focus – to the extent practicable –on firms in the U.S. chemical industry that are developing bio-based products, *e.g.*, fibers and plastics and renewable chemical platforms, as well as U.S. producers of liquid biofuels. Specifically, the Commission should:

1. Describe and compare government policies in the United States and key competitor countries throughout the world relating to the development of products by these industries.

2. Analyze the extent of business activity in these industries, including, but not limited to, trends in production, financial performance, investment, research and development, and impediments to development and trade.

3. Examine factors affecting the development of bio-based products, including liquid biofuels, and renewable chemical platforms being developed by the U.S. chemical industry – including, but not limited to, globalization of supply chains, capital investment sources, strategic alliances, intellectual property rights, and technology transfer mechanisms.

4. Determine, to the extent feasible, how the adoption of industrial biotechnology processing and products impacts the productivity and competitiveness of firms in these industries.

5. Assess how existing U.S. Government programs may affect the production and utilization of agricultural feedstocks for liquid biofuels as well as bio-based products and renewable chemical platforms being developed by the U.S. chemical industry.

The Commission should submit its report to the Committee not later than twenty months after receipt of this request. The report should be based on information collected from surveys and any other sources of relevant information. If the Commission finds it appropriate, it should hold a public hearing in the course of preparing the report.

The Committee intends to make the report available to the public in its entirety. Therefore, I request that the report not include any confidential business information.

Sincerely,

Chuck Grassley

Charles E. Grassley
Chairman

APPENDIX B
FEDERAL REGISTER NOTICE

INTERNATIONAL TRADE COMMISSION

[Investigation No. 332–481]

Industrial Biotechnology: Development and Adoption by the U.S. Chemical and Biofuel Industries

AGENCY: United States International Trade Commission.

ACTION: Institution of investigation.

EFFECTIVE DATE: November 27, 2006.

SUMMARY: Following receipt on November 2, 2006, of a request from the Committee on Finance of the U.S. Senate (Committee) under section 332(g) of the Tariff Act of 1930 (19 U.S.C. 1332(g)), the U.S. International Trade Commission (Commission) instituted investigation No. 332–481, Industrial Biotechnology: Development and Adoption by the U.S. Chemical and Biofuel Industries.

Background: As requested by the Committee, the Commission will institute an investigation under section 332(g) with respect to the competitive conditions affecting certain industries that are developing and adopting new biotechnology processes and products. The Commission will transmit its report to the Committee by July 2, 2008.

As requested by the Committee, the Commission's report will focus—to the extent practicable—on firms in the U.S. chemical industry that are developing bio-based products (e.g., fibers and plastics) and renewable chemical platforms, as well as U.S. producers of liquid biofuels. The Commission will—

1. Describe and compare government policies in the United States and key competitor countries throughout the world relating to the development of products by these industries;
2. Analyze the extent of business activity in these industries, including, but not limited to, trends in production, financial performance, investment, research and development, and impediments to development and trade;
3. Examine factors affecting the development of bio-based products, including liquid biofuels, and renewable chemical platforms being developed by the U.S. chemical industry, including, but not limited to, globalization of supply chains, capital investment sources, strategic alliances, intellectual property rights, and technology transfer mechanisms;
4. Determine, to the extent feasible, how the adoption of industrial biotechnology processing and products impacts the productivity and competitiveness of firms in these industries; and 5. Assess how existing U.S. government programs may affect the production and utilization of agricultural feedstocks for liquid biofuels as well as bio-based products and renewable chemical platforms being developed by the U.S. chemical industry.

FOR FURTHER INFORMATION, CONTACT:
Project Leader, David Lundy (202–205–3439 or *david.lundy@usitc.gov*)
Deputy Project Leader, Elizabeth R. Nesbitt (202–205–3355 or *elizabeth.nesbitt@usitc.gov*)
Deputy Project Leader, Laura Polly (202–205–3408 or *laura.polly@usitc.gov*)

Industry-specific information may be obtained from the above persons. For more information on legal aspects of the investigation, contact William Gearhart of the Commission's Office of the General Counsel at 202–205–3091 or *william.gearhart@usitc.gov*. The media should contact Margaret O'Laughlin, Office of External Relations at 202–205–1819 or *margaret.olaughlin@usitc.gov*. Hearing impaired individuals are advised that information on this matter can be obtained by contacting the TDD terminal on 202–205–1810. General information concerning the Commission may also be obtained by accessing its Internet server (*http://www.usitc.gov*). The public record for these investigations may be viewed on the Commission's electronic docket (EDIS–ONLINE) at *http://edis.usitc.gov/hvwebex*.

Public Hearing: A public hearing in connection with this investigation is scheduled to begin at 9:30 a.m. on April 24, 2007, at the U.S. International Trade Commission Building, 500 E Street, SW., Washington, DC. Requests to appear at the public hearing should be filed with the Secretary no later than 5:15 p.m., April 3, 2007, in accordance with the requirements in the ''Submissions'' section below. In the event that, as of the close of business on April 3, 2007, no witnesses are scheduled to appear, the hearing will be canceled. Any person interested in attending the hearing as an observer or nonparticipant may call the Secretary (202–205–2000) after April 3, 2007, to determine whether the hearing will be held.

Request for Certain Information: The Commission is interested in receiving information regarding the five topics in the ''Background'' section of this notice above, and any other relevant information relating to the development and adoption of industrial biotechnology products and processes by the U.S. chemical and biofuels industries, and requests that interested parties provide such information in their hearing testimony and pre- and posthearing briefs and other submissions, to the extent they can.

Statements and Briefs: In lieu of or in addition to participating in the hearing, interested parties are invited to submit written statements or briefs concerning this investigation in accordance with the requirements in the ''Submissions'' section below. Any pre-hearing briefs or statements should be filed not later than 5:15 p.m., April 10, 2007; the deadline for filing post-hearing briefs or statements is 5:15 p.m., May 2, 2007.

Submissions: All written submissions, including requests to appear at the hearing, statements, and briefs, should be addressed to the Secretary, United States International Trade Commission, 500 E Street, SW., Washington, DC 20436. All written submissions must conform with the provisions of section 201.8 of the Commission's Rules of Practice and Procedure (19 CFR 201.8); any submission that contains confidential business information must also conform with the requirements of section 201.6 of the Commission's Rules of Practice and Procedure (19 CFR 201.6). Section 201.8 of the rules require that a signed original (or a copy designated as an original) and fourteen (14) copies of each document be filed. In the event that confidential treatment of the document is requested, at least four (4) additional copies must be filed, in which the confidential information must be deleted. Section 201.6 of the rules requires that the cover of the document and the individual pages be clearly marked as to whether they are the ''confidential'' or ''nonconfidential'' version, and that the confidential business information be clearly identified by means of brackets. All written submissions, except for confidential business information, will be made available for inspection by interested parties.

In its request letter, the Committee stated that it intends to make the Commission's report available to the public in its entirety, and asked that the Commission not include any confidential business or national security confidential information in the report it sends to the Committee. The report that the Commission sends to the Committee will not contain any such information. Any confidential business information received by the Commission in this investigation and used in preparing the report will not be published in a manner that would reveal the operations of the firm supplying the information.

Persons with mobility impairments who will need special assistance in gaining access to the Commission should contact the Secretary at 202–205–2000.

By order of the Commission.

Issued: November 28, 2006.

Marilyn R. Abbott,

Secretary to the Commission.

[FR Doc. E6–20374 Filed 11–30–06; 8:45 am]

BILLING CODE 7020–02–P

APPENDIX C
LIQUID BIOFUEL AND BIO-BASED CHEMICAL INDUSTRY ACTIVITY IN THE UNITED STATES AND SELECTED COUNTRIES

TABLE C-1
Liquid biofuel and bio-based chemical industry activity, United States and selected countries

Major countries		
United States	Ethanol	6.5 billion gallons produced in 2007.
	Biodiesel	450 million gallons produced in 2007.
	Bio-based chemicals	Compostable polylactic acid (PLA) biopolymers; biodegradable polyhydroxyalkenoate (PHA) biopolymers; bio-based 1,3-propanediol; Sorona® biopolymer from Bio-PDO™; BiOH™ flexible foam polyols; propylene glycol; acrylic monomers and polymers.
Brazil	Ethanol	5.4 billion gallons produced in 2007.
	Biodiesel	106 million gallons produced in 2007.
	Bio-based chemicals	Biopolymer polyhydroxybutyrate—Pilot plant capacity of 55–66 tons in 2006; scheduled to begin commercial operations in 2008 with an annual capacity of 11,000 tons. Polyethylene from ethanol—Brazilian pilot plant operating; commercial production of 220,000 tons scheduled for 2009. Also a U.S.-Brazilian joint venture formed in 2007 to produce polyethylene from ethanol. Construction in 2008; production in 2011. Annual capacity is planned at 386,000 tons. Development of bioplastics packaging material using a polymer made from cassava starch.
Canada	Ethanol	223.1 million gallons annual capacity, with an additional 204.6 million gallons under construction in 2007. Two Canadian companies are on the leading edge of the development of commercial scale production of ethanol from cellulosic feedstocks.
	Biodiesel	26 million gallons annual capacity in 2007, with plans for a 59.4 million gallon per year plant to be operational by mid-2009.
	Bio-based chemicals	Enzyme products for the pulp and paper, textile, and animal feed industries; conversion of pulp and paper residues into high-quality cellulosic products, food-grade ethanol, a range of lignin byproducts and other chemical products; bio-based plastics such as polyethylene/thermoplastic starch blends and polyethylene resins; a nonpharmaceutical cholesterol lowering agent from a highly purified grain fiber fraction; personal care/pet care products made from highly purified oat fractions; and animal feed additives, organic fertilizers and purified vegetable gums that are used as thickening agents in food and cosmetics as well as clarifying agents for beer made from seaweed.

See source at end of table.

TABLE C-1—*Continued*
Liquid biofuel and bio-based chemical industry activity, United States and selected countries

Major countries—*Continued*		
China	Ethanol	485.5 million gallons of fuel ethanol produced in 2007; developing alternative feedstocks, including cellulosic.
	Biodiesel	Reportedly 9 million gallons produced in 2007; much was reportedly below quality standards for fuel use.
	Bio-based chemicals	Enzymes, starches and sweeteners, amino acids, organic acids, and vitamins; examples of fermentation products include glutamic acid, citric acid, lactic acid, xanthan gum, and vitamin C. Reported capacity in mid-2006 for PLA and PHA was 1,100 tons for each biopolymer. Many domestic and foreign companies are investing in bio-based production and/or R&D facilities in China. For example, China will be the location for Dow Epoxy's (U.S.) 165,345 short ton per year facility to produce bio-based epichlorohydrin (the first such facility to use Dow's proprietary technology using glycerin from biodiesel production as the feedstock) and its 110,230 short ton per year facility to produce liquid epoxy resins. Start-up of both facilities is expected in 2009–10.
EU	Ethanol	778 million gallons produced in 2007. Germany was the leading producer in 2006.
	Biodiesel	2.4 billion gallons produced in 2007. Germany was the leading producer and consumer in 2006.
	Bio-based chemicals	World's largest producer of biocatalysts (enzymes); also produces bioplastics and bio-based polymers (approximately 163,000 short tons per year).
Japan	Ethanol	7,920 gallons per year produced annually as of March 2006.
	Biodiesel	Slightly more than 1 million gallons per year produced annually as of March 2006.
	Bio-based chemicals	Bio-based acrylamide; biodegradable chelating agents; amino acids; methylester sulfonate from palm oil; pharmaceutical intermediates manufactured using genetically modified enzymes; and biomass-based plastics such as PHA, PLA, and starch composites.

See source at end of table.

TABLE C-1—*Continued*
Liquid biofuel and bio-based chemical industry activity, United States and selected countries

Other countries		
Australia	Ethanol	40.2 million gallons operating capacity in 2007. Pilot plant under construction will produce lignocellulosic ethanol; firm has worldwide exclusive license to use technology developed by Apace Research Limited.
	Biodiesel	29.1 million gallons operating capacity in 2007.
	Bio-based chemicals	Some bioplastics production (thermoplastic starch (TPS) polymer) from corn.
India	Ethanol	105.7 million gallons produced in 2007. Pioneering the use of jatropha for use as a biodiesel feedstock.
	Biodiesel	12 million gallons produced in 2007.
	Bio-based chemicals	Active in industrial enzymes; large pharmaceutical industry.
Indonesia	Ethanol	Negligible.
	Biodiesel	107.7 million gallons in 2007.
Korea	Ethanol	16 million gallons produced in 2006 (all ethanol grades). Lignocellulosic ethanol efforts are not likely to reach commercialization before 2016; potential feedstock is waste oak wood from mushroom farms.
	Biodiesel	Capacity to produce 160 million gallons; actual production 24 million gallons because of voluntary supply agreement between government and industry. Lipase-catalyzed biodiesel production from soybean oil in ionic liquids; R&D on winter canola for canola oil as a domestically-available biodiesel feedstock.
	Bio-based chemicals	Amino acids such as lysine; use of industrial biotechnology to make "super proteins" for medical use; biodegradable resins such as polybutylene succinate; Japan's Toray mass producing PLA sheet in Korea (annual capacity 5,000 tons of sheet); Korean plastics manufacturers using NatureWorks PLA in packaging materials.
Malaysia	Ethanol	None; planned ethanol plant to be first in world to use Nipah palm.
	Biodiesel	86.8 million gallons produced in 2007.
	Bio-based chemicals	Some production of glycerin and vitamin E.

See source at end of table.

TABLE C-1—*Continued*
Liquid biofuel and bio-based chemical industry activity, United States and selected countries

Other countries—*Continued*		
New Zealand	Ethanol	The only commercial ethanol plant in New Zealand produces ethanol from whey, a byproduct of the dairy industry. A couple of other companies are considering commercial-scale production of ethanol. LanzaTech NZ Ltd. claims to have developed a proprietary technology to generate ethanol from the carbon monoxide component of waste flue gases.
	Biodiesel	Ecodiesel Limited announced in October 2007 that it would establish the first commercial-scale biodiesel production facility in New Zealand. Production capacity is estimated to be 5.3 million gallons in 2008, increasing to 10.6 million gallons by the end of 2009. Most prospective biodiesel producers have stated their intention to use tallow to make biodiesel.
	Bio-based chemicals	There is minimal activity in bio-based chemicals. One ethanol producer is attempting to extract everything from its raw material, as petroleum refineries do, to make a plastic intermediate and to commercialize a sweetener. A biopolymer company is developing probiotics to enhance foods.
Philippines	Ethanol	Capacity to produce 7.9 million gallons as of April 2008.
	Biodiesel	Capacity to produce 29 million gallons; actual production was 17.4 million gallons in 2007; produces biodiesel from coconuts.
	Bio-based chemicals	Capacity to produce crude and refined glycerin, fractionated methylesters, coconut diethanolamides, coconut monoethanolamide.
South Africa	Ethanol	None currently.
	Biodiesel	Nascent.
	Bio-based chemicals	Little or no activity in bio-based chemicals.
Thailand	Ethanol	79.3 million gallons produced in 2007.
	Biodiesel	68.8 million gallons produced in 2007.
	Bio-based chemicals	Pilot scale production of bioplastics; biotech focus is largely in agriculture and medicine.

Source: Various industry and government publications.

APPENDIX D
PROCESS ADVANTAGES OF BIO-BASED PRODUCTS VERSUS THEIR CONVENTIONAL COUNTERPARTS

Process Advantages of Bio-based Products Versus Their Conventional Counterparts

The environmental benefits attributed to IB products and processes derive from both liquid biofuels and bio-based chemicals. Benefits range from lowered GHG emissions to reduced use of energy and fossil fuel inputs and decreased waste in chemical processes.

However, the degree of such benefits from currently-used liquid biofuels is debated. Numerous studies have been performed assessing the magnitude of ethanol's impact on GHG emissions and its net energy balance. Two analyses found that the use of corn-based ethanol can reduce GHG emissions by 12–13 percent.[1] One of them (Farrell, et al.), however, further indicates that a comparison of numerous studies evaluating corn-based ethanol versus gasoline showed divergent values regarding GHG emissions, ranging from a 20 percent increase to a 32 percent decrease, as well as divergent values for net energy values, largely resulting from variations in the values and parameters utilized in the studies.[2] Both analyses indicate that cellulosic ethanol has the potential to significantly expand reductions in GHG emissions.[3] Moreover, Hill, et al. noted that biodiesel reduces GHG emissions by 41 percent compared with diesel. They also found net energy balances[4] of about 25 percent for corn-based ethanol and 93 percent for biodiesel. However, an assessment of these findings, as well as of the impact of other questions raised in relation to corn-based ethanol, is beyond the scope of this study.[5]

Organizations switching to bio-based processes (or considering doing so) generally conduct feasibility studies that assess various factors, including performance[6] and other characteristics of the final/desired product; the time and cost involved with changing and/or developing new processes and production lines; and the best integration of such with (or in

---

[1] Farrell, et al., "Ethanol Can Contribute to Energy and Environmental Goals," January 27, 2006; and Hill, et al., "Environmental, Economic, and Energetic Costs and Benefits," July 25, 2006.

[2] Farrell, et al., "Ethanol Can Contribute to Energy and Environmental Goals," January 27, 2006. The authors note that their findings of a reduction of 13 percent in GHG emissions assume the agricultural inputs are derived from land already being farmed; the GHG emissions savings could be reduced or become negative if the feedstocks are derived from land converted to growing these crops.

[3] Assessments of the environmental impact of biobutanol are currently underway.

[4] Hill, et al., "Environmental, Economic, and Energetic Costs and Benefits," July 25, 2006. The authors note that the net energy balance is the amount of energy provided by the liquid biofuel versus the amount of energy used to produce it. Corn ethanol is said to have a low net energy balance because of the high energy input used in both the production of corn and the resulting ethanol.

[5] Other questions have also been raised about the production of ethanol from corn. These include, but are not limited to, whether the use of corn to produce ethanol has diverted supply from the food chain; whether the escalating use of corn and associated price rises have been responsible for the recent run-up in food prices; whether farmers are now devoting increased acreage to corn at the expense of soybeans (the main feedstock in the United States for biodiesel) or other crops; and whether the production of increased corn is environmentally sustainable.

[6] Industry sources reported that bio-based products must be competitive with conventionally-produced products, particularly in terms of performance, if these products are to be accepted by consumers.

lieu of) existing chemical processes.[7] Rapid identification and integration of bioprocesses with existing or planned chemical syntheses is often desirable. The development of pharmaceuticals, for example, often proceeds at an accelerated pace so as to maximize a product's period of exclusivity amidst shortened effective patent lives resulting from the multi-year regulatory process. Sufficient amounts of the product being developed have to be produced for use in clinical trials before the product is approved and marketed.[8]

The environmental benefits of utilizing bioprocesses, particularly biocatalysis, by companies manufacturing bio-based chemicals have been assessed for numerous products/processes through the use of life-cycle assessments (LCAs). LCAs are comprehensive inventories of inputs and outputs comparing process and environmental factors for the bio-based processes versus conventional chemical production processes.[9] Companies generally conduct LCAs after bio-based production starts but more are also conducting them earlier in the development process (e.g., when they conduct economic feasibility studies).[10] As reflected in table D-1, industrial biotechnology offers numerous process advantages, including but not limited to:

- process simplification;
- reductions in consumption of fossil fuel inputs and energy and in waste production (e.g., the enzymes themselves are biodegradable);
- the ability to increasingly use renewable resources as inputs;
- environmental benefits; and
- the ability to manufacture chemicals and pharmaceuticals that otherwise might not be able to be produced economically or in a technically-feasible manner.

For example, the use of enzymes can allow processes to be run at ambient temperatures, reducing or eliminating the need to heat or cool to conventional process levels, conserving

---

[7] Replacement of one or more conventional chemical steps with an enzymatic reaction is considered "difficult" given the integration of the step(s) in the existing process framework. As such, companies considering the use of bioprocesses often will redesign the process to take advantage of concomitant changes that could either allow for or enhance the considered bioprocess(es). Tao, Zhao, and Ran, Bioverdant, "Recent Advances in Developing Chemoenzymatic Processes," November 2007; and Pollard and Woodley, "Biocatalysis for Pharmaceutical Intermediates," December 20, 2006.

[8] Pollard and Woodley, "Biocatalysis for Pharmaceutical Intermediates," December 20, 2006. The authors state that use of isolated enzymes can allow for generation of initial quantities of product within as few as four days or less and allow for faster scale up to pilot plant quantities. In comparison, development of whole-cell systems, which require fermentation to grow the cells, can take longer. As such, many pharmaceutical companies will use isolated enzymes to allow for faster initial process development and then, when timing is less tight, develop whole-cell systems to optimize commercial production. The decision as to whether and when to use isolated enzymes versus whole-cell systems, however, is generally made on a case-by-case basis, taking into account numerous factors (e.g., type of enzyme/reaction needed, solvent types, substrate/product concentrations, speed of development, and cost, among other things). Industry official, e-mail message to Commission staff, February 19, 2008.

[9] A life-cycle assessment (LCA) is an "international standard-setting process" subject to criteria established by ISO 14040 and ISO 14044. LCAs for individual products can vary for a number of reasons, including the type of LCA (e.g., "cradle to gate," covering from manufacture to the output at the manufacturing facility, or "cradle to grave," covering from manufacture to eventual disposal of the product) and process differences. Industry official, e-mail message to Commission staff, December 18, 2007; Thum, "Biocatalysis: A Sustainable Method," October 10–12, 2007; Thum, "Enzymatic Production of Care Specialities," 2004; NatureWorks, "Life Cycle Assessment," undated (accessed February 7, 2008); and Farrell, et al., "Ethanol Can Contribute to Energy and Environmental Goals," January 27, 2006.

[10] Industry official, e-mail message to Commission staff, April 11, 2008. For example, Novozymes has started conducting LCAs when developing new products and projects.

energy consumption; reductions in GHG emissions, solvent use, and waste production are beneficial to the environment. On an overall basis, such advantages can translate to related cost savings and increased company competitiveness. Table D-1 presents information from several publicly-available LCAs comparing production and environmental factors for bio-based products versus their conventionally-produced counterparts.[11]

[11] This discussion addresses several publicly-available LCAs. It is not intended to be a complete listing of companies and/or products but rather a sampling of available analyses. Many companies not addressed in detail are utilizing industrial biotechnology and/or sustainable chemistry.

TABLE D-1
Results of life-cycle assessments for certain bio-based products and their petroleum-based counterparts

Company	Product/ Process	Air/GHG emissions	Energy/input Consumption	Other effects/comments
Hoffman La-Roche (Switzerland)	Vitamin B_2	Air emissions declined by 50 percent	Nonrenewable inputs reduced by 75 percent	A multi-step process was reduced to a single step using a genetically-modified version of the bacteria *Bacillus subtilis.* Water emissions declined by about 66 percent.[1]
DSM (Netherlands)	Cephalexin	Not available	Energy and inputs reduced by 65 percent	Refining the production process and using fermentation followed by “two mild enzymatic steps,” reduced the antibiotic’s production process from 10 steps to 4 and reduced the quantity/toxicity of the waste stream. The resulting water-based process (which reduced the need for organic solvents) reduced costs by 50 percent.[2] Two additional bioprocesses developed and commercialized by DSM are: (1) synthesis of an intermediate chemical used to produce statins, and (2) production of an intermediate chemical used to produce medicinal products, including a cardiovascular drug. In the first example, reported advantages of using an enzyme derived from *E. coli* include the ability to use readily-available, low-cost inputs; a one-step production process; and increased yield of the desired end-product. In the second example, use of an enzyme derived from the almond tree allows for almost 100 percent product yield.[3]
Mitsubishi Rayon (Japan)	Acrylamide	Not available	Not available	Conventional production processes for the commodity chemical used a strong acid or a copper catalyst. An enzymatic production process, started in 1985 partly to increase product purity, reduced byproduct generation largely because of the selectivity of the enzyme(s). After further process refinements, other reported advantages included ambient reaction temperatures; higher product purity and yield; elimination of the need to remove the catalyst from the process stream; lower production and equipment investment costs; and a more beneficial impact on the environment. A process licensee reported that plants utilizing this technology are “four times cheaper to build than facilities implementing a chemical process.”[4]

See footnotes at end of table.

TABLE D-1—*Continued*
Results of life-cycle assessments for certain bio-based products and their petroleum-based counterparts

Company	Product/ Process	Air/GHG emissions	Energy/input Consumption	Other effects/comments
Cargill (United States)	Bio-based flexible foam polyols	GHG emissions reduced by 36 percent	Energy consumption reduced by 23 percent	Marketed under the BiOH™ brand name, the products, derived from vegetable oils such as soybean oil, are used to produce polyurethane foams used in furniture, bedding, and automotive applications. The preliminary LCA results shown are in comparison to petrochemical-derived polyols. The company estimates that "for every million pounds of petroleum-based polyols replaced with BiOH polyols, nearly 2,200 barrels of crude oil are saved for more critical needs."[5]
Pfizer (United States)	Biocatalysis (new drug production processes)	Not available	Lyrica®: Energy use reduced by 83 percent Consumption of inputs reduced by 80 percent	Pfizer transitioned in the third quarter of 2006 to enzymatic processes in its production route for pregabalin, the active ingredient in a pharmaceutical marketed under the brand name Lyrica® (used in the treatment of neuropathic pain). The resulting water-based process also reduced consumption of organic solvents. Pfizer has also recently incorporated a biocatalytic (enzymatic) process in an intermediate step in its production of atorvastatin, the active ingredient in Lipitor®, a cholesterol-lowering medicine. According to preliminary published information, the conversion resulted in "the elimination of hazardous and toxic reagents, elimination of cryogenic reaction conditions and multiple distillations, reduction of organic solvent waste, and improved product purity and quality."[6]
Evonik Industries (Germany; formerly Degussa)	Myristyl myristate	Emissions reduced by almost 90 percent	Energy use reduced by about 62 percent	One of the company's bioprocesses is production of an emollient used in cosmetics. When compared to the conventionally-produced version (which utilized high temperatures and tin (II) oxalate as catalyst), the enzymatic production process also produced less waste water; increased yields from 61 percent to 93 percent; and, largely as a result of reducing the formation of side products, reduced post-production processing (often necessary to remove unwanted side products and to improve such product characteristics as color and odor).[7]

See footnotes at end of table.

TABLE D-1—*Continued*
Results of life-cycle assessments for certain bio-based products and their petroleum-based counterparts

Company	Product/ Process	Air/GHG emissions	Energy/input Consumption	Other effects/comments
DuPont (United States)	Bio-based 1,3-propanediol (Bio-PDO) Sorona® biopolymer (polytri-methylene-terephthalate).	Bio-PDO: GHG emissions reduced by 20 percent Sorona®: GHG emissions reduced by 55 percent	Bio-PDO: Energy use reduced by 40 percent Sorona®: Energy use reduced by 30 percent	Sorona® polymer was produced since 2004 using a petrochemical version of 1,3-propanediol (PDO) as the key intermediate. In a joint venture with Tate & Lyle PLC, DuPont developed a bio-based version of 1,3-propanediol (Bio-PDO™) derived from corn and converted to the corn-based process as of late 2006. Compared to PDO, a cradle-to-gate LCA has determined that the Bio-PDO™ production process saves “the equivalent of about 10 million gallons of gasoline per year, based on annual production volumes of 100 million pounds” of Bio-PDO™ (reportedly equal to the amount of gasoline consumed by 22,000 cars annually). In early 2007, DuPont started producing a bio-based version of Sorona® using Bio-PDO™, imparting a 37 percent renewable content to the biopolymer. The cradle-to-gate LCA compared the biopolymer’s production process to Nylon 6.[8]
DuPont (United States)	Cerenol®	GHG emissions reduced by 42 percent	Nonrenewable energy consumption reduced by 40 percent	Cerenol™, a 100 percent renewably-sourced polymer derived from Bio-PDO™, is used in numerous applications, including cosmetics, footwear, apparel, and automotive products. A cradle-to-gate LCA compared it with conventionally-produced, petroleum-based counterparts such as polytetramethylene ether glycol.[9] DuPont is also developing and commercializing other renewably-sourced products, including soy-based products; LCAs are underway on many of these products.
Telles (United States)	PHA resin	GHG emissions reduced by 200 percent	Nonrenewable energy use reduced by 96 percent	The cradle-to-gate LCA conducted on Mirel™, a PHA bioplastic resin commercialized in the United States by Telles™, a joint venture of ADM and Metabolix, compared it to petrochemical-based polymers such as polypropylene and polyethylene.[10]

See footnotes at end of table.

TABLE D-1—*Continued*
Results of life-cycle assessments for certain bio-based products and their petroleum-based counterparts

Company	Product/ Process	Air/GHG emissions	Energy/input Consumption	Other effects/comments
NatureWorks LLC (United States)	PLA resin	GHG emissions reduced by 80–90 percent	Fossil-fuel resource use reduced by almost 70 percent	A cradle-to-gate LCA for NatureWorks' PLA resin compared it to petrochemical-derived polymers such as nylon 6,6; polyethylene terephthalate; polystyrene; polypropylene; and polyethylene. The reductions in GHG emissions were said to be due in part to NatureWorks' use of wind power to generate its electricity and, as of 2006, its purchases of wind power-based Renewable Energy Certificates. NatureWorks plans to further improve the environmental impact of the PLA production process and eventually create a "sink" effect (i.e., absorbing GHG emissions) by expanding the use of wind energy to generate electricity and, perhaps by 2010, using feedstocks such as corn residue both as an input and to generate steam and heat for the facility (in addition to continuing generating electricity via wind power).[11]

[1] OECD, *The Application of Biotechnology to Industrial Sustainability*, 2001.
[2] OECD, *The Application of Biotechnology to Industrial Sustainability*, 2001; Centre for Sustainable Engineering, "Biocatalysis: Overview," 2005, 2; and Laane and Sijbesma, "Industrial Biotech at DSM: From Concept to Customer," 2006.
[3] Laane and Sijbesma, "Industrial Biotech at DSM: From Concept to Customer," 2006.
[4] *C&E News*, "Japan's Unique Perspective," May 21, 2001. Also, OECD, *The Application of Biotechnology to Industrial Sustainability*, 2001.
[5] Cargill, "Cargill Introduces BiOH ™ Brand Polyols," December 11, 2006; and Cargill, "Cargill's BiOH™ Polyols Business Expands," September 18, 2007.
[6] Industry official, e-mail message to Commission staff, February 12, 2008. Also, Dunn, Pfizer, "Green Chemistry in Process Development," December 5, 2007. Worldwide sales of Lyrica® in 2007 were valued at $1.83 billion (almost 60 percent were in the United States); worldwide sales of Lipitor® were valued at $12.68 billion (just over one-half were in the United States). Lipitor® has been described as the first pharmaceutical with sales greater than $10 billion. Industry official, e-mail message to Commission staff, February 29, 2008; and Ran, et al., "Recent Applications of Biocatalysis," December 4, 2007.
[7] Thum, "Biocatalysis: A Sustainable Method," October 10–12, 2007; Thum, "Enzymatic Production of Care Specialties," 2004, 287–90; and Thum and Oxenbøll, "Biocatalysis: A Sustainable Process for Production of Cosmetic Ingredients," January-February 2008.
[8] DuPont, "DuPont Engineering Polymers," June 20, 2006; DuPont, "Fact Sheet: The DuPont™ Sorona® Polymer Sustainability Story," November 2006; and DuPont, "Sorona® Renewably-Sourced Polymers," 2007.
[9] DuPont, "DuPont Launches DuPont™ Cerenol™," June 4, 2007.
[10] Metabolix, Inc., "Metabolix Announces Results of Life Cycle Assessment for Mirel™ Bioplastics," October 12, 2007.
[11] NatureWorks LLC, "Life Cycle Assessment," undated (accessed February 7, 2008); and Whelan, NatureWorks LLC, "Bio-Polymers Markets," May 15–16, 2008.

Source: Various industry and international organization publications.