Biomass Energy Data Book

Edition 1

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

Oak Ridge National Laboratory

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Pellet Fuels Institute	pelletheat.org
Renewable Fuels Association	www.ethanolrfa.org

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EDITION 1

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ACRONYMS

AEO	Annual Energy Outlook
ASABE	American Society of Agricultural and Biological Engineers
Btu	British thermal units
CO2	Carbon dioxide
CRP	Conservation Reserve Program
d.b.h.	Diameter at breast height
DOE	Department of Energy
EERE	Office of Energy Efficiency and Renewable Energy
EIA	Energy Information Administration
EPA	Environmental Protection Agency
EPAct	Energy Policy Act
ERS	Economic Research Service
FTE	Fuel Treatment Evaluator
FY	Fiscal Year
GHG	Greenhouse Gas
GPRA	Government Performance Results Act
GW	Gigawatt
IEA	International Energy Agency
LFG	Landfill Gas
MJ	Megajoule
MMBtu	Million British thermal units
MW	Megawatt
MSW	Municipal Solid Waste
NASS	National Agricultural Statistics Service
NEMS	National Energy Modeling System
NREL	National Renewable Energy Laboratory
NRCS	National Resources Conservation Service
ORNL	Oak Ridge National Laboratory
RPS	Renewable Portfolio Standard
SRIC	Short Rotation Intensive Culture
TBD	To Be Determined
TVA	Tennessee Valley Authority
USDA	United States Department of Agriculture

PREFACE

The Department of Energy, through the Office of Planning, Budget, and Analysis in the Office of Energy Efficiency and Renewable Energy, has contracted with Oak Ridge National Laboratory to prepare this Biomass Energy Data Book. The purpose of this data book is to draw together, under one cover, biomass data from diverse sources to produce a comprehensive document that supports anyone with an interest or stake in the biomass industry. Given the increasing demand for energy, policymakers and analysts need to be well-informed about current biomass energy production activity and the potential contribution biomass resources and technologies can make toward meeting the nation's energy demands. This is the first edition of the Biomass Energy Data Book and it is currently only available online in electronic format. This first edition focuses on biomass conversion technologies and commercially utilized biomass resources.

Biomass energy technologies used in the United States include an extremely diverse array of technologies - from wood or pellet stoves used in homes to large, sophisticated biorefineries producing multiple products. For some types of biomass energy production, there are no annual inventories or surveys on which to base statistical data. For some technology areas there are industry advocacy groups that track and publish annual statistics on energy production capacity, though not necessarily actual production or utilization. The Department of Energy's Energy Information Administration (EIA) produces annual estimates of biomass energy utilization and those estimates are included in this data book. Information from industry groups are also provided to give additional detail. An effort has been made to identify the best sources of information on capacity, production and utilization of many of the types of biomass energy being produced in this country. It is certain, however, that not all biomass energy contributions have been identified. The information may not be available, or may be proprietary.

It is even more difficult to track the diverse array of biomass resources being used as feedstocks for biomass energy production. Since most of the biomass resources currently being used for energy or bioproducts are residuals from industrial, agricultural or forestry activities, there is no way to systematically inventory biomass feedstock collection and use and report it in standard units. All biomass resource availability and utilization information available in the literature are estimates, not inventories of actual collection and utilization. Biomass utilization information is derived from biomass energy production data, but relies on assumptions about energy content and conversion efficiencies for each biomass type and conversion technology. Biomass availability data relies on understanding how much of a given biomass type (e.g., corn grain) is produced, alternate demands for that biomass type, economic profitability associated with each of those alternate demands, environmental impacts of collection of the biomass, and other factors such as incentives. This book presents some of the information needed for deriving those estimates, as well as providing biomass resource estimates that have been estimated by either ORNL staff or other scientists. For estimates derived from ORNL analysis, the methodology has been documented in Appendix C and additional references have been provided. In all cases it should be recognized that estimates are not precise and different assumptions will change the results.

ABSTRACT

The *Biomass Energy Data Book* is a statistical compendium prepared and published by Oak Ridge National Laboratory (ORNL) under contract with the Office of Planning, Budget, and Analysis in the Energy Efficiency and Renewable Energy (EERE) program of the Department of Energy (DOE). Designed for use as a convenient reference, the book represents an assembly and display of statistics and information that characterize the biomass industry, from the production of biomass feedstocks to their end use.

This is the first edition of the Biomass Energy Data Book and is currently only available online in electronic format. There are five main sections to this book. The first section is an introduction which provides an overview of biomass resources and consumption. Following the introduction to biomass, is a section on biofuels which covers ethanol, biodiesel and BioOil. The biopower section focuses on the use of biomass for electrical power generation and heating. The fourth section is on the developing area of biorefineries, and the fifth section covers feedstocks that are produced and used in the biomass industry. The sources used represent the latest available data. There are also three appendices which include measures of conversions, biomass characteristics and assumptions for selected tables and figures. A glossary of terms and a list of acronyms are also included for the reader's convenience.

1. INTRODUCTION TO BIOMASS

BIOMASS OVERVIEW

Biomass is material that comes from plants. Plants use the light energy from the sun to convert water and carbon dioxide to sugars that can be stored, through a process called photosynthesis. Some plants, like sugar cane and sugar beets, store the energy as simple sugars. These are mostly used for food. Other plants store the energy as more complex sugars, called starches. These plants include grains like corn and are also used for food.

Another type of plant matter, called cellulosic biomass, is made up of very complex sugar polymers (complex polysaccharides), and is not generally used as a food source. This type of biomass will be the future feedstock for bioethanol production. Specific feedstocks being tested include agricultural and forestry residues, organic urban wastes, food processing and other industrial wastes, and energy crops. For more detailed information on current and future biomass resources in the United States see the feedstock section.

In 2005, biomass production contributed 2.7 quadrillion Btu of energy to the 69.1 quadrillion Btu of energy produced in the United States or about 4% of total energy production. Since a substantial portion of U.S. energy is imported, the more commonly quoted figure is that biomass contributed 2.7 quadrillion Btu of energy to the 99.8 quadrillion Btu of energy consumed in the United States or about 3%. At present, wood resources contribute most to the biomass resources consumed in the United States and most of that is used in the generation of electricity and industrial process heat and steam. The industrial sector (primarily the wood products industry) used about 1.4 quadrillion Btu in 2005. The residential and commercial sectors consume .04 quadrillion Btu of biomass; however, this figure may understate consumption in these sectors due to unreported consumption, such as home heating by wood collected on private property. The use of biomass fuels such as ethanol and biodiesel by the transportation sector is small but rising rapidly.

There are many types of biomass resources currently used and potentially available. This includes everything from primary sources of crops and residues harvested/collected directly from the land, to secondary sources such as sawmill residuals, to tertiary sources of post-consumer residuals that often end up in landfills. Biomass resources also include the gases that result from anaerobic digestion of animal manures or organic materials in landfills. The estimated availability of agricultural and forestry biomass in 2001 was recently reported in a document entitled “Biomass as Feedstock For a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply;” prepared by Oak Ridge National Laboratory staff (for the Department of Energy) together with scientists from the U.S. Department of Agriculture (USDA), Agricultural Research Service and USDA Forest Service. The ultimate limit for the amount of biomass that can be sustainably produced on agricultural land in the United States depends on land availability. The areas of the country with adequate rainfall and soil quality for production and harvest of energy crops are roughly the same areas where major crops are currently produced in the United States. Changes in the way that land is managed will be necessary for increasing biomass resource availability in the U.S.

For additional overview information, visit the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy's Biomass Program at: http://www1.eere.energy.gov/biomass/index.html.

In 2005 biomass accounted for about 45% of the renewable energy production in the United States.

Table 1.1
Energy Production by Source, 1973—2005
(Quadrillion Btu)

	Fossil Fuels						Renewable Energy[a]						
Year	Coal	Natural Gas (Dry)	Crude Oil[b]	Natural Gas Plant Liquids	Total	Nuclear Electric Power	Hydro-electric Power[c]	Biomass[d]	Geo-thermal	Solar	Wind	Total	Total
1973	13.99	22.19	19.49	2.57	58.24	0.91	2.86	1.53	0.04	NA	NA	4.43	63.58
1974	14.07	21.21	18.57	2.47	56.33	1.27	3.18	1.54	0.05	NA	NA	4.77	62.37
1975	14.99	19.64	17.73	2.37	54.73	1.90	3.15	1.50	0.07	NA	NA	4.72	61.36
1976	15.65	19.48	17.26	2.33	54.72	2.11	2.98	1.71	0.08	NA	NA	4.77	61.60
1977	15.75	19.57	17.45	2.33	55.10	2.70	2.33	1.84	0.08	NA	NA	4.25	62.05
1978	14.91	19.49	18.43	2.25	55.07	3.02	2.94	2.04	0.06	NA	NA	5.04	63.14
1979	17.54	20.08	18.10	2.29	58.01	2.78	2.93	2.15	0.08	NA	NA	5.17	65.95
1980	18.60	19.91	18.25	2.25	59.01	2.74	2.90	2.48	0.11	NA	NA	5.49	67.24
1981	18.38	19.70	18.15	2.31	58.53	3.01	2.76	2.59	0.12	NA	NA	5.47	67.01
1982	18.64	18.32	18.31	2.19	57.46	3.13	3.27	2.62	0.10	NA	NA	5.99	66.57
1983	17.25	16.59	18.39	2.18	54.42	3.20	3.53	2.83	0.13	NA	0.00	6.49	64.11
1984	19.72	18.01	18.85	2.27	58.85	3.55	3.39	2.88	0.16	0.00	0.00	6.43	68.83
1985	19.33	16.98	18.99	2.24	57.54	4.08	2.97	2.86	0.20	0.00	0.00	6.03	67.65
1986	19.51	16.54	18.38	2.15	56.58	4.38	3.07	2.84	0.22	0.00	0.00	6.13	67.09
1987	20.14	17.14	17.67	2.22	57.17	4.75	2.63	2.82	0.23	0.00	0.00	5.69	67.61
1988	20.74	17.60	17.28	2.26	57.87	5.59	2.33	2.94	0.22	0.00	0.00	5.49	68.95
1989	21.35	17.85	16.12	2.16	57.47	5.60	2.84	3.06	0.32	0.06	0.02	6.29	69.36
1990	22.46	18.33	15.57	2.17	58.53	6.10	3.05	2.66	0.34	0.06	0.03	6.13	70.77
1991	21.59	18.23	15.70	2.31	57.83	6.42	3.02	2.70	0.35	0.06	0.03	6.16	70.41
1992	21.63	18.38	15.22	2.36	57.59	6.48	2.62	2.85	0.35	0.06	0.03	5.91	69.98
1993	20.25	18.58	14.49	2.41	55.74	6.41	2.89	2.80	0.36	0.07	0.03	6.16	68.30
1994	22.11	19.35	14.10	2.39	57.95	6.69	2.68	2.94	0.34	0.07	0.04	6.06	70.71
1995	22.03	19.08	13.89	2.44	57.44	7.08	3.21	3.07	0.29	0.07	0.03	6.67	71.18
1996	22.68	19.34	13.72	2.53	58.28	7.09	3.59	3.13	0.32	0.07	0.03	7.14	72.50
1997	23.21	19.39	13.66	2.50	58.76	6.60	3.64	3.01	0.32	0.07	0.03	7.08	72.43
1998	23.94	19.61	13.24	2.42	59.20	7.07	3.30	2.83	0.33	0.07	0.03	6.56	72.83
1999	23.19	19.34	12.45	2.53	57.51	7.61	3.27	2.89	0.33	0.07	0.05	6.60	71.71
2000	22.62	19.66	12.36	2.61	57.25	7.86	2.81	2.91	0.32	0.07	0.06	6.16	71.27
2001	23.49	20.20	12.28	2.55	58.52	8.03	2.24	2.64	0.31	0.07	0.07	5.33	71.88
2002	22.62	19.44	12.16	2.56	56.78	8.14	2.69	2.65	0.33	0.06	0.11	5.84	70.76
2003	21.97	19.69	12.03	2.35	56.03	7.96	2.82	2.74	0.34	0.06	0.11	6.08	70.07
2004	22.71	19.26	11.50	2.47	55.95	8.22	2.69	2.88	0.35	0.06	0.14	6.12	70.29
2005	23.15	18.66	10.84	2.32	54.97	8.13	2.71	2.73	0.36	0.06	0.15	6.01	69.11

Source:
Energy Information Administration, Monthly Energy Review, March 2006. Table 1.2, www.eia.doe.gov/emeu/mer/overview.html

Note: NA = Not available.

[a] End-use consumption and electricity net generation.
[b] Includes lease condensate.
[c] Conventional hydroelectric power.
[d] Wood, waste, and alcohol fuels (ethanol blended into motor gasoline).

Table 1.2
Energy Consumption by Source, 1973—2005
(Quadrillion Btu)

	Fossil Fuels					Renewable Energy[a]						
Year	Coal	Natural Gas[b]	Petroleum[c,d]	Total[e]	Nuclear Electric Power	Hydroelectric Power[f]	Biomass[d,g]	Geothermal	Solar	Wind	Total	Total[d,h]
1973	12.97	22.51	34.84	70.32	0.91	2.86	1.53	0.04	NA	NA	4.43	75.71
1974	12.66	21.73	33.45	67.91	1.27	3.18	1.54	0.05	NA	NA	4.77	73.99
1975	12.66	19.95	32.73	65.35	1.90	3.15	1.50	0.07	NA	NA	4.72	72.00
1976	13.58	20.35	35.17	69.10	2.11	2.98	1.71	0.08	NA	NA	4.77	76.01
1977	13.92	19.93	37.12	70.99	2.70	2.33	1.84	0.08	NA	NA	4.25	78.00
1978	13.77	20.00	37.97	71.86	3.02	2.94	2.04	0.06	NA	NA	5.04	79.99
1979	15.04	20.67	37.12	72.89	2.78	2.93	2.15	0.08	NA	NA	5.17	80.90
1980	15.42	20.39	34.20	69.98	2.74	2.90	2.48	0.11	NA	NA	5.49	78.29
1981	15.91	19.93	31.93	67.75	3.01	2.76	2.59	0.12	NA	NA	5.47	76.34
1982	15.32	18.51	30.23	64.04	3.13	3.27	2.62	0.10	NA	NA	5.99	73.25
1983	15.89	17.36	30.05	63.29	3.20	3.53	2.83	0.13	NA	0.00	6.49	73.10
1984	17.07	18.51	31.05	66.62	3.55	3.39	2.88	0.16	0.00	0.00	6.43	76.74
1985	17.48	17.83	30.92	66.22	4.08	2.97	2.86	0.20	0.00	0.00	6.03	76.47
1986	17.26	16.71	32.20	66.15	4.38	3.07	2.84	0.22	0.00	0.00	6.13	76.78
1987	18.01	17.74	32.87	68.63	4.75	2.63	2.82	0.23	0.00	0.00	5.69	79.23
1988	18.85	18.55	34.22	71.66	5.59	2.33	2.94	0.22	0.00	0.00	5.49	82.84
1989	19.07	19.71	34.21	73.02	5.60	2.84	3.06	0.32	0.06	0.02	6.29	84.96
1990	19.17	19.73	33.55	72.46	6.10	3.05	2.66	0.34	0.06	0.03	6.13	84.70
1991	18.99	20.15	32.85	72.00	6.42	3.02	2.70	0.35	0.06	0.03	6.16	84.64
1992	19.12	20.84	33.53	73.52	6.48	2.62	2.85	0.35	0.06	0.03	5.91	85.99
1993	19.84	21.35	33.84	75.05	6.41	2.89	2.80	0.36	0.07	0.03	6.16	87.62
1994	19.91	21.84	34.67	76.48	6.69	2.68	2.94	0.34	0.07	0.04	6.06	89.28
1995	20.09	22.78	34.55	77.49	7.08	3.21	3.07	0.29	0.07	0.03	6.67	91.25
1996	21.00	23.20	35.76	79.98	7.09	3.59	3.13	0.32	0.07	0.03	7.14	94.26
1997	21.45	23.33	36.27	81.09	6.60	3.64	3.01	0.32	0.07	0.03	7.08	94.77
1998	21.66	22.94	36.93	81.59	7.07	3.30	2.83	0.33	0.07	0.03	6.56	95.19
1999	21.62	23.01	37.96	82.65	7.61	3.27	2.89	0.33	0.07	0.05	6.60	96.84
2000	22.58	23.92	38.40	84.96	7.86	2.81	2.91	0.32	0.07	0.06	6.16	98.96
2001	21.91	22.91	38.33	83.18	8.03	2.24	2.64	0.31	0.07	0.07	5.33	96.47
2002	21.90	23.63	38.40	83.99	8.14	2.69	2.65	0.33	0.06	0.11	5.84	97.88
2003	22.32	22.97	39.05	84.39	7.96	2.82	2.74	0.34	0.06	0.11	6.08	98.21
2004	22.47	23.04	40.59	86.23	8.22	2.69	2.88	0.35	0.06	0.14	6.12	100.32
2005	22.89	22.57	40.44	85.95	8.13	2.71	2.73	0.36	0.06	0.15	6.01	99.84

Source:
Energy Information Administration, Monthly Energy Review March 2006. Table 1.3, www.eia.doe.gov/emeu/mer/overview.html

Note: NA = Not available.

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[a] End-use consumption and electricity net generation.
[b] Natural gas, plus a small amount of supplemental gaseous fuels that cannot be identified separately.
[c] Petroleum products supplied, including natural gas plant liquids and crude oil burned as fuel. Beginning in 1993, also includes ethanol blended into other gasoline.
[d] Beginning in 1993, ethanol blended into motor gasoline is included in both "Petroleum and "biomass," but is counted only once in total consumption.
[e] Includes coal coke net imports.
[f] Conventional hydroelectric power.
[g] Wood, waste, and alcohol fuels (ethanol blended into motor gasoline).
[h] Includes coal coke net imports and electricity net imports, which are not separately displayed.

Except for corn and soybeans, all biomass resources being used in 2005 for energy are some type of residue or waste. Corn grain is used for ethanol and soybeans are used for biodiesel fuel.

Table 1.3
Renewable Energy Consumption by Source, 1973—2005
(Trillion Btu)

Year	Hydro-electric Power[a]	Biomass				Geo-thermal[e]	Solar[f]	Wind[g]	Total
		Wood[b]	Waste[c]	Alcohol Fuels[d]	Total				
1973	2,861.45	1,527.01	2.06	NA	1,529.07	42.61	NA	NA	4,433.12
1974	3,176.58	1,537.76	1.90	NA	1,539.66	53.16	NA	NA	4,769.40
1975	3,154.61	1,496.93	1.81	NA	1,498.73	70.15	NA	NA	4,723.49
1976	2,976.27	1,711.48	1.89	NA	1,713.37	78.15	NA	NA	4,767.79
1977	2,333.25	1,836.52	1.81	NA	1,838.33	77.42	NA	NA	4,249.00
1978	2,936.98	2,036.15	1.46	NA	2,037.61	64.35	NA	NA	5,038.94
1979	2,930.69	2,149.85	2.05	NA	2,151.91	83.79	NA	NA	5,166.38
1980	2,900.14	2,482.86	1.64	NA	2,484.50	109.78	NA	NA	5,494.42
1981	2,757.97	2,494.56	88.00	7.00	2,589.56	123.04	NA	NA	5,470.57
1982	3,265.56	2,477.05	119.00	19.00	2,615.05	104.75	NA	NA	5,985.35
1983	3,527.26	2,639.27	157.00	35.00	2,831.27	129.34	NA	0.03	6,487.90
1984	3,385.81	2,628.82	208.00	43.00	2,879.82	164.90	0.06	0.07	6,430.65
1985	2,970.19	2,575.77	236.32	52.00	2,864.08	198.28	0.11	0.06	6,032.73
1986	3,071.18	2,518.13	262.86	60.00	2,841.00	219.18	0.15	0.04	6,131.54
1987	2,634.51	2,465.16	289.00	69.00	2,823.16	229.12	0.11	0.04	5,686.93
1988	2,334.27	2,551.66	315.33	70.00	2,936.99	217.29	0.09	0.01	5,488.65
1989	2,837.26	2,637.10	354.36	71.00	3,062.46	317.16	55.29	22.03	6,294.21
1990	3,046.39	2,190.58	408.08	63.00	2,661.66	335.80	59.72	29.01	6,132.57
1991	3,015.94	2,189.70	439.72	73.00	2,702.41	346.25	62.69	30.80	6,158.09
1992	2,617.44	2,290.45	473.20	83.00	2,846.65	349.31	63.89	29.86	5,907.15
1993	2,891.61	2,226.86	479.34	96.99	2,803.18	363.72	66.46	30.99	6,155.96
1994	2,683.46	2,315.17	515.32	108.61	2,939.11	338.11	68.55	35.56	6,064.78
1995	3,205.31	2,419.60	531.48	116.50	3,067.57	293.89	69.86	32.63	6,669.26
1996	3,589.66	2,466.79	576.99	83.56	3,127.34	315.53	70.83	33.44	7,136.80
1997	3,640.46	2,349.50	550.60	105.81	3,005.92	324.96	70.24	33.58	7,075.15
1998	3,297.05	2,175.42	542.30	116.92	2,834.64	328.30	69.79	30.85	6,560.63
1999	3,267.58	2,223.73	540.16	121.57	2,885.45	330.92	68.79	45.89	6,598.63
2000	2,811.12	2,256.75	510.80	139.32	2,906.88	316.80	66.39	57.06	6,158.23
2001	2,241.86	1,979.50	513.54	146.67	2,639.72	311.26	65.45	69.62	5,327.91
2002	2,689.02	1,898.77	575.55	174.69	2,649.01	328.31	64.39	105.33	5,836.06
2003	2,824.53	1,929.37	571.35	238.13	2,738.84	339.14	63.62	114.57	6,080.71
2004	2,690.08	2,015.07	564.78	299.31	2,879.16	349.16	63.20	141.75	6,123.35
2005	2,714.66	1,825.52	563.91	339.77	2,729.20	355.75	62.98	149.49	6,012.08

Source:
Energy Information Administration, Monthly Energy Review March 2006, Table 10.1., www.eia.doe.gov/emeu/mer/renew.html

Note: NA = Not available.

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[a] Conventional hydroelectric power.
[b] Wood, black liquor, and other wood waste.
[c] Municipal solid waste, landfill gas, sludge waste, tires, agricultural byproducts, and other biomass.
[d] Ethanol blended into motor gasoline.
[e] Geothermal electricity net generation, heat pump, and direct use energy.
[f] Solar thermal and photovoltaic electricity net generation, and solar thermal direct use energy.
[g] Wind electricity net generation.

Ethanol provided 1.2% of the transportation fuels consumed in the United States in 2005 and biomass provided 0.15% of primary industrial energy consumed in the United States The forest products industry consumes 85% of all wood residues (including black liquor) currently used for energy in the United States, generating over half of their own energy.

Table 1.4
Estimated Renewable Energy Consumption for Industrial and Transportation Sectors, 1973–2005
(Trillion Btu)

	Industrial Sector[a]						Transportation Sector
		Biomass					Biomass
Year	Hydro-electric Power[b]	Wood[c]	Waste[d]	Total	Geo-thermal[e]	Total	Alcohol Fuels[f]
1973	34.77	1,164.85	NA	1,164.85	NA	1,199.63	NA
1974	33.20	1,159.07	NA	1,159.07	NA	1,192.28	NA
1975	32.32	1,063.27	NA	1,063.27	NA	1,095.59	NA
1976	33.37	1,219.88	NA	1,219.88	NA	1,253.25	NA
1977	32.60	1,281.25	NA	1,281.25	NA	1,313.85	NA
1978	31.56	1,400.42	NA	1,400.42	NA	1,431.99	NA
1979	34.09	1,404.86	NA	1,404.86	NA	1,438.96	NA
1980	32.84	1,600.00	NA	1,600.00	NA	1,632.84	NA
1981	33.04	1,602.00	86.72	1,688.72	NA	1,721.76	7.00
1982	33.05	1,516.00	117.69	1,633.69	NA	1,666.74	19.00
1983	33.26	1,690.00	155.29	1,845.29	NA	1,878.54	35.00
1984	33.00	1,679.00	203.57	1,882.57	NA	1,915.57	43.00
1985	33.02	1,645.00	229.64	1,874.64	NA	1,907.66	52.00
1986	33.02	1,610.00	255.70	1,865.70	NA	1,898.72	60.00
1987	32.94	1,576.00	281.77	1,857.77	NA	1,890.71	69.00
1988	32.64	1,625.00	307.71	1,932.71	NA	1,965.34	70.00
1989	28.40	1,583.57	200.41	1,783.97	1.80	1,814.17	71.00
1990	30.95	1,441.91	192.32	1,634.24	1.90	1,667.09	63.00
1991	29.68	1,409.85	184.68	1,594.52	2.10	1,626.30	73.00
1992	30.51	1,461.23	178.51	1,639.74	2.20	1,672.45	83.00
1993	29.59	1,483.17	181.16	1,664.33	2.40	1,696.32	96.99
1994	62.19	1,579.74	199.25	1,778.98	2.80	1,843.97	108.61
1995	54.70	1,652.08	195.03	1,847.11	3.00	1,904.80	116.50
1996	60.77	1,683.50	223.55	1,907.05	2.90	1,970.72	83.56
1997	58.06	1,730.62	184.02	1,914.63	3.10	1,975.79	105.81
1998	54.54	1,603.44	180.35	1,783.79	3.00	1,841.33	116.92
1999	48.66	1,619.52	171.04	1,790.56	4.10	1,843.32	121.57
2000	42.18	1,635.93	145.11	1,781.04	4.40	1,827.62	139.32
2001	32.50	1,442.61	150.28	1,592.89	4.76	1,630.15	146.67
2002	38.91	1,396.44	168.12	1,564.56	4.79	1,608.25	174.69
2003	43.24	1,363.32	169.63	1,532.94	4.55	1,580.73	238.13
2004	32.56	1,476.12	164.85	1,640.97	4.79	1,678.31	299.31
2005	31.79	1,284.14	154.80	1,438.93	4.79	1,475.51	339.77

Source:
Source: Energy Information Administration, *Monthly Energy Review*, March 2006, Table 10.2b
www.eia.doe.gov/emeu/mer/renew.html
Note: NA = Not available.

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[a] Industrial sector fuel use, including that at industrial combined-heat-and-power (CHP) and industrial electricity plants.
[b] Conventional hydroelectric power.
[c] Wood, black liquor, and other wood waste.
[d] Municipal solid waste, landfill gas, sludge waste, tires, agricultural byproducts, and other biomass.
[e] Geothermal heat pump and direct use energy.
[f] Ethanol blended into motor gasoline.

In 2005, biomass accounted for about 82% of the renewable energy used in the residential sector and about 84% of the renewable energy used in the commercial sector.

Table 1.5
Estimated Renewable Energy Consumption for Residential and Commercial Sectors, 1973–2005
(Trillion Btu)

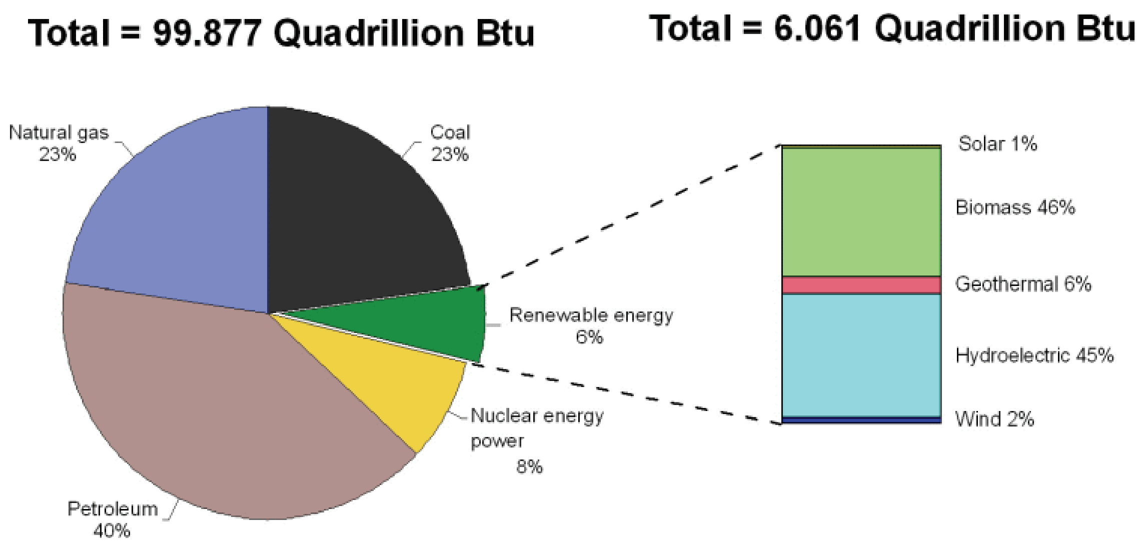
	Residential Sector				Commercial Sector[a]					
	Biomass					Biomass				
Year	Wood[b]	Geo-thermal[c]	Solar[d]	Total	Hydro-electric	Wood[b]	Waste	Total	Geo-thermal[c]	Total
1973	354.10	NA	NA	354.10	NA	6.71	NA	6.71	NA	6.71
1974	370.95	NA	NA	370.95	NA	7.02	NA	7.02	NA	7.02
1975	425.41	NA	NA	425.41	NA	8.07	NA	8.07	NA	8.07
1976	481.63	NA	NA	481.63	NA	9.10	NA	9.10	NA	9.10
1977	541.78	NA	NA	541.78	NA	10.29	NA	10.29	NA	10.29
1978	621.85	NA	NA	621.85	NA	11.83	NA	11.83	NA	11.83
1979	728.08	NA	NA	728.08	NA	13.81	NA	13.81	NA	13.81
1980	859.00	NA	NA	859.00	NA	21.00	NA	21.00	NA	21.00
1981	869.00	NA	NA	869.00	NA	21.00	NA	21.00	NA	21.00
1982	937.00	NA	NA	937.00	NA	22.00	NA	22.00	NA	22.00
1983	925.00	NA	NA	925.00	NA	22.00	NA	22.00	NA	22.00
1984	923.00	NA	NA	923.00	NA	22.00	NA	22.00	NA	22.00
1985	899.00	NA	NA	899.00	NA	24.00	NA	24.00	NA	24.00
1986	876.00	NA	NA	876.00	NA	27.00	NA	27.00	NA	27.00
1987	852.00	NA	NA	852.00	NA	29.00	NA	29.00	NA	29.00
1988	885.00	NA	NA	885.00	NA	32.00	NA	32.00	NA	32.00
1989	918.00	5.00	52.68	975.68	0.69	35.96	22.00	57.96	2.50	61.14
1990	581.00	5.50	55.90	642.40	1.43	39.15	27.77	66.91	2.80	71.14
1991	613.00	5.90	57.77	676.67	1.37	41.05	26.49	67.54	3.00	71.91
1992	645.00	6.40	59.75	711.15	1.27	44.01	32.45	76.46	3.20	80.92
1993	548.00	6.80	61.69	616.49	1.03	45.86	33.39	79.25	3.40	83.68
1994	537.00	6.20	63.53	606.73	0.96	46.10	34.52	80.63	4.20	85.78
1995	596.00	6.60	64.73	667.33	1.22	46.11	40.20	86.30	4.50	92.02
1996	595.00	7.00	65.44	667.44	1.30	50.43	53.03	103.46	5.30	110.06
1997	433.00	7.50	65.02	505.52	1.23	48.90	57.61	106.50	5.70	113.43
1998	387.14	7.70	64.66	459.50	1.23	48.13	54.16	102.30	7.10	110.62
1999	413.87	8.50	63.73	486.10	1.17	52.31	53.92	106.22	6.70	114.10
2000	433.35	8.60	61.36	503.30	1.02	53.16	47.26	100.41	7.60	109.03
2001	370.00	9.45	59.85	439.30	0.69	40.49	39.22	79.71	8.27	88.67
2002	313.00	10.20	58.75	381.95	0.13	39.15	41.96	81.11	8.75	89.99
2003	359.00	16.96	58.15	434.11	0.74	39.76	47.48	87.24	14.48	102.46
2004	332.34	17.85	57.44	407.63	1.05	41.42	55.47	96.88	15.24	113.18
2005	332.34	17.85	57.44	407.63	0.82	41.43	45.67	87.10	15.24	103.16

Source:
Energy Information Administration, Monthly Energy Review March 6, 2006, Table 10.2a, www.eia.doe.gov/emeu/mer/renew.html
Note: NA = Not available.

[a] Commercial sector fuel use, including that at commercial combined-heat-and-power (CHP) and commercial electricity-only plants.
[b] Wood, black liquor, and other wood waste.
[c] Geothermal heat pump and direct use energy.
[d] Solar thermal direct use energy and photovoltaic electricity generation. Small amounts of commercial sector are included in the residential sector.

Biomass is the single largest source of renewable energy in the United States, recently surpassing hydroelectric power. In 2005, biomass contributed 2.8% of the total U.S. energy consumption of nearly 100 quadrillion Btu (EIA, 2006). Wood, wood waste, and black liquor from pulp mills is the single largest source accounting for more than two-thirds of total biomass energy consumption. Wastes (which include municipal solid waste, landfill gas, sludge waste, tires, agricultural by-products, and other secondary and tertiary sources of biomass) accounts for about 20% of total biomass consumption. The remaining share is alcohol fuel derived principally from corn grain.

Figure 1.1
Summary of Biomass Energy Consumption, 2005



Source:
Energy Information Administration, Monthly Energy Review, August 2006.
http://www.eia.doe.gov/emeu/mer/contents.html

Total industrial biomass energy consumption was approximately 1,533 trillion Btu in 2003. The bulk of industrial biomass energy consumption is derived from forestlands. More than one-half of this total is black liquor – a pulping mill by-product containing unutilized wood fiber and chemicals. Black liquor is combusted in recovery boilers to recover valuable chemicals and to produce heat and power. Wood and wood wastes generated in primary wood processing mills account for another third of total industrial biomass energy consumption. The data contained in this table are from a survey of manufacturers that is conducted every four years by the EIA.

Table 1.6
Industrial Biomass Energy Consumption and Electricity Net Generation by Industry and Energy Sources, 2003

		Biomass Energy Consumption (Trillon Btus)			
Industry	**Energy Source**	**Total**	**For Electricity**	**For Useful Thermal Output**	**Net Generation (Million**
Total	**Total**	**1,532.947**	**378.706**	**1,154.242**	**29,001**
Agriculture, Forestry, and Mining	**Total**	**9.010**	**2.720**	**6.290**	**167**
	Agricultural Byproducts/Crops	9.010	2.720	6.290	167
Manufacturing	**Total**	**1,444.208**	**375.986**	**1,068.222**	**28,834**
Food and Kindred Industry Products	**Total**	**41.318**	**5.176**	**36.142**	**104**
	Agricultural Byproducts/Crops	37.153	4.073	33.079	28
	Other Biomass Gases	0.278	0.217	0.062	8
	Other Biomass Liquids	0.067	0.067	-	5
	Tires	0.379	0.179	0.201	14
	Wood/Wood Waste Solids	3.441	0.641	2.801	49
Lumber	**Total**	**216.442**	**16.364**	**200.078**	**1,499**
	Sludge Waste	0.058	0.019	0.039	3
	Wood/Wood Waste Liquids	0.248	0.080	0.168	12
	Wood/Wood Waste Solids	216.137	16.265	199.872	1,483
Paper and Allied Products	**Total**	**1,150.781**	**352.138**	**798.643**	**27,039**
	Agricultural Byproducts/Crops	1.131	0.092	1.040	7
	Black Liquor	814.120	239.340	574.780	18,311
	Landfill Gas	0.310	0.063	0.247	7
	Municipal Solid Waste	2.274	0.427	1.848	53
	Other Biomass Liquids	0.071	0.034	0.037	2
	Other Biomass Solids	0.741	0.586	0.155	59
	Sludge Waste	10.136	3.536	6.600	251
	Tires	7.540	2.627	4.913	253
	Wood/Wood Waste Liquids	21.019	4.697	16.322	416
	Wood/Wood Waste Solids	293.439	100.738	192.701	7,679
Chemicals and Allied Products	**Total**	**3.870**	**0.745**	**3.125**	**43**
	Landfill Gas	0.214	0.041	0.173	4
	Municipal Solid Waste	1.398	0.122	1.276	12
	Other Biomass Liquids	0.073	0.014	0.059	0
	Other Biomass Solids	0.004	0.001	0.003	0
	Sludge Waste	0.300	0.072	0.228	9
	Wood/Wood Waste Solids	1.881	0.496	1.385	18
Other[a]	**Total**	**31.797**	**1.564**	**30.233**	**149**
Nonspecified[b]	**Total**	**79.730**	**-**	**79.730**	**-**
	Landfill Gas	74.730	-	74.730	-
	Municipal Solid Waste	5.000	-	5.000	-

Sources:
Energy Information Administration, Form EIA-906, "Power Plant Report," Government Advisory Associates, Resource Recovery Yearbook and Methane Recovery Yearbook; and analysis conducted by the Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels.
Notes: Totals may not equal sum of components due to independent rounding.

[a] Other includes Apparel; Petroleum Refining; Rubber and Misc. Plastic Products; Transportation Equipment; Stone, Clay, Glass, and Concrete Products; Furniture and Fixtures; and related industries.
[b] Primary purpose of business is not specified.
- = Not Applicable.

Approximately 492 million dry tons of biomass residues are produced from agricultural lands in the United States. Nearly half of this total residue production is from corn. The amount of this residue that can be collected depends on numerous factors affecting soil sustainability, such as water and wind erosion, as well as the efficiency of the collection equipment.

Table 1.7
Total Residue Produced on Agricultural Lands, 2001

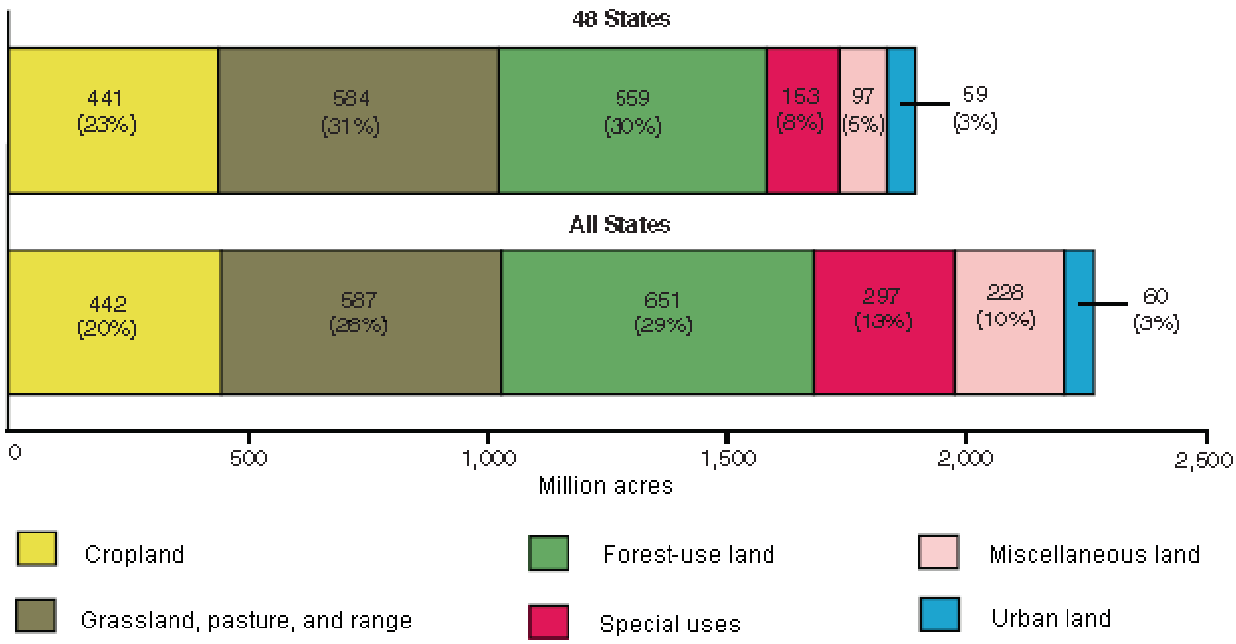
Crop	Acres harvested or reserved	Product Yield	Fiber Yield	Residue Yield	Total cropland plant mass	Total redsidue produced
	million acres	dry tons/acre/year			million dry tons/year	
Corn Grain	68.8	3.3	NA	3.3	450.0	225.0
Sorghum	8.6	1.4	NA	1.4	24.8	12.4
Barley	4.3	1.2	NA	1.8	12.8	7.7
Oats	1.9	0.8	NA	1.7	4.8	3.2
Wheat-winter	31.3	1.1	NA	1.9	95.4	60.1
Wheat-spring	17.5	0.9	NA	1.2	35.5	20.1
Soybeans	73.0	1.1	NA	1.6	193.0	115.8
Rice	3.3	2.9	NA	4.3	23.7	14.2
Cotton lint	13.8	0.3	NA	1.0	17.7	13.3
Alfalfa	23.8	3.0	NA	0.0	70.6	0.0
Other hay	39.7	1.7	NA	0.0	67.4	0.0
Silage corn	6.1	6.6	NA	0.0	40.8	0.0
Silage sorghum	0.3	4.4	NA	0.0	1.5	0.0
Other Crops	20.1	1.0	NA	1.0	20.1	20.1
Crop failure	10.0	0.5	NA	0.0	5.0	0.0
Summer fallow	21.0	0.0	NA	0.0	0.0	0.0
Grasses (CRP)	25.4	2.0	NA	0.0	50.8	0.0
Trees (CRP)	2.2	2.0	NA	0.0	4.4	0.0
Environment (CRP)	6.4	2.0	NA	0.0	12.7	0.0
UNAccounted	3.0	0.0	NA	0.0	0.0	0.0
Pasture	67.5	1.5	NA	0.0	101.3	0.0
Wood fiber	0.1	0.0	6.0	2.0	0.8	0.2
Perennials	0.0	0.0	0.0	0.0	0.0	0.0
Totals	**448.1**				**1233.1**	**492.1**

Source:
Table from page 55 of: Perlack, R.D., Wright, L.L., Turhollow, A.F., Graham, R.L., Stokes, B.J., and Erbach, DC. 2005. *Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply*. http://www.eere.energy.gov/biomass/publications.html. (Scroll down to feedstocks.)

Note: Some totals may differ slightly from the original source due to rounding differences.
NA = Not available.
Based on 2001 Agricultural Statistics, these data were used to provide the baseline supply for the document noted in the source.

The United States has a total land area in all 50 states of 2.263 billion acres. Based on the 2002 land use inventory, 20% of that land was categorized as cropland and 29% as forest-use land, thus about 49% of U.S. land is a potential source of biomass residuals or biomass crops for bioenergy. Grassland pasture and range land is, for the most part, too dry to provide much biomass resources. Miscellaneous, special use land and urban land may be a source of post-consumer biomass residuals, but are not areas where biomass crops could be produced on a large scale.

Figure 1.2
Major Uses of Land in the United States, 2002



U.S. land use categories differ slightly depending on who is reporting the results. The numbers below published in 2006, but based on a 2002 land inventory, were generated by the Economic Research Service (ERS) of USDA. They have been producing similar estimates since 1945. Other USDA organizations, the Natural Resources Conservation Service (NRCS) and the Forest Service (FS) place land into somewhat different categories. URL's for NRCS and FS estimates are given below. The NRCS divides the land into additional sub-categories (such as a "Federal land" category), and only gives values for the lower 48 states. The Forest Service documents only deal with forest land, but include a larger area of the U.S. in that category (747 million acres based on 1997 inventory data). However, ERS in a 2002 publication on land use stated that 105 million acres in the special uses category overlaps with forestland. If that area is added to the ERS forestland category then it nearly matches the NRCS forest land use estimate. Definitions of the ERS land use categories follow. NRCS and FS land use references can be found at: www.nrcs.usda.gov/technical/nri02/landuse.pdf and by searching for publications by Alig at: www.treesearch.fs.fed.us/pubs.

Source:

Lubowski, R.N., Vesterby, M., Bucholtz, S., Baez, A., Roberts, M.J. 2006. "Major Uses of Land in the United States, 2002" USDA Economic Research Service, Economic Information Bulletin Number 14, May 2006. www.ers.usda.gov/publications/eib14.

Figure 1.2 (Continued)
Major Uses of Land in the United States, 2002

Notes: Cropland: All land in the crop rotation, including cropland used for crops, land with crop failure, summer fallow, idle cropland (including Conservation Reserve Program land), and cropland used only for pasture. Cropland in Alaska and Hawaii total less than 0.4 million acres.

Grassland pasture and range: Permanent grassland and other nonforested pasture and range.

Forest-use land: Total forest land as classified by the U.S. Forest Service includes grazed forest land (134 million acres) as well as other forest land (517 million acres). It does not include land in the special uses category that is forested. This category includes a small amount of rural residential area within forested areas.

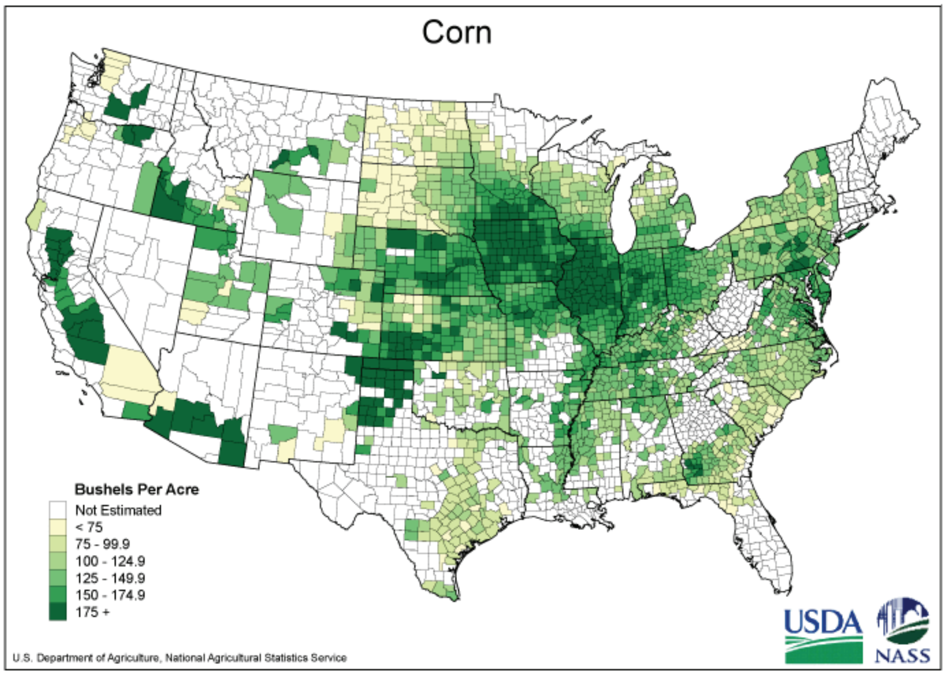
Special Uses: This land includes recreation and wildlife areas, national defense areas, and land used for rural highways, roads and railroad rights-of-way, and rural airports. It also includes 11 million acres for farmsteads and farm roads.

Miscellaneous land: This includes tundra, deserts, bare rock areas, snow and ice fields, swamps, marshes, and other unclassified areas generally of low agricultural value.

Urban land: Urban lands are newly separated from special use lands in the 2006 Major Land Uses report prepared by ERS. Urban areas are based on Census Bureau definitions which identify “urban clusters” based primarily on population density, not political boundaries.

Current commodity crop locations are good indicators of where biomass resources can be cultivated.

Figure 1.3
Geographic Locations of Major Crops, 2004



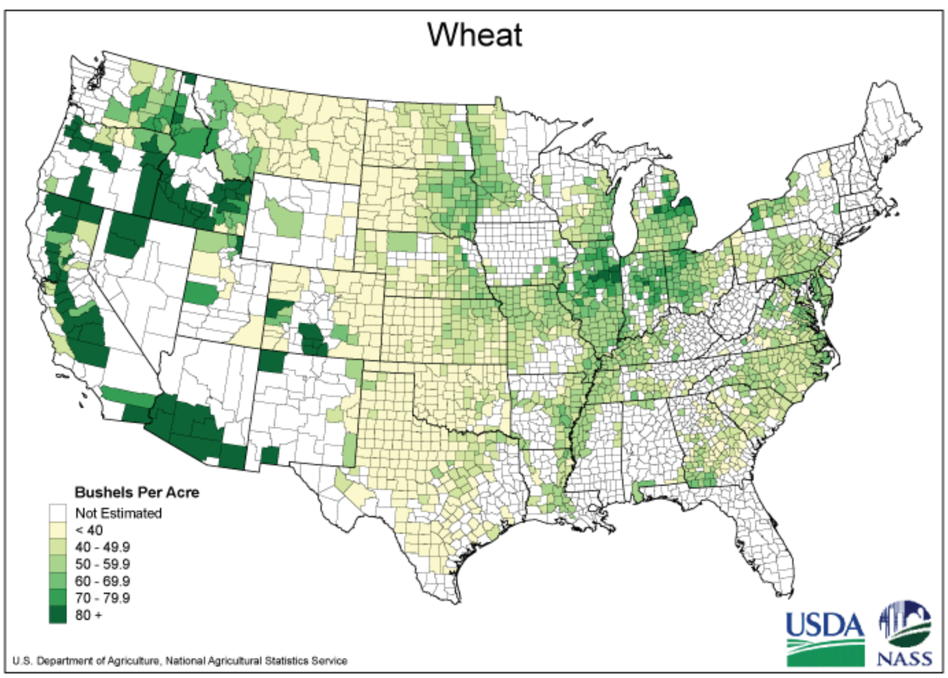
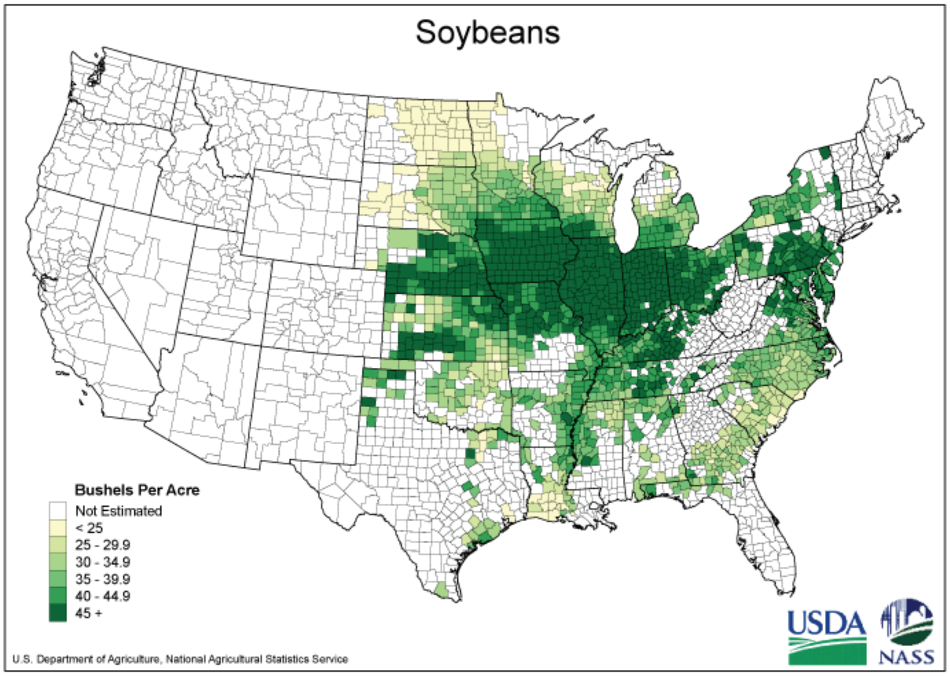
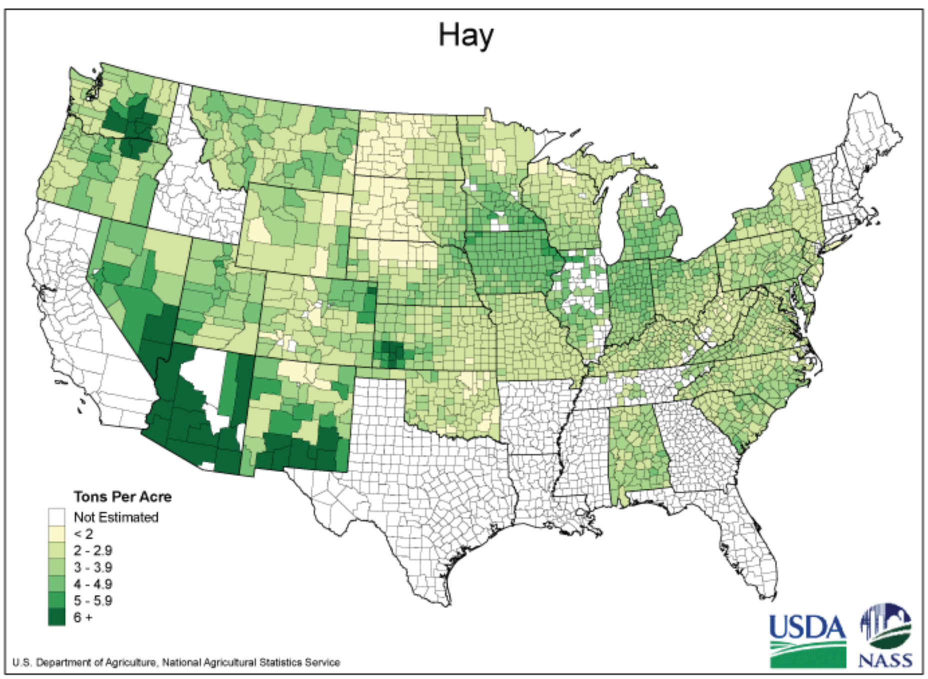


Figure 1.3 (Continued)
Geographic Locations of Major Crops, 2004





Source:
U.S. Department of Agriculture, National Agricultural Statistics Service.
http://www.usda.gov/nass/aggraphs/cropmap.htm.

FUTURE ENERGY CROP SUPPLY POTENTIAL—CELLULOSIC BIOMASS

"Woodchips, Stalks, and Switchgrass" - Cellulosic Biomass:
A Discussion of Future Energy Crop Supply Potential

President Bush spoke in his January 31, 2006, State of the Union address of producing biofuels by 2012 using "woodchips, stalks and switchgrass" as the source of cellulosic biomass. These represent both existing and potential biomass resources.

The "woodchips and stalks" represent resources that are currently available from forestry and agriculture, though very underutilized. One of the largest unexploited categories is wood that needs to be removed from forests to reduce the risk of forest fires. Well over 8 billion dry tons of biomass has been identified by the U.S. Forest Service as needing fuel treatment removal. The amount of this biomass potentially available for bioenergy uses is estimated to be about 60 million dry tons annually. This estimate takes into consideration factors affecting forest access, residue recovery and the desirability of using some of the recoverable biomass for conventional wood products. The fraction that could be available for bioenergy and bioproducts is less than 1% of the total size of the fuel treatment biomass resource. Factors affecting the rate at which this source of material will become available include public opinion toward this type of removal, as well as delivered costs and the extent to which technology is developed for utilizing small diameter wood for products other than bioenergy. The other large underutilized forest sources of woodchips are logging residues and urban wood residues. In both cases, the relatively high costs of removal, handling, and transportation has not compared favorably to their relatively low value as an energy resource. Also, the compost market could compete for urban wood resources. From the agricultural sector, the major cellulosic resources are corn "stalks" and wheat straw. Both are left in the field after the grain is harvested in much of the U.S. While a portion of this residue does have a value in maintaining soil quality and crop productivity, in some higher yield areas of the U.S. there is an excess of residue produced that could be beneficially removed. It is important to use this resource in a way that is environmentally and economically sound and that supplies the needs of biorefineries in terms of cost, quality and consistency.

Switchgrass is a thin-stemmed, warm season, perennial grass that has shown high potential as a high-yielding crop that can be grown in most areas of the nation that are also suitable for crop production. There are, in fact, many perennial crops (grass and tree species) that show high potential for production of cost-competitive cellulosic biomass. The “best” crop for a given area can only be determined by local soil and climate conditions and the desired end-use. Thus “switchgrass” can be viewed as a surrogate for many “perennial energy crops” when doing biomass supply analysis. Other perennial energy crops that might be preferred in some situations include other thin-stemmed grasses, such as Reed Canary grass or Big Bluestem grass, or thick-stemmed grasses with rhizomes, such as Miscanthus, Energy cane, or Arundo (all may sometimes be marketed as E-Grass); trees grown as single stem row crops, such as poplars, eucalyptus, silver maple, sweetgum and sycamore, or trees grown as multiple stem row crops such as willow or poplar coppice. Some annual crops are also being evaluated as dedicated energy crops including corn, sorghum, and kenaf (a woody annual crop), because of very high yields. The perennial crops will normally show better environmental performance due to lower chemical requirements and better erosion control. Cost of production of energy crops is very sensitive to yield, thus development of better energy crops involves traditional genetic selection and/or molecular genetics. It is also extremely important to select appropriate sites and optimize agronomic or silvicultural management techniques to eliminate weed competition and assure that adequate nutrients and water are available (but without over-fertilizing or irrigating).

Crop residues and high yield dedicated energy crops will not become cellulosic biomass supplies unless efficient, integrated biomass supply systems are developed. This means first of all, fully integrating crop production, harvesting and collection, storage, preprocessing, and transportation for each crop type and end use scenario. A roadmap developed jointly by researchers, producers, and users in 2003 spells out the R&D needs for assuring that cellulosic biomass can be supplied in a way that meets the cost, quality and consistency requirements of biorefineries (or biopower or biofuels production facilities).

Source: U.S. Department of Energy, 2003. Roadmap for Agricultural Biomass Feedstock Supply in the United States. Available at: http://www1.eere.energy.gov/biomass/document_database.html (search for Roadmap).

2. BIOFUELS

BRIEF OVERVIEW

A variety of fuels can be produced from biomass resources including liquid fuels, such as ethanol, methanol, biodiesel, Fischer-Tropsch diesel, and gaseous fuels, such as hydrogen and methane. Biofuels are primarily used to fuel vehicles, but can also fuel engines or fuel cells for electricity generation.

FUELS

Ethanol

Ethanol is made by converting the carbohydrate from biomass into sugar, which is then converted into ethanol in a fermentation process similar to brewing beer. Ethanol is the most widely used biofuel today with current capacity of 4.3 billion gallons per year based on starch crops, such as corn. Ethanol produced from cellulosic biomass is currently the subject of extensive research, development and demonstration efforts.

Biodiesel

Biodiesel is produced through a process in which organically derived oils are combined with alcohol (ethanol or methanol) in the presence of a catalyst to form ethyl or methyl ester. The biomass-derived ethyl or methyl esters can be blended with conventional diesel fuel or used as a neat fuel (100% biodiesel). Biodiesel can be made from any vegetable oil, animal fats, waste vegetable oils, or microalgae oils. Soybeans and Canola (rapeseed) oils are the most common vegetable oils used today.

BioOil

A totally different process than that used for biodiesel production can be used to convert biomass into a type of fuel similar to diesel which is known as BioOil. The process, called fast or flash pyrolysis, occurs when heating compact solid fuels at temperatures between 350 and 500 degrees Celcius for a very short period of time (less than 2 seconds). While there are several fast pyrolysis technologies under development, there are only two commercial fast pyrolysis technologies as of 2006. The BioOils currently produced are suitable for use in boilers for electricity generation. Additional research and development is needed to produce BioOil of sufficient quality for transportation applications.

Biofuels from Synthesis Gas

Biomass can be gasified to produce a synthesis gas composed primarily of hydrogen and carbon monoxide, also called syngas or biosyngas. Syngas produced today is used directly to generate heat and power but several types of biofuels may be derived from syngas. Hydrogen can be recovered from this syngas, or it can be catalytically converted to methanol. The gas can also be run through a biological reactor to produce ethanol or can also be converted using Fischer-Tropsch catalyst into a liquid stream with properties similar to diesel fuel, called Fischer-Tropsch diesel. However, all of these fuels can also be produced from natural gas using a similar process. Data on biofuels from synthesis gas are not currently included in the Biomass Data Book.

Source: U.S. Department of Energy, Energy Efficiency and Renewable Energy,
http://www.eere.energy.gov/RE/bio_fuels.html

Federal tax incentives for alcohol fuels were first established in 1978 for 10% blended gasoline (gasohol) creating an effective Federal subsidy for ethanol of $0.40/gallon. Various subsequent acts have raised or lowered, modified, and extended the subsidy. Tax incentives for biodiesel were first initiated in 2004 with the American Jobs Creation Act. In addition to the tax subsidies, there is the Renewable Portfolio Standard for biofuels and several other types of incentives.

Table 2.1
Major Federal Biofuel Tax Incentives

Title	Code or Law[a]	Fuel Type	Incentive	Qualifying Period	Limits[c]
Volumetric Ethanol Excise Tax Credit (VEETC)	Public Law 108-357[b]	ethanol of 190 proof or greater from biomass (e.g. corn grain, cellulosics)	$0.51 per pure gal of ethanol used or blended.	January 2005 – December 2010	Available to blenders/ retailers
Volumetric Excise Tax Credit for Biodiesel	EPACT 2005 [c] §1344, Title XIII, Subtitle D	Agri-biodiesel (e.g. from soybeans or other oil seeds)	$1.00 per pure gal of agri-biodiesel used or blended	Expires December 31, 2008	Available to blenders/ retailers
Volumetric Excise Tax Credit for Biodiesel	EPACT 2005 §1344, Title XIII, Subtitle D	Waste-grease biodiesel	$0.50 per pure gal of waste-grease biodiesel used or blended	Expires December 31, 2008	Available to blenders/ retailers
Volumetric Excise Tax Credit for Biodiesel	EPACT 2005 §1344, Title XIII, Subtitle D	Renewable diesel – made from biomass by thermal deploymerization	$1.00 per gal of diesel fuel used or blended	Expires December 31, 2008	Available to blenders/ retailers
Small Ethanol Producer Credit	EPACT 2005 §1347, Title XIII, Subtitle D	Ethanol from biomass (e.g. corn grain, cellulosics)	$0.10 per gallon ethanol or biodiesel produced up to 30 million gallons	Expires December 31, 2008	< 60 million gallon production capacity Cap at $1.5 million per yr per producer Can offset the alternative minimum tax
Small Biodiesel Producer Credit	EPACT 2005 §1345, Title XIII, Subtitle D	Agri-biodiesel	$0.10 per gallon ethanol or biodiesel produced up to 15 million gallons	Expires December 31, 2008	Same as above
Income Tax Credit for E85 and B20 Infrastructure	EPACT 2005 §1342, Title XIII, Subtitle D	Ethanol or biodiesel	Permits taxpayers to claim a 30% credit for cost of installing clean-fuel vehicle refueling property at business or residence	January 2006 – December 2007	$30,000 limit on tax credit

Source:
Renewable Fuels Association, http://www.ethanolrfa.org/policy/regulations/federal/standard/

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[a] Most recent Internal Revenue Service code or public law affecting the status of the incentive. In several cases, the most recent action is a modification of prior actions.

[b] Public Law 108-357 was the American Jobs Creation Act of 2004.

[c] EPACT 2005 is the Energy Policy Act of 2005. See brief summary of all biofuel related provisions in the final version of the Energy Policy Act at:
http://www.ethanolrfa.org/policy/regulations/federal/standard/

Table 2.2
Selected Non-Tax Federal Biofuel Incentives

Federal Action	Title	Goal	Notes and More information
EPACT 2005 [a]	Title II, §203 Renewable Fuels Standard (RFS)	4.0 billion gallons ethanol in 2006; 7.5 billion gallons of ethanol by 2012	brief summary of RFS provisions: http://www.ethanolrfa.org/policy/regulations/federal/standard/ summary of RFS and other biofuels incentives: http://www.ethanol.org/rfs.html EPA regulations relevant to RFS: http://www.epa.gov/oms/renewablefuels/
EPACT 2005	Title II, §941	Effective biomass R,D&D	Modifies the Biomass Research and Development Act of 2000. Broadens scope from industrial products to fuels and biobased products. Includes development and demonstration as relevant activities. It spells out research priorities and distribution of funds. 50% of the funds are to go to demonstration projects with 20% or greater cost-share.
EPACT 2005	Title II, §942 Production Incentive for Cellulosic Biofuels	Cost competitive cellulosic biomass by 2015	One gallon of cellulosic ethanol and ethanol produced in facilities using animal waste to displace fossil fuel use qualifies as 2.5 gallons towards satisfying the RFS
EPACT 2005	Title II, §943 Procurement of Biobased Products	Federal agencies to showcase biobased products	Expands Biobased Procurement Program to Federal government contractors, and establishes program of public education regarding federal use of biobased products
EPACT 2005	Title XV, §1511	Incentive for commercial cellulosic ethanol	Directs Department of Energy to provide loan guarantees for not more than 4 commercial demonstrations, to include one using cereal straw and one using MSW as feedstocks. Must have capacity of 30 million gallons or more.
Farm Security and Rural Investment Act of 2002	Commodity Credit Corporation Bioenergy Program	Increase ethanol production	The USDA Farm Service Agency has for several years encouraged new biofuel production capacity by making cash payments to bioethanol and biodiesel producers for new production. The program is scheduled to end in September 2006.

Source:
The Energy Policy Act of 2005 and the Farm Security and Rural Investment Act of 2002.
http://thomas.loc.gov/cgi-bin/thomas.
http://www.ers.usda.gov/Features/FarmBill/.

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[a] The Energy Policy Act of 2005 contains many sections that could help in facilitating the development of biofuels or biomass power and/or that request new studies to assist in developing further policy. For a description of 42 of the relevant sections see the September-October 2005 newsletter published by General Bioenergy, Inc. (www.bioenergyupdate.com) under newsletter Archives. Not included in this summary are sections pertaining to alternative-fueled vehicles.

ETHANOL OVERVIEW

There are two types of ethanol produced in the United States – fermentation ethanol and synthetic ethanol. Fermentation ethanol (or bioethanol) is produced from corn or other biomass feedstocks and is by far the most common type of ethanol produced, accounting for more than 90% of all ethanol production. Fermentation ethanol is mainly produced for fuel, though a small share is used by the beverage industry and the industrial industry. Synthetic ethanol is produced from ethylene, a petroleum by-product, and is used mainly in industrial applications. A small amount of synthetic ethanol is exported to other countries.

Ethanol is the most widely used biofuel today. In 2005, more than 3.6 billion gallons were added to gasoline in the United States to improve vehicle performance and reduce air pollution. Ethanol is currently produced using a process similar to brewing beer where starch crops are converted into sugars, the sugars are fermented into ethanol, and the ethanol is then distilled into its final form.

Ethanol is used to increase octane and improve the emissions quality of gasoline. In many areas of the United States today, ethanol is blended with gasoline to form an E10 blend (10% ethanol and 90% gasoline), but it can be used in higher concentrations, such as E85, or in its pure form E100. All automobile manufacturers that do business in the United States approve the use of E10 in gasoline engines; however, only flex fuel vehicles (FFVs) are designed to use E85. Pure ethanol or E100 is used in Brazil but is not currently compatible with vehicles manufactured for the U.S. market. Manufacturer approval of ethanol blends is found in vehicle owners' manuals under references to refueling or gasoline.

Bioethanol from cellulosic biomass materials (such as agricultural residues, trees, and grasses) is made by first using pretreatment and hydrolysis processes to extract sugars, followed by fermentation of the sugars. Although producing bioethanol from cellulosic biomass is currently more costly than producing bioethanol from starch crops, the U.S. Government has launched a Biofuels Initiative with the objective of quickly reducing the cost of cellulosic bioethanol. Researchers are working to improve the efficiency and economics of the cellulosic bioethanol production process. When cellulosic bioethanol becomes commercially available, it will be used exactly as the bioethanol currently made from corn grain.

Source: DOE Energy Efficiency and Renewable Energy,
http://www1.eere.energy.gov/biomass/abcs_biofuels.html and
http://www1.eere.energy.gov/biomass/bioethanol

Below are the primary quality specifications for denatured fuel ethanol for blending with gasoline meeting Federal requirements. The state of California has additional restrictions that apply in addition to the performance requirements in ASTM D 4806.

Table 2.3
Specifications Contained in ASTM D 4806 Standard Specification for Denatured Fuel Ethanol for Blending with Gasoline

Property	Specification	ASTM Test Method
Ethanol volume %, min	92.1	D 5501
Methanol, volume %. max	0.5	
Solvent-washed gum, mg/100 ml max	5	D 381
Water content, volume %, max	1	E 203
Denaturant content, volume %, min	1.96	
volume %, max	4.76	
Inorganic Chloride content, mass ppm (mg/L) max	40	D 512
Copper content, mg/kg, max	0.1	D1688
Acidity (as acetic acid CH3COOH), mass percent (mg/L), max	0.007	D1613
pHe	6.5-9.0	D 6423
Appearance	Visibly free of suspended or precipitated contaminants (clear & bright)	

Source:
Renewable Fuels Association, Industry Guidelines, Specifications, and Procedures. http://www.ethanolrfa.org/industry/resources/guidelines/.

Table 2.4
Fuel Property Comparison for Ethanol, Gasoline and No. 2 Diesel

Property	Ethanol	Gasoline	No. 2 Diesel
Chemical Formula	C2H5OH	C4 to C12	C3 to C25
Molecular Weight	46.07	100–105	≈200
Carbon	52.2	85–88	84–87
Hydrogen	13.1	12–15	33–16
Oxygen	34.7	0	0
Specific gravity, 60° F/60° F	0.796	0.72–0.78	0.81–0.89
Density, lb/gal @ 60° F	6.61	6.0–6.5	6.7–7.4
Boiling temperature, °F	172	80–437	370–650
Reid vapor pressure, psi	2.3	8–15	0.2
Research octane no.	108	90–100	--
Motor octane no.	92	81–90	--
(R + M)/2	100	86–94	N/A
Cetane no.(1)	--	5–20	40–55
Fuel in water, volume %	100	Negligible	Negligible
Water in fuel, volume %	100	Negligible	Negligible
Freezing point, °F	-173.2	-40	-40–30[b]
Centipoise @ 60° F	1.19	0.37–0.44[a]	2.6–4.1
Flash point, closed cup, °F	55	-45	165
Autoignition temperature, °F	793	495	≈600
Lower	4.3	1.4	1
Higher	19	7.6	6
Btu/gal @ 60° F	2,378	≈900	≈700
Btu/lb @ 60° F	396	≈150	≈100
Btu/lb air for stoichiometric mixture @ 60° F	44	≈10	≈8
Higher (liquid fuel-liquid water) Btu/lb	12,800	18,800–20,400	19,200–20000
Lower (liquid fuel-water vapor) Btu/lb	11,500	18,000–19,000	18,000–19,000
Higher (liquid fuel-liquid water) Btu/gal	84,100	124,800	138,700
Lower (liquid fuel-water vapor) Btu/gal @ 60° F	76,000[a]	115,000	128,400
Mixture in vapor state, Btu/cubic foot @ 68° F	92.9	95.2	96.9[c]
Fuel in liquid state, Btu/lb or air	1,280	1,290	–
Specific heat, Btu/lb °F	0.57	0.48	0.43
Stoichiometric air/fuel, weight	9	14.7[a]	14.7
Volume % fuel in vaporized stoichiometric mixture	6.5	2	–

Source:
U.S. Department of Energy, Office of Energy Effiency and Renewable Energy, Alternative Fuels Data Center. http://www.eere.energy.gov/afdc/altfuel/fuel_properties.html.

[a] Calculated.
[b] Pour Point, ASTM D97.
[c] Based on Cetane.

The U.S. and Brazil produced about 70 percent of the world's ethanol in 2005. The table below includes all types of ethanol, not just fuel ethanol.

Table 2.5
World Ethanol Production by Country, 2005
(Millions of gallons, all grades)

Country	2005
U.S.	4,264
Brazil	4,227
China	1,004
India	449
France	240
Russia	198
Germany	114
South Africa	103
Spain	93
U.K.	92
Thailand	79
Ukraine	65
Canada	61
Poland	58
Indonesia	45
Argentina	44
Italy	40
Australia	33
Saudi Arabia	32
Japan	30
Sweden	29
Pakistan	24
Philippines	22
South Korea	17
Guatemala	17
Ecuador	14
Cuba	12
Mexico	12
Nicaragua	7
Zimbabwe	5
Kenya	4
Mauritius	3
Swaziland	3
Others	710
Total	**12,150**

Source:
Renewable Fuels Association, Industry Statistics,
http://www.ethanolrfa.org/industry/statistics/#E

Note: Some countries listed in the table titled: "U.S. Fuel Ethanol Imports by Country" do not appear in this table because they process ethanol (dehydration) rather than produce it from feedstock.

The United States imports a small percentage of ethanol from countries within relatively close geographic proximity.

Table 2.6
Fuel Ethanol Imports by Country
(Millions of gallons)

Country	2002	2003	2004
Brazil	0	0	90.3
Costa Rica	12	14.7	25.4
El Salvadore	4.5	6.9	5.7
Jamaica	29	39.3	36.6
Total	**45.5**	**60.9**	**159.9**

Source:
Renewable Fuel Association, http://www.ethanolrfa.org/industry/statistics/

Note: Some countries listed in this table do not appear in the table titled: "World Ethanol Production by Country" because they process ethanol (dehydration) rather than produce it from feedstock.

Fuel ethanol production has been on the rise in the United States since 1980, though production has increased dramatically since 2001.

Table 2.7
Historic Fuel Ethanol Production

Year	Millions of Gallons
1980	175
1981	215
1982	350
1983	375
1984	430
1985	610
1986	710
1987	830
1988	845
1989	870
1990	900
1991	950
1992	1,100
1993	1,200
1994	1,350
1995	1,400
1996	1,100
1997	1,300
1998	1,400
1999	1,470
2000	1,630
2001	1,770
2002	2,130
2003	2,800
2004	3,400
2005	3,900

Source:
1998-2005: Energy Information Administration, Monthly Oxygenate Report http://www.eia.doe.gov/oil_gas/petroleum/data_publications/monthly_oxygenate_telephone_report/motr.html; 1908-1997: Renewable Fuels Association, http://www.ethanolrfa.org/industry/outlook/index.php, "From Niche to Nation: Ethanol Industry Outlook 2006."

Between 1999 and 2006, the number of ethanol plants in the United States nearly doubled, accompanied by a rapid rise in production capacity. Additional information on specific plant locations and up-to-date statistics can be obtained at the Renewable Fuels Association, www.ethanolrfa.org/industry/statistics/

Table 2.8
Ethanol Production Statistics, 1999-2006
(as of January of each year)

Year	1999	2000	2001	2002	2003	2004	2005	2006
Total Ethanol Plants	50	54	56	61	68	72	81	95
Ethanol Production Capacity (million gallons per year)	1,701.7	1,748.7	1,921.9	2,347.3	2,706.8	3,100.8	3,643.7	4,336.4
Plants Under Construction	5	6	6	13	11	15	16	31
Capacity Under Construction (million gallons per year)	77.0	91.5	64.7	390.7	483.0	598.0	754.0	1,778.0
Farmer Owned Plants	14	18	21	25	28	33	40	46
Farmer Owned Capacity (million gallons per year)	293.3	340.3	473.0	645.6	796.6	1,041.1	1,388.6	1,677.1
Percent of Total Capacity that is Farmer Owned	17%	19%	25%	28%	29%	34%	38%	39%
Farmer Owned Plants Under Construction	5	3	3	10	8	12	10	4
Farmer Owned Capacity Under Construction (million gallons per year)	77	60	60	335	318	447	450	187
Percent of Total Under Construction Capacity	100%	66%	71%	86%	66%	75%	60%	11%
States with Ethanol Plants	17	17	18	19	20	19	18	20

Source:
Renewable Fuels Association, Table titled: "Ethanol Industry Overview,"
www.ethanolrfa.org/industry/statistics/

Although ethanol can be made from a wide variety of feedstocks, the vast majority of ethanol is made from corn. Future cellulosic production methods using grasses and woody plant material may eventually account for a sizeable share, but in the near term, corn remains the dominant feedstock.

Table 2.9
Ethanol Production by Feedstock, 2006

Plant Feedstock	Capacity (million galllons/year)	% of Capacity	No. of Plants	% of Plants
Corn[a]	4,516	92.7%	85	83.3%
Corn/Milo	162	3.3%	5	4.9%
Corn/Wheat	90	1.8%	2	2.0%
Corn/Barley	40	0.8%	1	1.0%
Milo/Wheat	40	0.8%	1	1.0%
Waste Beverage[b]	16	0.3%	5	4.9%
Cheese Whey	8	0.2%	2	2.0%
Sugars & Starches	2	0.0%	1	1.0%
Total	**4,872**	**100.0%**	**102**	**100.0%**

Source:
Environmental Protection Agency, Office of Transportation and Air Quality "Renewable Fuel Standard Program - Draft Regulatory Impact Analysis" September 2006, EPA420-D-06-008.

[a] Includes seed corn.
[b] Includes brewery waste

The great majority of ethanol production facilities operating in the United States use natural gas as their energy source.

Table 2.10
Ethanol Production by Plant Energy Source, 2006

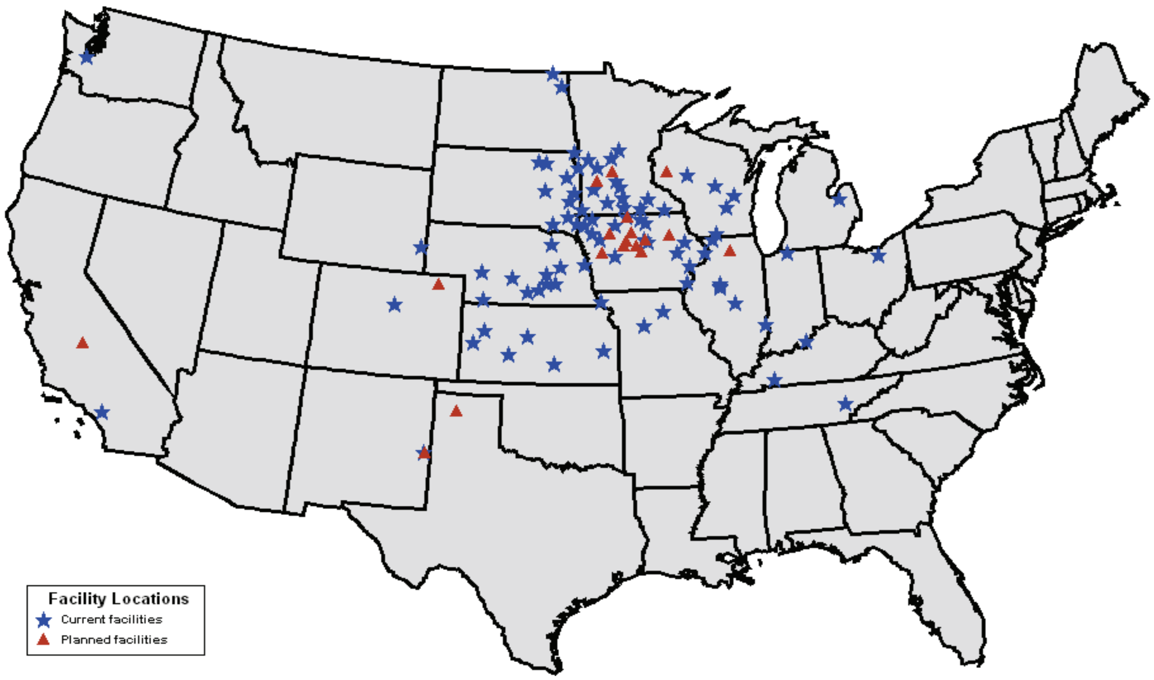
Energy Source	Capacity MMGal/year	% of Capacity	No. of Plants	% of Plants
Natural Gas[a]	4671	95.9%	98	96.1%
Coal	102	2.1%	2	2.0%
Coal & Biomass	50	1.0%	1	1.0%
Syrup	49	1.0%	1	1.0%
Total	**4872**	**100.0%**	**102**	**100.0%**

Source:
Environmental Protection Agency, Office of Transportation and Air Quality, "Renewable Fuel Standard Program - Draft Regulatory Impact Analysis," September 2006, EPA420-D-06-008.

[a] Includes a natural gas facility which is considering transitioning to coal.

The majority of ethanol production facilities are concentrated where corn is grown. For an up-to-date listing of all production facilities, visit the Renewable Fuels Association, http://www.ethanolrfa.org/.

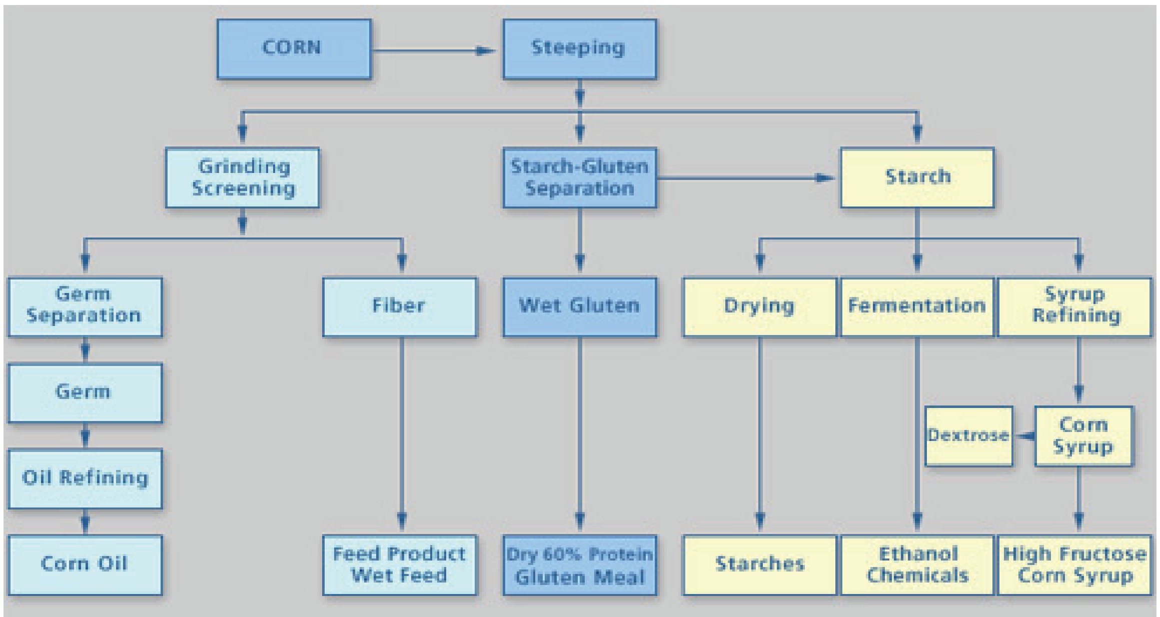
Figure 2.1
Ethanol Production Facilities Current and Planned, 2005



Source:
Renewable Fuels Association, www.ethanolrfa.org/.

The production of ethanol or ethyl alcohol from starch or sugar-based feedstocks is among man's earliest ventures into value-added processing. While the basic steps remain the same, the process has been considerably refined in recent years, leading to a very efficient process. There are two production processes: wet milling and dry milling. The main difference between the two is in the initial treatment of the grain.

Figure 2.2
The Ethanol Production Process - Wet Milling



In wet milling, the grain is soaked or "steeped" in water and dilute sulfurous acid for 24 to 48 hours. This steeping facilitates the separation of the grain into its many component parts.

After steeping, the corn slurry is processed through a series of grinders to separate the corn germ. The corn oil from the germ is either extracted on-site or sold to crushers who extract the corn oil. The remaining fiber, gluten and starch components are further segregated using centrifugal, screen and hydroclonic separators.

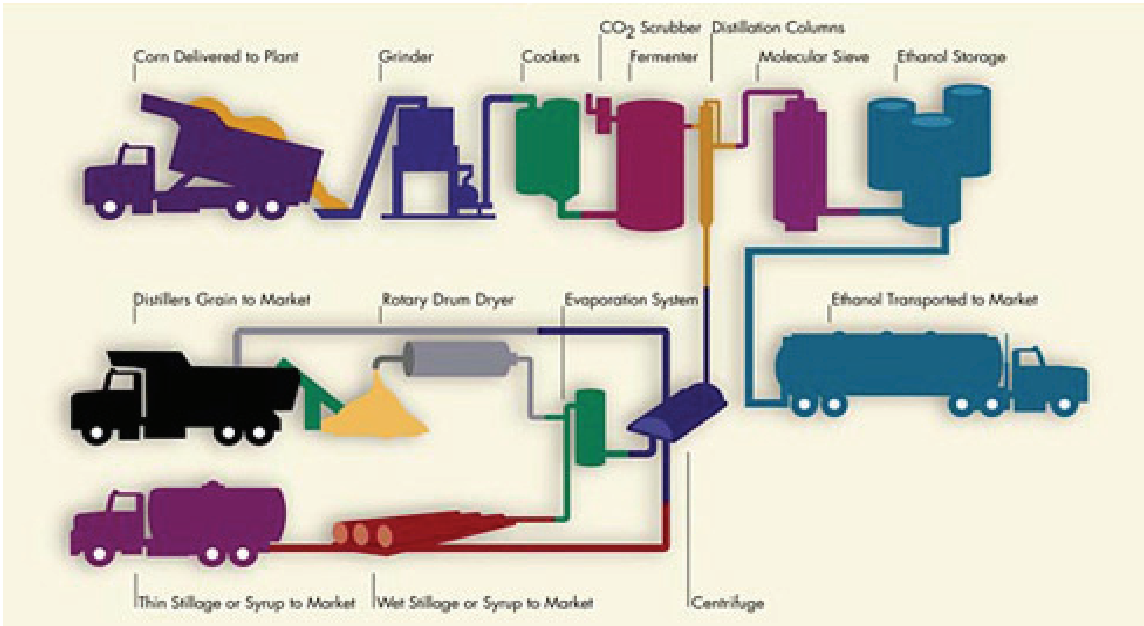
The steeping liquor is concentrated in an evaporator. This concentrated product, heavy steep water, is co-dried with the fiber component and is then sold as corn gluten feed to the livestock industry. Heavy steep water is also sold by itself as a feed ingredient and is used as a component in Ice Ban, an environmentally friendly alternative to salt for removing ice from roads.

The gluten component (protein) is filtered and dried to produce the corn gluten meal co-product. This product is highly sought after as a feed ingredient in poultry broiler operations.

The starch and any remaining water from the mash can then be processed in one of three ways: fermented into ethanol, dried and sold as dried or modified corn starch, or processed into corn syrup. The fermentation process for ethanol is very similar to the dry mill process.

Source:
Renewable Fuels Association, http://www.ethanolrfa.org/resource/made/

Figure 2.3
The Ethanol Production Process - Dry Milling



In dry milling, the entire corn kernel or other starchy grain is first ground into flour, which is referred to in the industry as "meal" and processed without separating out the various component parts of the grain. The meal is slurried with water to form a "mash." Enzymes are added to the mash to convert the starch to dextrose, a simple sugar. Ammonia is added for pH control and as a nutrient to the yeast.

The mash is processed in a high-temperature cooker to reduce bacteria levels ahead of fermentation. The mash is cooled and transferred to fermenters where yeast is added and the conversion of sugar to ethanol and carbon dioxide (CO_2) begins.

The fermentation process generally takes about 40 to 50 hours. During this part of the process, the mash is agitated and kept cool to facilitate the activity of the yeast. After fermentation, the resulting "beer" is transferred to distillation columns where the ethanol is separated from the remaining "stillage." The ethanol is concentrated to 190 proof using conventional distillation and is then dehydrated to approximately 200 proof in a molecular sieve system.

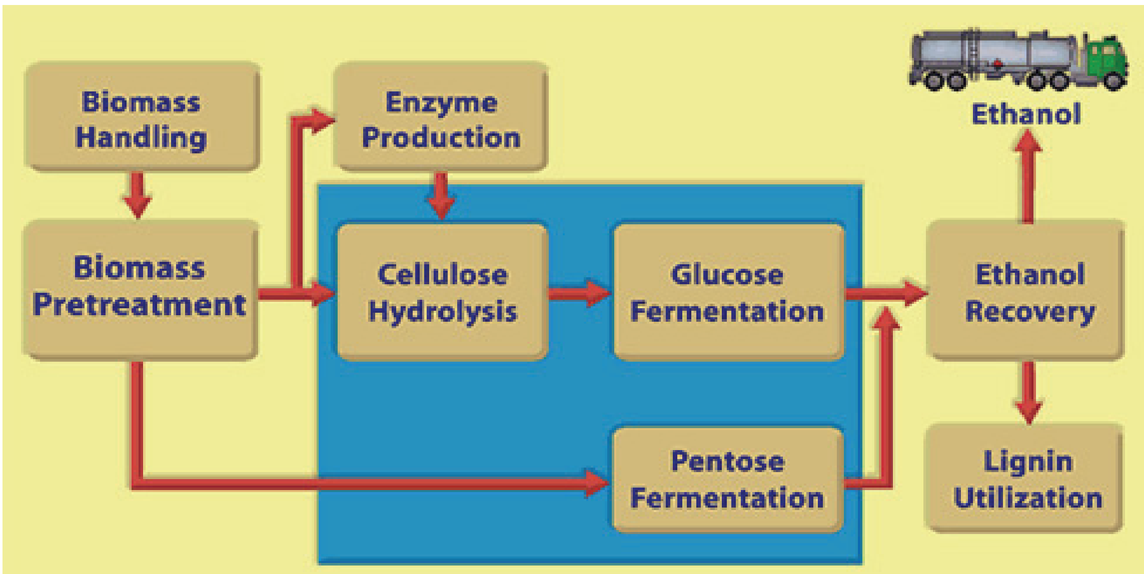
The anhydrous ethanol is blended with about 5% denaturant (such as natural gasoline) to render it undrinkable and thus not subject to beverage alcohol tax. It is then ready for shipment to gasoline terminals or retailers.

The stillage is sent through a centrifuge that separates the coarse grain from the solubles. The solubles are then concentrated to about 30% solids by evaporation, resulting in Condensed Distillers Solubles (CDS) or "syrup." The coarse grain and the syrup are dried together to produce dried distillers grains with solubles (DDGS), a high quality, nutritious livestock feed. The CO_2 released during fermentation is captured and sold for use in carbonating soft drinks and the manufacture of dry ice.

Source:
Renewable Fuels Association, http://www.ethanolrfa.org/resource/made/

This process flow diagram shows the basic steps in production of ethanol from cellulosic biomass. While cellulosic ethanol is not yet commercial in the U.S., it has been demonstrated by several groups and commercial facilities are being planned in North America. Note that there are a variety of options for pretreatment and other steps in the process and that some specific technologies combine two or all three of the hydrolysis and fermentation steps within the shaded box. Chart courtesy of the National Renewable Energy Laboratory.

Figure 2.4
The Production of Ethanol from Cellulosic Biomass



- **Hydrolysis** is the chemical reaction that converts the complex polysaccharides in the raw feedstock to simple sugars. In the biomass-to-bioethanol process, acids and enzymes are used to catalyze this reaction.
- **Fermentation** is a series of chemical reactions that convert sugars to ethanol. The fermentation reaction is caused by yeast or bacteria, which feed on the sugars. Ethanol and carbon dioxide are produced as the sugar is consumed.
- **Process Description.** The basic processes for converting sugar and starch crops are well-known and used commercially today. While these types of plants generally have a greater value as food sources than as fuel sources there are some exceptions to this. For example, Brazil uses its huge crops of sugar cane to produce fuel for its transportation needs. The current U.S. fuel ethanol industry is based primarily on the starch in the kernels of feed corn, America's largest agricultural crop.
- **Biomass Handling.** Biomass goes through a size-reduction step to make it easier to handle and to make the ethanol production process more efficient. For example, agricultural residues go through a grinding process and wood goes through a chipping process to achieve a uniform particle size.
- **Biomass Pretreatment.** In this step, the hemicellulose fraction of the biomass is broken down into simple sugars. A chemical reaction called hydrolysis occurs when dilute sulfuric acid is mixed with the biomass feedstock. In this hydrolysis reaction, the complex chains of sugars that make up the hemicellulose are broken, releasing simple sugars. The complex hemicellulose sugars are converted to a mix of soluble five-carbon sugars, xylose and arabinose, and soluble six-carbon sugars, mannose and galactose. A small portion of the cellulose is also converted to glucose in this step.

Figure 2.4 (Continued)
The Production of Ethanol from Cellulosic Biomass

- **Enzyme Production.** The cellulase enzymes that are used to hydrolyze the cellulose fraction of the biomass are grown in this step. Alternatively the enzymes might be purchased from commercial enzyme companies.
- **Cellulose Hydrolysis.** In this step, the remaining cellulose is hydrolyzed to glucose. In this enzymatic hydrolysis reaction, cellulase enzymes are used to break the chains of sugars that make up the cellulose, releasing glucose. Cellulose hydrolysis is also called cellulose saccharification because it produces sugars.
- **Glucose Fermentation.** The glucose is converted to ethanol, through a process called fermentation. Fermentation is a series of chemical reactions that convert sugars to ethanol. The fermentation reaction is caused by yeast or bacteria, which feed on the sugars. As the sugars are consumed, ethanol and carbon dioxide are produced.
- **Pentose Fermentation.** The hemicellulose fraction of biomass is rich in five-carbon sugars, which are also called pentoses. Xylose is the most prevalent pentose released by the hemicellulose hydrolysis reaction. In this step, xylose is fermented using Zymomonas mobilis or other genetically engineered bacteria.
- **Ethanol Recovery.** The fermentation product from the glucose and pentose fermentation is called ethanol broth. In this step the ethanol is separated from the other components in the broth. A final dehydration step removes any remaining water from the ethanol.
- **Lignin Utilization.** Lignin and other byproducts of the biomass-to-ethanol process can be used to produce the electricity required for the ethanol production process. Burning lignin actually creates more energy than needed and selling electricity may help the process economics.

Converting cellulosic biomass to ethanol is currently too expensive to be used on a commercial scale. Researchers are working to improve the efficiency and economics of the ethanol production process by focusing their efforts on the two most challenging steps:

- **Cellulose Hydrolysis.** The crystalline structure of cellulose makes it difficult to hydrolyze to simple sugars, ready for fermentation. Researchers are developing enzymes that work together to efficiently break down cellulose.
- **Pentose Fermentation.** While there are a variety of yeast and bacteria that will ferment six-carbon sugars, most cannot easily ferment five-carbon sugars, which limits ethanol production from cellulosic biomass. Researchers are using genetic engineering to design microorganisms that can efficiently ferment both five- and six-carbon sugars to ethanol at the same time.

Source:
Renewable Fuels Association, http://www.ethanolrfa.org/resource/made/ and the Department of Energy, Energy Efficiency and Renewable Energy, http://www1.eere.energy.gov/biomass/abcs_biofuels.html

Table 2.11
Ethanol-Blended Fuel Use by State, 2004

State	Thousands of gallons
Alabama	313,837
Alaska	3,209
Arizona	—
Arkansas	—
California	15,779,408
Colorado	840,135
Connecticut	1,590,629
Delaware	—
Dist. of Col.	—
Florida	552
Georgia	—
Hawaii	—
Idaho	—
Illinois	4,215,207
Indiana	1,480,385
Iowa	1,167,313
Kansas	43,295
Kentucky	302,696
Louisiana	1,793
Maine	—
Maryland	3,033
Massachusetts	—
Michigan	—
Minnesota	2,766,931
Mississippi	—
Missouri	1,220,178
Montana	18,898
Nebraska	371,983
Nevada	466,421
New Hampshire	—
New Jersey	—
New Mexico	64,975
New York	—
North Carolina	1,795
North Dakota	105,022
Ohio	1,916,299
Oklahoma	—
Oregon	—
Pennsylvania	—
Rhode Island	—
South Carolina	—
South Dakota	239,001
Tennessee	—
Texas	332,940
Utah	—
Vermont	—
Virginia	32
Washington	4,785
West Virginia	12,660
Wisconsin	1,085,639
Wyoming	—
U.S. Total	**34,349,052**

Source:
Renewable Fuels Association,
http://www.ethanolrfa.org/industry/outlook/index.php,
"From Niche to Nation: Ethanol Industry Outlook 2006."

While the current production cost for gasoline is significantly less than for ethanol, gasoline production cost is projected to increase over time. Production cost for ethanol is projected to decrease over time.

Table 2.12
Gasoline and Ethanol: Comparison of Current and Potential Production Costs in North America
(U.S. dollars per gasoline-equivalent liter)

	2002	2010	Post-2010
Gasoline	$0.21	$0.23	$0.25
Ethanol from corn	$0.43	$0.40	$0.37
Ethanol from cellulose (poplar)	$0.53	$0.43	$0.27

Source:
International Energy Agency, *Biofuels for Transport*, Table 4.6

Note: Gasoline gate cost based on $24/barrel oil in 2002, $30/barrel in 2020; corn ethanol from IEA, with about 1% per year cost reduction in future; cellulosic costs from IEA based on NREL estimates.

Twenty-one ethanol dry mill processing plants contributed to the survey results reported here. The costs reported are 2002 dollars.

Table 2.13
Undenatured Ethanol Cash Operating Expenses and Net Feedstock Costs for Dry-milling Process by Plant Size, 2002

Feedstock	Unit	All Dry Mills	Small	Large
Corn	1,000 bu	193,185	103,213	89,972
Sorghum	1,000 bu	10,409	NA	10,409
Other	1,000 ton	44.9	NA	44.9
Alcohol production:				
Fuel	1,000 gal	548,684	275,900	272,784
Industrial	1,000 gal	1,000	1,000	
Total	1,000 gal	549,684	276,900	272,784
Ethanol yield	Gal/bu	2.6623	2.6828	2.649
Feedstock costs	Dol/gal	0.8030	0.7965	0.8095
Byproducts credits:				
Distiller's dried grains	Dol/gal	0.2520	0.2433	0.261
Carbon dioxide	Dol/gal	0.0060	0.0038	0.008
Net feedstock costs	Dol/gal	0.5450	0.5494	0.5405
Cash operating expenses:				
Electricity	Dol/gal	0.0374	0.04	0.0349
Fuels	Dol/gal	0.1355	0.1607	0.1099
Waste management	Dol/gal	0.0059	0.0077	0.0041
Water	Dol/gal	0.0030	0.0044	0.0015
Enzymes	Dol/gal	0.0366	0.0377	0.0365
Yeast	Dol/gal	0.0043	0.0039	0.0046
Chemicals	Dol/gal	0.0229	0.0231	0.0228
Denaturant	Dol/gal	0.0348	0.0356	0.0339
Maintenance	Dol/gal	0.0396	0.0319	0.0474
Labor	Dol/gal	0.0544	0.0609	0.0478
Administrative costs	Dol/gal	0.0341	0.0357	0.0325
Other	Dol/gal	0.0039	0.0035	0.0043
Total	**Dol/gal**	**0.4124**	**0.4451**	**0.3802**
Total cash costs and net feedstock costs	**Dol/gal**	**0.9574**	**0.9945**	**0.9207**

Source:
Shapouri, H. and Gallagher, P. 2005. USDA's Ethanol Cost of Production Survey. U.S. Department of Agriculture, Agricultural Economic Report Number 841. July 2005.

Note:
bu – bushels
gal – gallons
dol – dollars

The ethanol industry spent nearly $5.3 billion in 2004 to produce ethanol. Most of this spending was for corn grain, followed by new plant construction. These expenditures created an estimated $15.3 billion in additional output in the U.S. economy, increased household earnings by nearly $3.9 billion, and created over 143,000 jobs.

Table 2.14
Economic Contribution of the Ethanol Industry, 2004

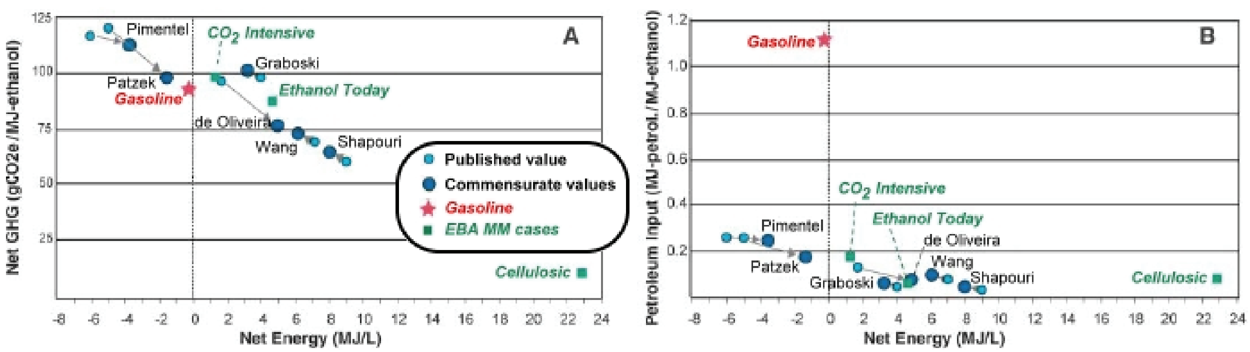
	2004 Expenditure (Mil $)	2004 Impact Output (Mil $)	Earnings (Mil $)	Employment (Jobs)
Corn	$3,175.90	$8,759.50	$2,054.50	89,263
Chemicals	$279.50	$844.10	$201.00	4,967
Electricity	$276.50	$645.80	$142.80	3,546
Natural Gas	$311.50	$1,034.30	$179.90	4,607
Water	$26.60	$78.90	$21.00	608
Labor	$46.30	$129.20	$42.50	1,243
Maintenance	$166.70	$528.70	$167.00	5,262
Insurance	$94.10	$270.60	$94.30	3,046
Overhead	$205.10	$688.70	$264.10	8,988
Subtotal	**$4,582.20**	**$12,979.80**	**$3,166.90**	**121,530**
Construction	$700.00	$2,351.00	$712.20	21,826
Total	**$5,282.20**	**$15,330.70**	**$3,879.10**	**143,356**

Source:
John M. Urbanchuk, Director, LECG LLC, 1255 Drummers Lane, Suite 320, Wayne, PA 19087, www.lecg.com

Figure 2.5
Ethanol Net Energy Balances and Greenhouse Gas Emissions

The net energy balance and greenhouse gas emissions associated with ethanol production have been analyzed by multiple groups in the past 5 years. Some analysts have shown negative energy input to output balances while others have shown neutral to positive balances. Greenhouse gas emission estimates have also varied accordingly. Some differences can be explained by use of older versus new data, by inclusion or exclusion of co-products and by use of different system boundaries. Alexander Farrell and others in the Energy and Resources Group at the University of California, Berkeley, recently developed a Biofuel Analysis MetaModel (EBAMM) as a new analyses tool. The group first replicated the results of six published studies with EBAMM then adjusted all six analyses to (a) add coproduct credit where needed, (b) apply a consistent system boundary, (c) account for different energy types, and (d) calculate policy relevant metrics.

The results shown below in figures A & B show the original and adjusted values for the six studies, EBAMM generated values for 3 cases including CO2 intensive ethanol, ethanol today, and cellulosic ethanol, and a gasoline comparison. Adjusting system boundaries reduces scatter in the results. All studies show that ethanol made from conventionally grown corn can have greenhouse gas emissions that are slightly more or less than gasoline per unit of energy but that conventional corn ethanol requires much less petroleum inputs. The model suggests that ethanol produced from cellulosic materials reduces both GHG's and petroleum inputs substantially.



Source:
A.E. Farrell, R.J. Plevin, B.T. Turner, A.D. Jones, M. O'Hare, D.M. kammen, 2006. Ethanol Can Contribute To Energy and Environmental Goals. *Science*, Vol. 311, January 27, 2006.

Additional references:

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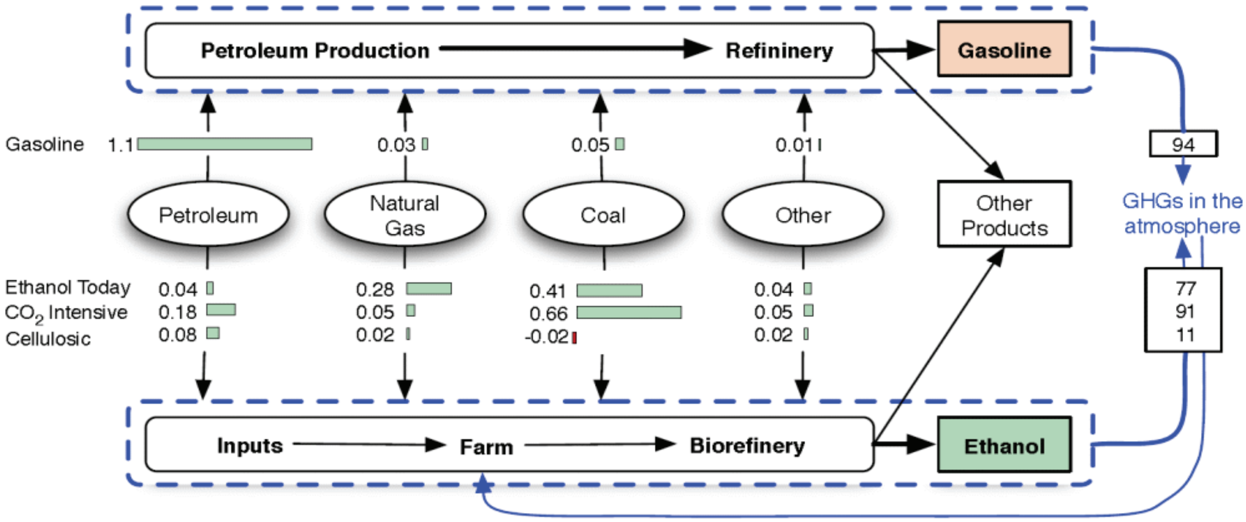
M.E.D. de Olivera, B.E. Vaughn, E.J. Rykiel, Bioscience, 55, 593(2005)
H. Shappouri, A. McAloon, "The 2001 Net Energy Balance of Corn Ethanol," (U.S. Department of Agriculture, Washington, DC, 2004).
M. Graboski, "Fossil Energy Use in the Manufacture of Corn Ethanol," (National Corn Growers Association, Washington, DC, 2002). www.ncga.com/ethanol/main
M. Wang, "Development and Use of GREET 1.6 Fuel-Cycle Model for Transportation Fuels and Vehicle Technologies," (Tech. Rep. ANL/ESD/TM-163, Argonne National laboratory, Argonne, IL, 2001). http://www.transportation.anl.gov/pdfs/TA/153.pdf

Figure 2.6
Comparisons of Energy Inputs and GHG Emissions for Three Ethanol Scenarios and Gasoline



The graphic above was developed by the Energy and Resources group at the University of California, Berkeley using their Biofuel Analysis MetaModel. It is comparing the intensity of primary energy inputs (MJ) per MJ of fuel produced (ethanol or gasoline) and of net greenhouse gas emissions (kg CO2 – equivalent) per MJ. For gasoline both petroleum feedstock and petroleum energy inputs are included. "Other" includes nuclear and hydroelectric generation. The Ethanol Today case includes typical values for the current U.S. corn ethanol industry. The CO2 intensive case assumes the ethanol is produced in a lignite-fired biorefinery located far from where the corn is grown. The Cellulosic case assumes ethanol is produced from switchgrassgrown locally. Cellulosic ethanol is expected to have an extremely low intensity for all fossil fuels and a very slightly negative coal intensity due to electricity sales that would displace coal.

Source:

A.E. Farrell, R.J. Plevin, B.T. Turner, A.D. Jones, M. O'Hare, D.M. Kammen, 2006. Ethanol Can Contribute To Energy and Environmental Goals. *Science*, Vol 311, January 27, 2006, www.science.org

Figure 2.5 includes a data point from M. Wang based on use of the GREET (Greenhouse gases, Regulated Emissions, and Energy Use in Transportation) model. This page provides more information about this public domain model that is available at:
http://www.transportation.anl.gov/software/GREET/index.html

Figure 2.7
Comparative Results between Ethanol and Gasoline Based on an Evaluation by the GREET Model

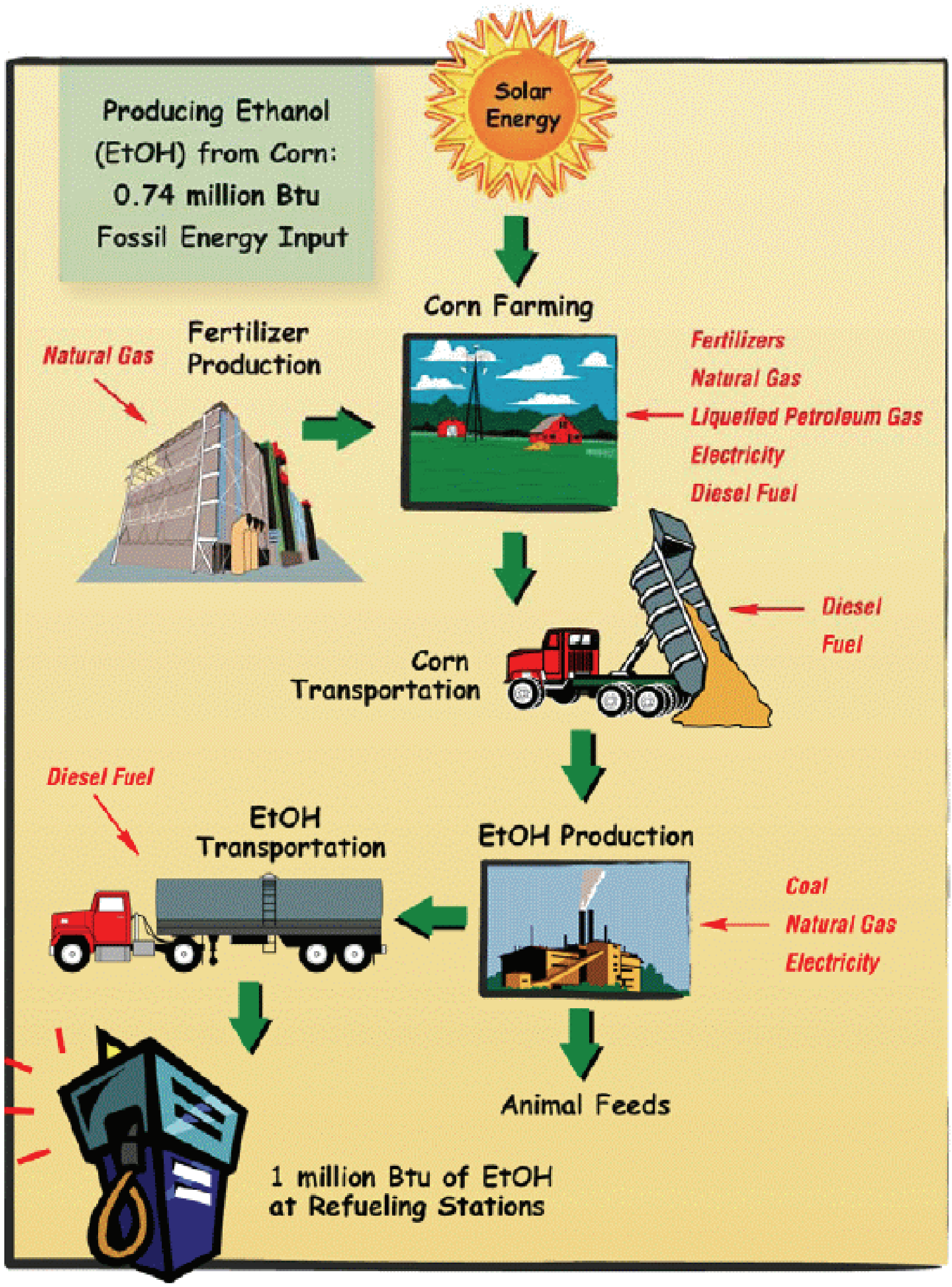
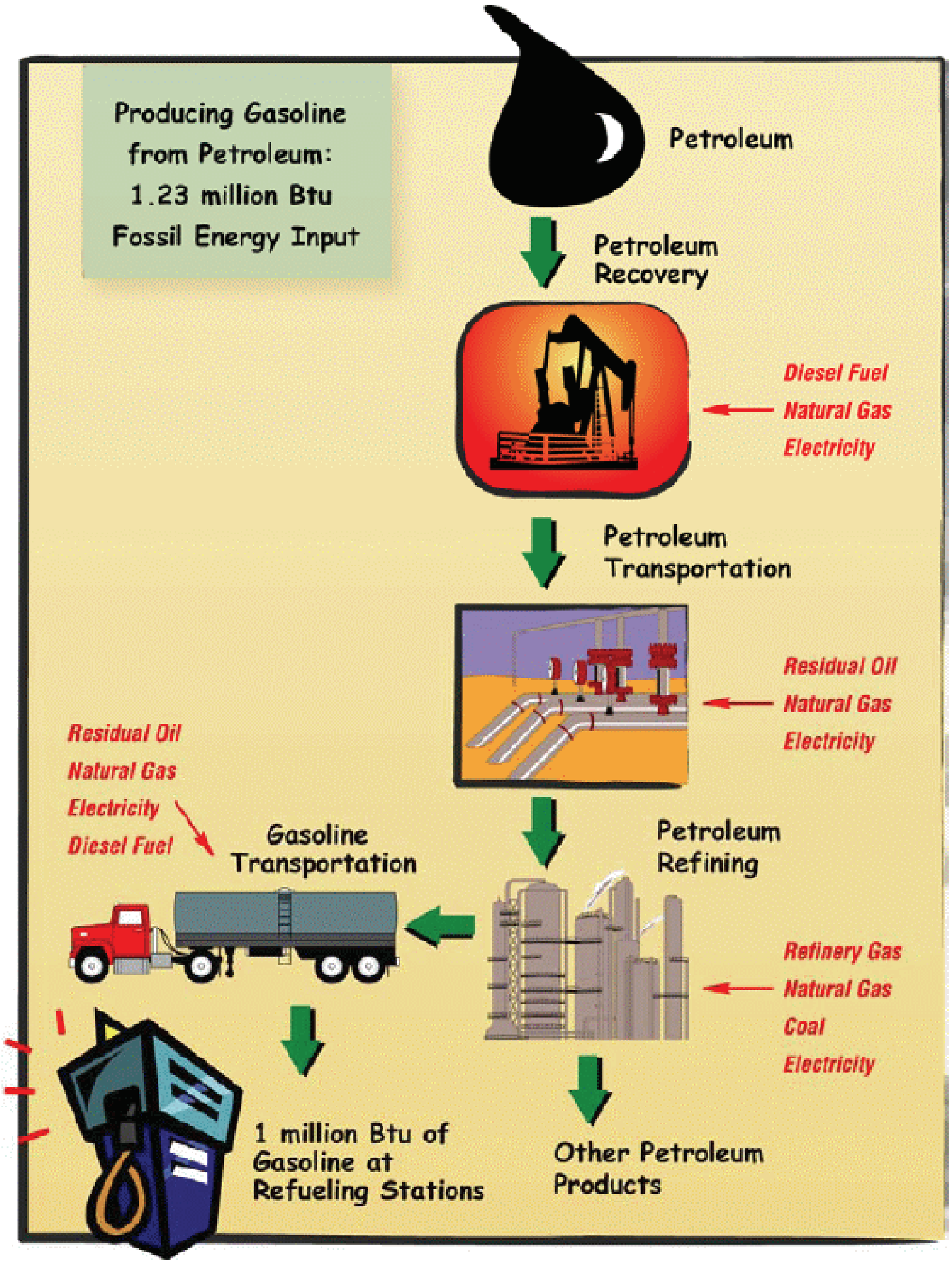


Figure 2.7 (Continued)
Comparative Results between Ethanol and Gasoline Based on an Evaluation by the GREET Model



Sources:

Figures: Michael Wang "The Debate on Energy and Greenhouse Gas Emissions Impacts of Fuel Ethanol", Energy Systems Division Seminar Argonne National Laboratory August 3, 2005. Text: Argonne National Laboratory, Transportation Technology R&D Center, http://www.transportation.anl.gov/software/GREET/index.html.

Figure 2.7 (Continued)
Comparative Results between Ethanol and Gasoline Based on an Evaluation by the GREET Model

The GREET model was developed by Argonne National Laboratory under the sponsorship of the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy in order to fully evaluate energy and emission impacts of advanced vehicle technologies and new transportation fuels. The first version of this public domain model was released in 1996. Since then, Argonne has continued to update and expand the model with GREET 1.7 version now available. The model allows researchers and analysts to evaluate various vehicle and fuel combinations on a full fuel-cycle basis that includes wells to wheels and the vehicle cycle through material recovery and vehicle disposal.

For a given vehicle and fuel system, GREET separately calculates the following:

- Consumption of total energy (energy in non-renewable and renewable sources) and fossil fuels (petroleum, natural gas, and coal).
- Emissions of CO2-equivalent greenhouse gases – primarily carbon dioxide, methane, and nitrous oxide.
- Emissions of five criteria pollutants: volatile organic oxide, particulate matter with size smaller than 10 micron (PM10), and sulfur oxides.

GREET includes more than 30 fuel-cycle pathway groups and the following vehicle technologies:

- Conventional spark-ignition engines
- Direct injection, compression ignition engines
- Grid-connected hybrid electric vehicles
- Grid-independent hybrid electric vehicles
- Battery-powered electric vehicles
- Fuel-cell vehicles

Table 2.15
Comparison of Ethanol Energy Balance with and Without Inclusion of Coproduct Energy Credits

Tables A and B, from a paper by H. Shapouri and A. McAloon, show the effects of partitioning the energy inputs to coproducts as well as to the ethanol produced at wet and dry mills.

Table A summarizes the input energy requirements, by phase of ethanol production on a Btu per gallon basis (LHV) for 2001, without byproduct credits. Energy estimates are provided for both dry- and wet-milling as well as industry average. In each case, corn ethanol has a positive energy balance, even before subtracting the energy allocated to byproducts.

Table B presents the final net energy balance of corn ethanol adjusted for byproducts. The net energy balance estimate for corn ethanol produced from wet-milling is 27,729 Btu per gallon, the net energy balance estimate for dry-milling is 33,196 Btu per gallon, and the weighted average is 30,528 Btu per gallon. The energy ratio is 1.57 and 1.77 for wet- and dry-milling, respectively, and the weighted average energy ratio is 1.67.

Table A
Energy Use and Net Energy Value Per Gallon Without Coproduct Energy Credits, 2001

Production Process	Milling Process Dry	Milling Process Wet	Weighted average
	Btu per gallon		
Corn production	18,875	18,551	18,713
Corn transport	2,138	2,101	2,120
Ethanol conversion	47,116	52,349	49,733
ethanol distribution	1,487	1,487	1,487
Total energy used	69,616	74,488	72,052
Net energy value	6,714	1,842	4,278
Energy ratio	1.10	1.02	1.06

Table B
Energy Use and Net Energy Value Per Gallon with Coproduct Energy Credits, 2001

Production Process	Milling process Dry	Milling process Wet	Weighted average
	Btu per gallon		
Corn production	12,457	12,244	12,350
Corn transport	1,411	1,387	1,399
Ethanol conversion	27,799	33,503	30,586
ethanol distribution	1,467	1,467	1,467
Total energy used	43,134	48,601	45,802
Net energy value	33,196	27,729	30,528
Energy ratio	1.77	1.57	1.67

Source:
H. Shappouri, A. McAloon, "The 2001 Net Energy Balance of Corn Ethanol," (U.S. Department of Agriculture, Washington, DC, 2004).

These states offer extra incentives for ethanol production or consumption (gasohol or E85). Details on these incentives can be found at www.eere.energy.gov/cleancities/vbg/ progs/laws.cgi

Table 2.16
State Ethanol Incentives, 2005

State	Producer incentives	State tax incentives	Other incentives
Illinois			✓
Iowa		✓	
Kansas		✓	
Maine	✓	✓	
Maryland	✓		
Minnesota	✓	✓	
Mississippi	✓		
Missouri	✓		
Nebraska	✓	✓	
New Jersey			✓
New Mexico	✓		
Pennsylvania			✓

Source:
U.S. Department of Energy, Vehicle Buyer's Guide for Consumers, State and Federal Laws and Incentives, www.eere.energy.gov/cleancities/vbg/progs/laws.cgi

BIODIESEL

Biodiesel Overview

Biodiesel is a clean burning alternative fuel produced from domestic, renewable resources. The fuel is a mixture of fatty acid alkyl esters made from vegetable oils, animal fats or recycled greases. Where available, biodiesel can be used in compression-ignition (diesel) engines in its pure form with little or no modifications. Biodiesel is simple to use, biodegradable, nontoxic, and essentially free of sulfur and aromatics. It is usually used as a petroleum diesel additive to reduce levels of particulates, carbon monoxide, hydrocarbons and air toxics from diesel-powered vehicles. When used as an additive, the resulting diesel fuel may be called B5, B10 or B20, representing the percentage of the biodiesel that is blended with petroleum diesel.

In the United States, most biodiesel is made from soybean oil or recycled cooking oils. Animal fats, other vegetable oils, and other recycled oils can also be used to produce biodiesel, depending on their costs and availability. In the future, blends of all kinds of fats and oils may be used to produce biodiesel. Biodiesel is made through a chemical process called transesterification whereby the glycerin is separated from the fat or vegetable oil. The process leaves behind two products -- methyl esters (the chemical name for biodiesel) and glycerin (a valuable byproduct usually sold to be used in soaps and other products).

Fuel-grade biodiesel must be produced to strict industry specifications (ASTM D6751) in order to insure proper performance. Biodiesel is the only alternative fuel to have fully completed the health effects testing requirements of the 1990 Clean Air Act Amendments. Biodiesel that meets ASTM D6751 and is legally registered with the Environmental Protection Agency is a legal motor fuel for sale and distribution. Raw vegetable oil cannot meet biodiesel fuel specifications; therefore, it is not registered with the EPA and it is not a legal motor fuel.

Source:
U.S. Department of Energy, Energy Efficiency and Renewable Energy, http://www.eere.energy.gov/RE/bio_fuels.html and the National Biodiesel Board, http://www.biodiesel.org/resources/biodiesel_basics/default.shtm

During 2002, Europe, in general, and particularly the EU countries of Germany, France and Italy, were the dominant producers of biodiesel worldwide.

Table 2.17
World Biodiesel Capacity, 2002
(million gallons)

Country	Capacity[a]	Typical use
United States	18.49	blends <25%
IEA North America	**18.49**	
Austria	8.45	blends <25%
Belgium	9.51	
Denmark	0.79	
France	101.97	mainly 5%
Germany	165.11	100% biodiesel; some blends
Italy	63.14	blends <25%
Spain	2.38	
Sweeden	4.49	blends <25%
UK	1.59	
EU	**357.42**	
Poland	21.13	
IEA Europe	**378.56**	
World	**397.05**	

Source:
International Energy Agency "Biofuels For Transport: An International Perspective," page 30, Table 1.1, May 2004.

Note: Production of biodiesel in 2003 is roughly 65% of capacity. Some minor production (e.g. India, Africa) not reported.

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[a] Feedstock in the United States is soy; in Europe, rapeseed and sunflower.

The geographic distribution of biodiesel production facilities is wide ranging, covering all regions of the United States.

Table 2.18
Active Biodiesel Production Facilities, 2005

Company	City	State
Bean Commercial Grease	Belgrade	ME
Soymor	Glenville	MN
Channel Chemical Corporation	Gulfport	MS
SeQuential Biofuels	Salem	OR
American Bio-Fuels LLC	Bakersfield	CA
Bio-Energy Systems, LLC	Vallejo	CA
Imperial Western Products	Coachella	CA
Procter and Gamble	Sacramento	CA
Bio Energy of Colorado	Denver	CO
Rocky Mountain Biodiesel Industries	Berthoud	CO
Purada Processing, LLC	Lakeland	FL
Peach State Labs	Rome	GA
US Biofuels Inc.	Rome	GA
Pacific Biodiesel	Kahului	HI
Pacific Biodiesel	Honolulu	HI
Ag Processing, Inc	Sergeant Bluff	IA
Mid-States Biodiesel	Nevada	IA
Soy Solutions	Milford	IA
West Central	Ralston	IA
Stepan Company	Millsdale	IL
Griffin Industries	Butler	KY
FUMPA BioFuels	Redwood Falls	MN
Minnesota Soybean Processors	Brewster	MN
Missouri Better Bean	Bunceton	MO
Biodiesel of Mississippi, Inc.	Nettleton	MS
Earth Biofuels	Meridan	MS
Earthship Biodiesel, LLC	Taos	NM
Biodiesel Industries	Las Vegas	NV
Biodiesel of Las Vegas	Las Vegas	NV
Environmental Alternatives	Brooklyn	NY
American Ag Fuels, LLC	Defiance	OH
Peter Cremer (TRI-NI)	Cincinnati	OH
Green Country Biodiesel, Inc	Claremore	OK
Blue Sky Biodiesel	Wartburg	TN
Biodiesel Industries of Greater Dallas-Fort Worth	Denton	TX
Corsicana Technologies, Inc.	Corsicana	TX
Huish Detergents	Pasadena	TX
Johann Haltermann, LTD	Houston	TX
SMS Envirofuels	Poteet	TX
South Texas Blending	Laredo	TX
Sun Cotton Biofuels	Roaring Springs	TX
Texoga Technologies	Oak Ridge	TX
Virginia Biodiesel Refinery	New Kent	VA
Seattle Biodiesel, LLC	Seattle	WA
Renewable Alternatives	Howard	WI

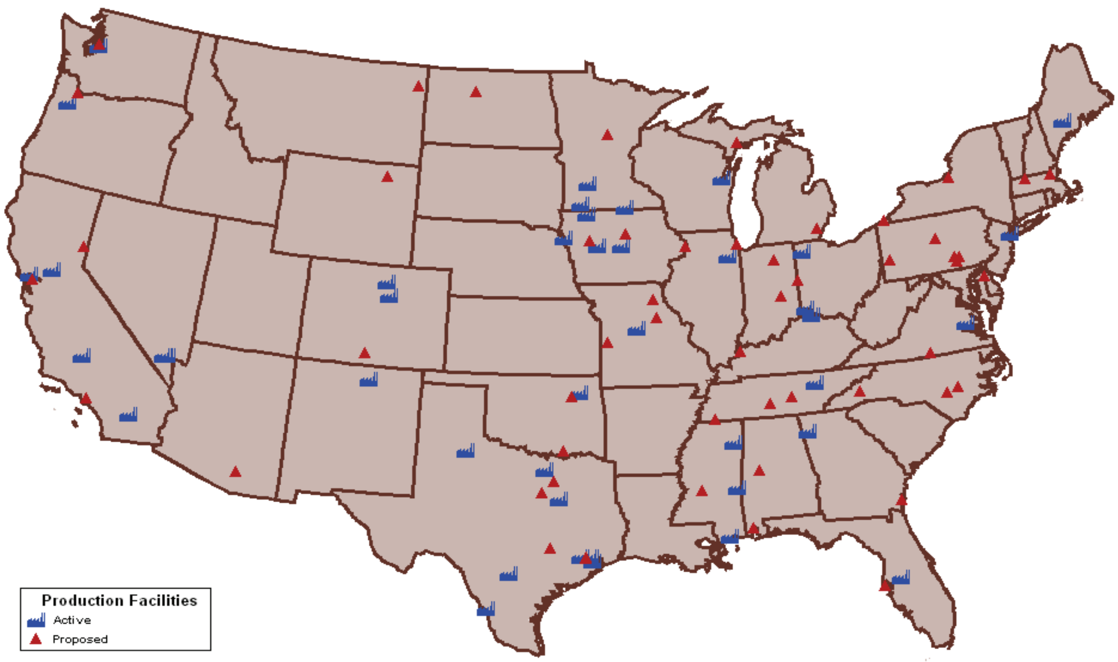
Source:
National Biodiesel Board, http://www.biodiesel.org/resources/fuelfactsheets/default.shtm, Under Production, "Existing Plants - Production Map & Table."

Table 2.19
Proposed Biodiesel Production Facilities, 2005

Company	City	State
Alabama Biodiesel Corporation	Moundville	AL
EarthFirst Americas	Mobile	AL
Grecycle Arizona, LLC	Tucson	AZ
Baker Commodities	Las Angeles	CA
Bay Biodiesel, LLC	Martinez	CA
Simple Fuels, LLC	Vinton	CA
Blue Sun Biodiesel	Alamosa	CO
Mid-Atlantic Biodiesel	Clayton	DE
Renewable Energy System	Pinellas Park	FL
Biomass Energy Services	Brunswick	GA
Baker Commodities	Honolulu	HI
Cargill	Iowa Falls	IA
Clinton County BioEnergy	Clinton	IA
Western Iowa Energy	Wall Lake	IA
Chicago Biodiesel	Chicago	IL
Integrity Biofuels	Morristown	IN
Louis Dreyfus	Claypool	IN
Union County Biodiesel Company, LLC	Morganfield	KY
Baker Commodities	Billerica	MA
Northeast Biodiesel Co.	Greenfield	MA
Ag Solutions	Gladstone	MI
Michigan Biofuels, LLC	Belleville	MI
Green Range Renewable Energy	Ironton	MN
Mid America Biofuels	Mexico	MO
Missouri Biofuels	Bethel	MO
Prairie Pride	Butler	MO
Earth Biofuels, Inc.	Jackson	MS
Sustainable Systems, LLC	Culbertson	MT
Atlantic Bioenergy, LLC	Mount Olive	NC
Blue Ridge Biofuels	Ashville	NC
Filter Specialty Bioenergy, LLC	Autryville	NC
North Dakota Biodiesel, Inc	Minot	ND
NextGen Fuel, Inc	Fulton	NY
Jatrodiesel Inc.	Dayton	OH
Best Energy Solutions, LLC	Tulsa	OK
Earth Biofuels, Inc.	Durant	OK
SeQuential Biofuels	Portland	OR
Agra Biofuels	Middletown	PA
BioPreserve	Erie	PA
Duff Science Co.	Howard	PA
Keystone BioFuels, Inc.	Shiremanstown	PA
Three Rivers Biofuels	Neville Island	PA
United Biofuels, Inc.	York	PA
Agri-Energy, Inc	Louisburg	TN
AMPM Environmental Services	Moscow	TN
Biodiesel of Mississippi	McMinnville	TN
Central Texas Biofuels	Giddings	TX
New Fuel Company	Dallas	TX
NFE Biofuel & Energy, Inc.	Houston	TX
Organic Fuels, LLC	Houston	TX
Smithfield Biofuels, LLC	Cleburne	TX
Renroh Environmental Company	South Boston	VA
Baker Commodities	Seattle	WA
Energy Fuel Dynamics, LLC	Gillette	WY

Source:
http://www.biodiesel.org/buyingbiodiesel/producers_marketers/ProducersMap-existingandpotential.pdf

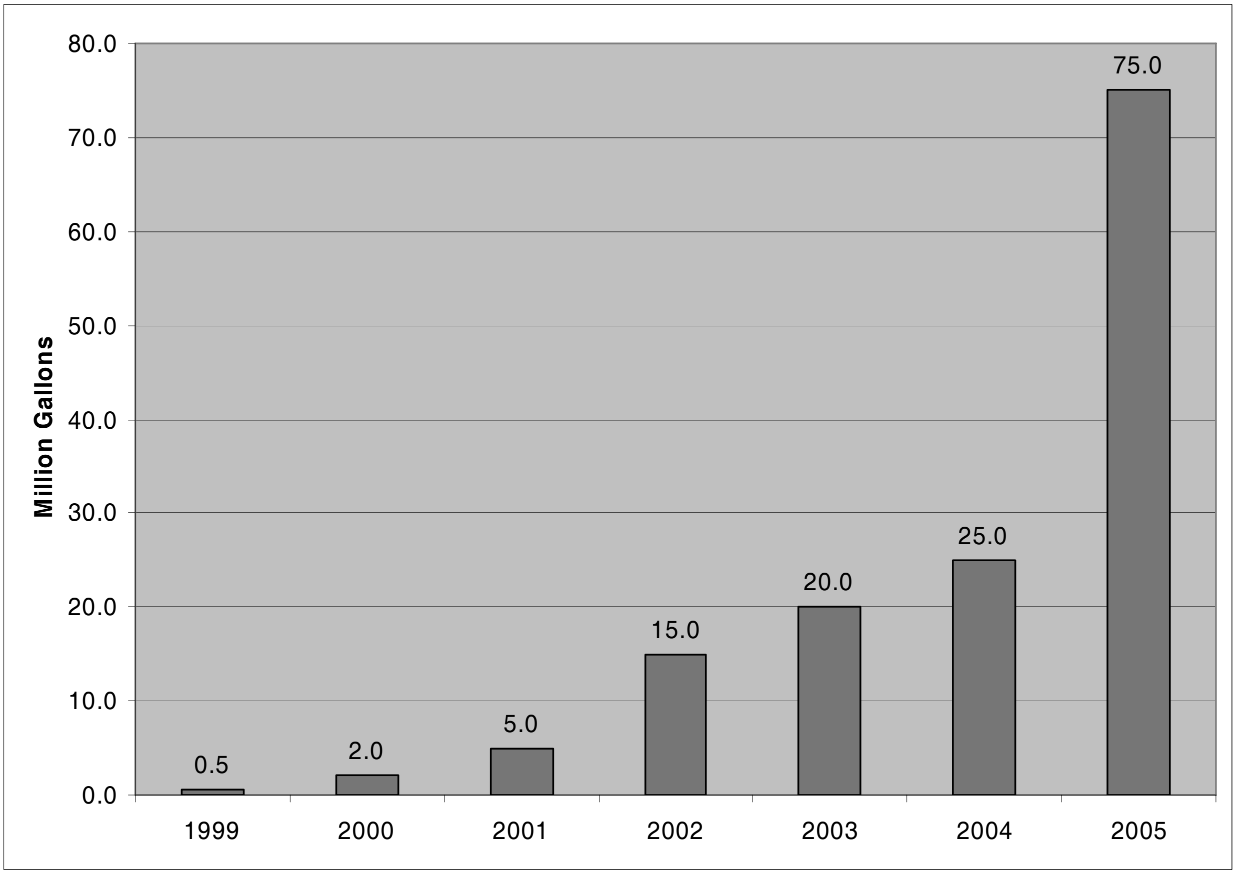
Figure 2.8
Active and Proposed Biodiesel Production Facilities, 2005



Source:
http://www.biodiesel.org/buyingbiodiesel/producers_marketers/ProducersMap-existingandpotential.pdf

Production of biodiesel has grown since 1999, but the most notable growth was in 2005 when production tripled to 75 million gallons.

Figure 2.9
Estimated U.S. Biodiesel Production, 1999-2005



Source:
National Biodiesel Board, Biodiesel Fact Sheets, Production Capacity, http://www.biodiesel.org/resources/fuelfactsheets/default.shtm

It is extremely important to realize that vegetable oils are mixtures of tryglycerides from various fatty acids. The composition of vegetable oils varies with the plant source. The table below indicates the percentages of each type of fatty acid that is in common vegetable oils or animal fats. The two numbers at the top of each column represents the number of carbon atoms and double bonds (e.g. 16:0 refers to the 16 carbon atoms and 0 double bonds found in the long chain of Palmitic acid). See text on Typical Proportions of Chemicals Used to Make Biodiesel (Figure 2.10) for a description of several types of tryglycerides that are found in vegetable oils.

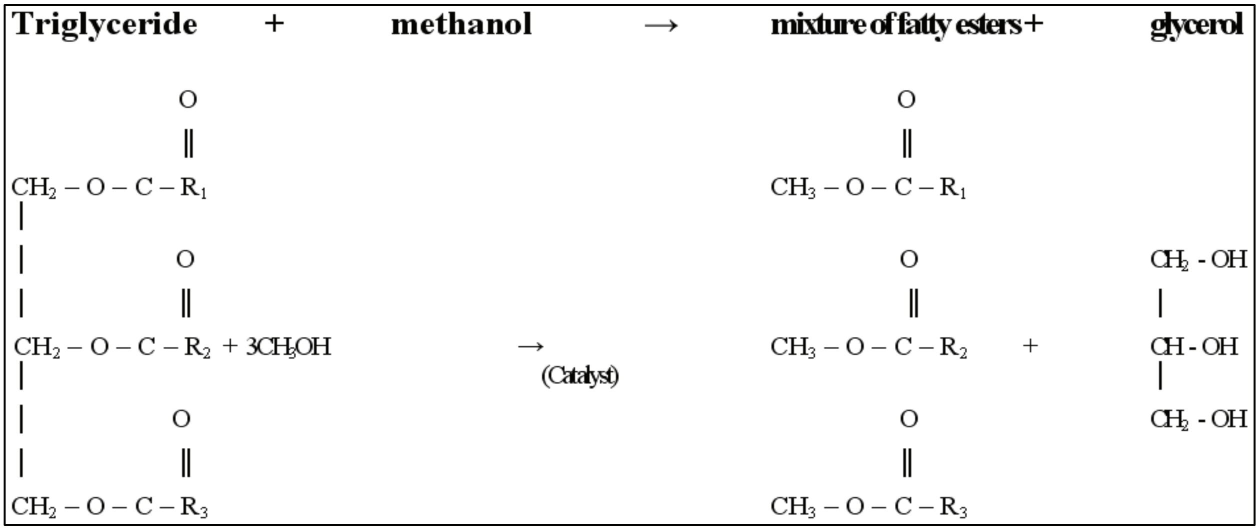
Table 2.20
Composition of Various Oils and Fats Used for Biodiesel
(Percentage of each type of fatty acid common to each type of feedstock)

Oil or fat	14:00	16:00	18:00	18:01	18:02	18:03	20:00	22:01
Soybean		6-10	2-5	20-30	50-60	5-11		
Corn	1-2	8-12	2-5	19-49	34-52	trace		
Peanut		8-9	2-3	50-60	20-30			
Olive		9-10	2-3	73-84	10-12	trace		
Cottonseed	0-2	20-25	1-2	23-35	40-50	trace		
Hi Linoleic Safflower		5.9	1.5	8.8	83.8			
Hi Oleic Safflower		4.8	1.4	74.1	19.7			
Hi Oleic Rapeseed		4.3	1.3	59.9	21.1	13.2		
Hi Erucic Rapeseed		3.0	0.8	13.1	14.1	9.7	7.4	50.7
Butter	7-10	24-26	10-13	28-31	1-2.5	.2-.5		
Lard	1-2	28-30	12-18	40-50	7-13	0-1		
Tallow	3-6	24-32	20-25	37-43	2-3			
Linseed Oil		4-7	2-4	25-40	35-40	25-60		
Yellow grease (typical)	2.43	23.24	12.96	44.32	6.97	0.67		
		16:1=3.						

Source:
Adapted from: J. Van Gerpen, B. Shanks, and R. Pruszko, D. Clements, and G. Knothe, 2004, "Biodiesel Production Technology," National Renewable Energy Laboratory subcontractor report NREL/SR-510-36244, chapter 1, page 1. Please see this document for a full discussion. Available on-line in DOE's biomass document database. Search by author or title. http://www1.eere.energy.gov/biomass/document_database.html.

Figure 2.10
Typical Proportions of Chemicals Used to Make Biodiesel

The most cursory look at the literature relating to biodiesel reveals the following relationship for production of biodiesel from fats and oils: 100 lbs of oil + 10 lbs of methanol → 100 lbs of biodiesel + 10 lbs of glycerol - This equation is a simplified form of the following transesterfication reaction:



R1, R2, and R3 in the above equation are long chains of carbons and hydrogen atoms, sometimes called fatty acid chains. There are five types of chains that are common in soybean oil and animal fats shown below (others are present in small amounts).

Palmitic:	R = $-(CH_2)_{14}-CH_3$	16 carbons, 0 double bonds (16:0)
Stearic:	R = $-(CH_2)_{16}-CH_3$	18 carbons, 0 double bonds (18:0)
Oleic:	R = $-(CH_2)_7\ CH{=}CH(CH_2)_7CH_3$	18 carbons, 1 double bonds (18:1)
Linoleic:	R = $-(CH_2)_7\ CH{=}CH{-}CH_2{-}CH{=}CH(CH_2)_4CH_3$	18 carbons, 2 double bonds (18:2)
Linolenic:	R = $-(CH_2)_7\ CH{=}CH{-}CH_2{-}CH{=}CH{-}CH_2{-}CH{=}CH{-}CH_2{-}CH_3$	18 carbons, 3 double bonds (18:3)

As indicated, a short-hand designation for these chains is two numbers separated by a colon. The first number designates the number of carbon atoms in the chain and the second number designates the number of double bonds. Note that the number of carbon atoms includes the carbon that is double bonded to the oxygen atom at one end of the fatty acid (called the carboxylic carbon). This is the end that the methanol attaches to when methyl ester is produced.

Source:
Reproduced from: J. Van Gerpen, B. Shanks, and R. Pruszko, D. Clements, and G. Knothe, 2004. Biodiesel Production Technology. National Renewable Energy Laboratory subcontractor report NREL/SR-510-36244; Chapter 1, page 1.

Available on-line in DOE's biomass document database. Search by author or title.
http://www1.eere.energy.gov/biomass/document_database.html

The parameters for B100 fuel are specified through the biodiesel standard, ASTM D 6751. This standard identifies the parameters that pure biodiesel (B100) must meet before being used as a pure fuel or being blended with petrodiesel. The National Biodiesel Board has adopted ASTM biodiesel specifications.

Table 2.21
Specification for Biodiesel (B100)

Property	ASTM Method	Limits	Units
Flash Point	D93	130 min.	Degrees C
Water & Sediment	D2709	0.050 max.	% vol.
Kinematic Viscosity, 40 C	D445	1.9 - 6.0	mm2/sec.
Sulfated Ash	D874	0.020 max.	% mass
Sulfur	D5453	0.05 max.	% mass
Copper Strip Corrosion	D130	No. 3 max.	
Cetane	D613	47 min.	
Cloud Point	D2500	Report	Degrees C
Carbon Residue 100% sample	D4530[a]	0.050 max.	% mass
Acid Number	D664	0.80 max.	mg KOH/gm
Free Glycerin	D6584	0.020 max.	% mass
Total Glycerin	D6584	0.240 max.	% mass
Phosphorus Content	D 4951	0.001 max.	% mass
Distillation Temp, Atmospheric Equivalent Temperature, 90% Recovered	D 1160	360 max.	Degrees C

Source:
National Biodiesel Board, Biodiesel Fact Sheets, Biodiesel Production & Quality Standards.

Notes:
1. To meet special operating conditions, modifications of individual limiting requirements may be agreed upon between purchaser, seller and manufacturer.
2. A considerable amount of experience exists in the US with a 20% blend of biodiesel with 80% diesel fuel (B20). Although biodiesel (B100) can be used, blends of over 20% biodiesel with diesel fuel should be evaluated on a case-by-case basis until further experience is available.

Alternate source providing explanations for the various specifications can be found at:
J. Van Gerpen, B. Shanks, and R. Pruszko, D. Clements, and G. Knothe, 2004. Biodiesel Production Technology. National Renewable Energy Laboratory subcontractor report NREL/SR-510-36244; Chapter 1, page 23. Available on-line in DOE's biomass document database. Search by author or title. http://www1.eere.energy.gov/biomass/document_database.html

[a] The carbon residue shall be run on the 100% sample.

Figure 2.11
Commercial Biodiesel Production Methods

The production processes for biodiesel are well known. There are three basic routes to biodiesel production from oils and fats:

1. Base catalyzed transesterification of the oil.
2. Direct acid catalyzed transesterification of the oil.
3. Conversion of the oil to its fatty acids and then to biodiesel.

Most of the biodiesel produced today uses the base catalyzed reaction for several reasons:

- It is low temperature and pressure.
- It yields high conversion (98%) with minimal side reactions and reaction time.
- It is a direct conversion to biodiesel with no intermediate compounds.
- No exotic materials of construction are needed.

The chemical reaction for base catalyzed biodiesel production is depicted below. One hundred pounds of fat or oil (such as soybean oil) are reacted with 10 pounds of a short chain alcohol in the presence of a catalyst to produce 10 pounds of glycerin and 100 pounds of biodiesel. The short chain alcohol, signified by ROH (usually methanol, but sometimes ethanol) is charged in excess to assist in quick conversion. The catalyst is usually sodium or potassium hydroxide that has already been mixed with the methanol. R', R'', and R''' indicate the fatty acid chains associated with the oil or fat which are largely palmitic, stearic, oleic, and linoleic acids for naturally occurring oils and fats.

CH_2OCOR'''				CH_2OH		R'''COOR
|			Catalyst	|		
CH_2OCOR''	+	3 ROH	------>	CH_2OH	+	R''COOR
|				|		
CH_2OCOR'				CH_2OH		R'COOR
100 pounds Oil or Fat		10 pounds Alcohol (3)		10 pounds Glycerin		100 pounds Biodiesel (3)

Source:
National Biodiesel Board, Fact Sheet "Biodiesel Production and Quality,"
http://www.biodiesel.org/resources/fuelfactsheets/default.shtm

Note: The term glycerin may include glycerol and related co-products of the glycerol production process.

The results of a study conducted by the EPA on the emissions produced by biodiesel show that except for nitrogen oxides (NOx), regulated and non regulated emissions from both B100 (100% biodiesel) and B20 (20% biodiesel) are significantly lower than for conventional petroleum based diesel.

Table 2.22
Average Biodiesel (B100 and B20) Emissions Compared to Conventional Diesel

Emission Type	B100	B20
	Emissions in relation to conventional diesel	
Regulated		
Total Unburned Hydrocarbons	-67%	-20%
Carbon Monoxide	-48%	-12%
Particulate Matter	-47%	-12%
Nox	+10%	+2%
Non-Regulated		
Sulfates	-100%	-20%[a]
PAH (Polycyclic Aromatic Hydrocarbons)[b]	-80%	-13%
nPAH (nitrated PAH's)[b]	-90%	-50%[c]
Ozone potential of speciated HC	-50%	-10%

Source:
National Biodiesel Board, Biodiesel Fact Sheets, Emissions.

Note: Testing was performed by the EPA. The full report titled "A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions" can be found at: www.epa.gov/otaq/models/biodsl.htm
B100 is 100% biodiesel while B20 is a blend of 20% biodiesel and 80% conventional petroleum based diesel.

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[a] Estimated from B100 result.
[b] Average reduction across all compounds measured.
[c] 2-nitroflourine results were within test method variability.

The market effects of increased biodiesel production and use in the United States would likely drive up the price of soybean oil while driving down the price for soybean meal used in livestock feed. The overall net impact on farm incomes is estimated to be an increase of about 0.3%.

Table 2.23
Estimated Impacts from Increased Use of Biodiesel

	Market scenario (percentage change from baseline)		
	Low	**Medium**	**High**
Soybean oil production	0.3	0.8	1.6
Soybean oil price	2.8	7.2	14.1
Soybean meal price	–0.7	–1.7	–3.3
Soybean price	0.4	1	2
Livestock price (“broilers”)	–0.3	–0.7	–1.4
US net farm income	0.1	0.2	0.3

Source:
International Energy Agency "Biofuels for Transport: An International Perspective," Page 96, Table 4.12.

BioOil Overview

A totally different process than that used to produce biodiesel can be used to convert biomass into a type of fuel similar to diesel known as BioOil. The process, called fast or flash pyrolysis, occurs when heating compact solid fuels at temperatures between 350 and 500 degrees Celsius for a very short period of time (less than 2 seconds). While there are several fast pyrolysis technologies under development, there are only two commercial fast pyrolysis technologies as of 2006. The BioOils currently produced are suitable for use in boilers for electricity generation. Additional research and development is needed to produce BioOil of sufficient quality for transportation applications.

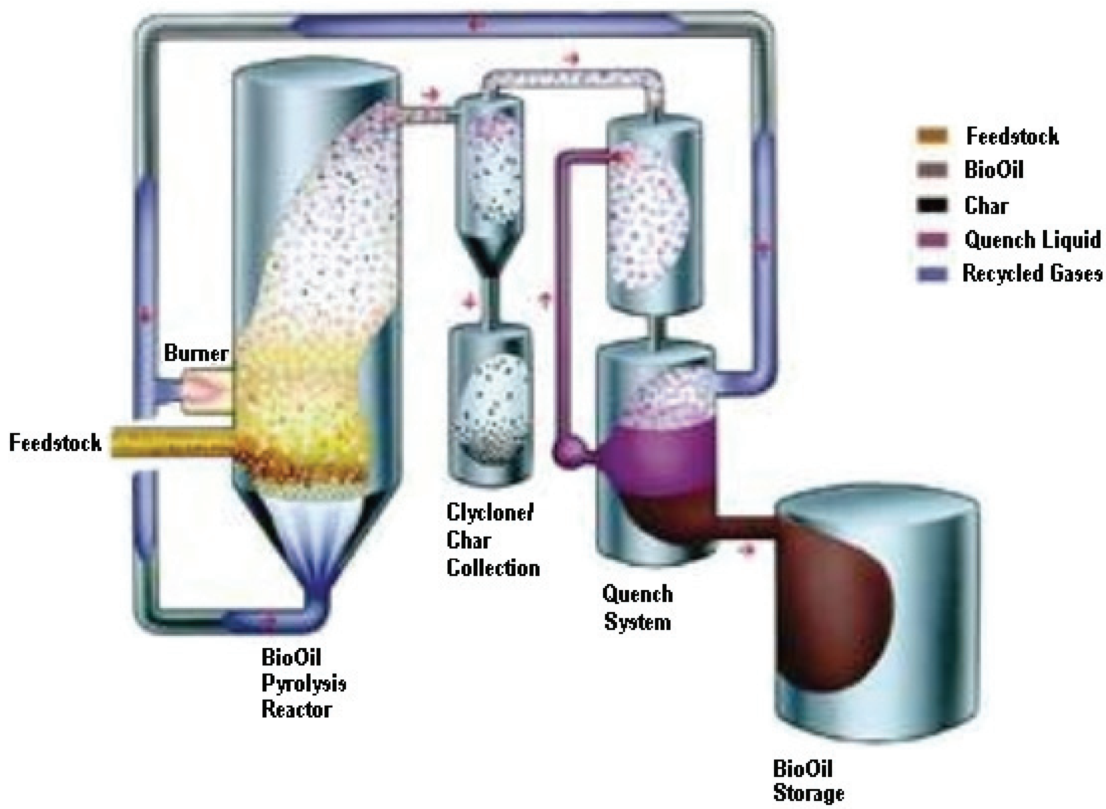
DynaMotive Energy Systems is commercializing a proprietary fast pyrolysis process that converts forest and agricultural residue into liquid BioOil and char. The company launched the first BioOil cogeneration facility in West Lorn, Ontario, in collaboration with Erie Flooring and Wood Products Company. The flooring company provides the wood residue and DynaMotive's 2.5 megawatt plant uses its fast pyrolysis technology and a gas turbine to supply power to the wood product's mills and lumber kilns. DynaMotive is now in the process of building a second 200 ton-per-day plant in Western Canada.

Ensyn Group Inc. has commercialized a fast pyrolysis technology under the name of Rapid Thermal Processing RTP[tm]. This technology is based on the biomass refining concept, where value added chemicals are produced in addition to a consistent quality BioOil. Ensyn has four RTP[tm] facilities in commercial operation; a new facility and a BioOil refining plant are currently under construction. Three of the commercial facilities are in Wisconsin and one is in Ottawa, Canada. The largest of these facilities, built in 1996, processes about 75 green tons per day of mixed hardwood wastes. Ensyn currently produces about 30 chemicals products from RTP[tm] BioOil with lower value remnant BioOil used for energy. Ensyn is just beginning to enter the energy market.

Sources: DynaMotive Energy Systems Corporation, http://www.dynamotive.com/; Ensyn Group Inc. http://www.ensyn.com/

BioOils are being commercially produced in North America by only two companies as of 2006—Ensyn Group, Inc, and DynaMotive Energy Systems. BioOil has many of the advantages of petroleum fuels since it can be stored, pumped and transported. It is currently being combusted directly in boilers, gas turbines, and slow and medium speed diesels for heat and power applications.

Figure 2.12
A Fast Pyrolysis Process for Making BioOil



Source:
http://www.dynamotive.com/biooil/technology.html

Information from DynaMotive's website describes the process as follows. Prepared feedstocks with less than 10% moisture content and a 1-2 mm particle size are fed into the bubbling fluid-bed reactor. The fluidized bed is heated to 450-500 degrees Celsius in the absence of oxygen. The feedstock flashes and vaporizes and the resulting gases pass into a cyclone where solid particles, char, are extracted. The gases enter a quench tower where they are quickly cooled using BioOil already made in the process. The BioOil condenses and falls into the product tank, while the non-condensable gases are returned to the reactor to maintain process heating. The entire reaction from injection to quenching takes only two seconds.

One hundred percent of the feedstock is utilized in the process to produce BioOil and char. The characteristics of the BioOil are described in tables found under BioOil in the Biofuels section of this book and can also be found at the source listed above. The char that is collected is a high Btu value solid fuel that can be used in kilns, boilers and the briquette industry. The non-condensed gases are re-circulated to fuel approximately 75% of the energy needed by the pyrolysis process. The relative yields of BioOil, char, and non-condensable gases vary depending on feedstock composition.

"BioOil is a dark brown, free flowing liquid comprised of highly oxygenated compounds. As a fuel, BioOil is considered to be CO_2 neutral, and emits no SO_x and low NO_x when combusted. BioOil density is high at 1.2 kgs/litre. Heating value on a weight basis is approximately 40 % to that of diesel. On a volume basis the heating value compared to diesel is approximately 55%." –DynaMotive.

Table 2.24
BioOil Characteristics

BioOil Characteristics	Feedstock: Pine 53% Spruce 47% (including bark)	Feedstock: Bagasse
pH	2.4	2.6
Water Content wt%	23.4	20.8
Methanol Insolvable Solids (Lignin content wt%)	24.9	23.5
Solids Content wt%	<0.10	<0.10
Ash Content wt%	<0.02	<0.02
Density kg/L	1.19	1.2
Low Heating Mj/kg	16.4	15.4
Kinematic Viscosity cSt @ 20^{o}C	40	50
Kinematic Viscosity cSt @ 80^{o}C	6	7

Source:
DynaMotive, http://www.dynamotive.com/biooil/whatisbiooil.html

Note: wt% =percent by weight.
The exact composition of BioOil may vary depending on feedstock and processing. The table above is based on the fast pyrolysis method using the specific feedstock listed in the table. Other companies also produce BioOil though conversion processes and feedstocks can vary widely.

"BioOil is miscible with alcohols such as ethanol and methanol but is immiscible with hydrocarbons. The following table lists the chemical composition of major BioOil constituents." –DynaMotive.

Table 2.25
BioOil Composition

Concentrations wt%	**Feedstock:** Pine 53% Spruce 47% (including bark)	**Bagasse**
Water	23.4	20.8
Methanol Insolvable Solids & Lignin	24.9	23.5
Cellubiosan	1.9	-
Glyoxal	1.9	2.2
Hydroxyacetaldehyde	10.2	10.2
Levoglucosan	6.3	3
Formaldehyde	3	3.4
Formic Acid	3.7	5.7
Acetic Acid	4.2	6.6
Acetol	4.8	5.8

Source:
DynaMotive, http://www.dynamotive.com/biooil/whatisbiooil.html

Note: wt% =percent by weight.
The exact composition of BioOil may vary depending on feedstock and processing. The table above is based on the fast pyrolysis method using the specific feedstock listed in the table. Other companies also produce BioOil though conversion processes and feedstocks can vary widely.

"BioOil fuels have unique characteristics that distinguish them from petroleum-based (hydro carbon) products. The table below illustrates the primary differences between BioOil and other fuels including light and heavy fuel oil." –DynaMotive

Table 2.26
BioOil Fuel Comparisons

	BioTherm BioOil	Light Fuel Oil	Heavy Fuel Oil
Heat of combustion Btu/lb	7,100	18,200	17,600
Heat of combustion MJ/liter	19.5	36.9	39.4
Viscosity (centistokes) 50°C	7	4	50
Viscosity (centistokes) 80°C	4	2	41
Ash % by weight	<0.02	<0.01	0.03
Sulphur % by weight	Trace	0.15 to 0.5	0.5 to 3
Nitrogen % by weight	Trace	0	0.3
Pour Point °C	-33	-15	-18
Turbine NOx g/MJ	<0.7	1.4	N/A
Turbine SOx g/MJ	0	0.28	N/A

Source:
DynaMotive, http://www.dynamotive.com/biooil/whatisbiooil.html

Note: N/A = Not available.
The exact characteristics of BioOil may vary depending on feedstock and processing. The table above is based on the fast pyrolysis method using feedstock composed of 53% pine and 47% spruce including bark. Other companies also produce BioOil though conversion processes and feedstocks can vary widely.

3. BIOPOWER

BIOMASS POWER OVERVIEW

Biomass power technologies convert renewable biomass fuels to heat and electricity using processes similar to that used with fossil fuels. Next to hydropower, more electricity is generated from biomass than any other renewable energy resource in the United States. A key attribute of biomass is its availability upon demand - the energy is stored within the biomass until it is needed. Other forms of renewable energy are dependent on variable environmental conditions such as wind speed or sunlight intensity.

Today in parts of the developing world (and until several decades ago in the United States), biomass is primarily used to provide heat for cooking and comfort. Technologies have now been developed which can generate electricity from the energy in biomass fuels. Biomass technologies are highly scaleable – small enough to be used on a farm or in remote villages, or large enough to provide power for a small city.

There are four primary classes of biopower systems: direct-fired, co-fired, gasification, and modular systems. Most of today's biopower plants are **direct-fired** systems that are similar to most fossil-fuel fired power plants. The biomass fuel is burned in a boiler to produce high-pressure steam. This steam is introduced into a steam turbine, where it flows over a series of aerodynamic turbine blades, causing the turbine to rotate. The turbine is connected to an electric generator, so as the steam flow causes the turbine to rotate, the electric generator turns and electricity is produced. Biomass power boilers are typically in the 20-50 MW range, compared to coal-fired plants in the 100-1500 MW range. The small capacity plants tend to be lower in efficiency because of economic trade-offs; efficiency-enhancing equipment cannot pay for itself in small plants. Although techniques exist to push biomass steam generation efficiency over 40%, actual plant efficiencies are often in the low 20% range.

Co-firing involves substituting biomass for a portion of coal in an existing power plant furnace. It is the most economic near-term option for introducing new biomass power generation. Because much of the existing power plant equipment can be used without major modifications, co-firing is far less expensive than building a new biopower plant. Compared to the coal it replaces, biomass reduces sulphur dioxide (SO2), nitrogen oxides (NOx), and other air emissions. After "tuning" the boiler for peak performance, there is little or no loss in efficiency from adding biomass. This allows the energy in biomass to be converted to electricity with the high efficiency (in the 33-37% range) of a modern coal-fired power plant.

Biomass gasifiers operate by heating biomass in an environment where the solid biomass breaks down to form a flammable gas. The biogas can be cleaned and filtered to remove problem chemical compounds. The gas can be used in more efficient power generation systems called combined-cycles, which combine gas turbines and steam turbines to produce electricity. The efficiency of these systems can reach 60%.

Modular systems employ some of the same technologies mentioned above, but on a smaller scale that is more applicable to villages, farms, and small industry. These systems are now under development and could be most useful in remote areas where biomass is abundant and electricity is scarce. There are many opportunities for these systems in developing countries.

Source:
U.S. Department of Energy, Energy Efficiency and Renewable Energy.

Table 3.1
Biomass Power Technology in Commercial/Demonstration Phase during 2000-2006

Technology Category	Biomass Conversion Technology	Primary Energy Form Produced	Primary Energy Conversion Technology	Final Energy Products
Direct combustion	Stove/Furnace	Heat	Heat exchanger	Hot air, hot water
Direct combustion	Pile burners	Heat, steam	Steam turbine	Electricity
Direct combustion	Stoker grate boilers	Heat, steam	Steam turbine	Electricity
Direct combustion	Suspension boilers: Air spreader stoker or cyclonic	Heat, steam	Steam turbine	Electricity
Direct combustion	Fluidized-bed combustor FB – bubbling CFB-circulating	Heat, steam	Steam turbine	Electricity
Direct combustion	Co-firing in coal-fired boilers (several types)	Heat, steam	Steam turbine	Electricity
Gasification (atmospheric)	updraft, counter current fixed bed	Low Btu producer gas	Combustion boiler + steam generator and turbine	Process heat or heat plus electricity
Gasification (atmospheric)	Downdraft, moving bed	Low Btu producer gas	Spark engine (internal combustion)	Power, electricity
Gasification (atmospheric)	Circulating Fluidized Bed (CFB) dual vessel	medium Btu producer gas	Burn gas in boiler w/ Steam Turbine	Electricity
Gasification (atmospheric)	Co-firing in CFB gasifiers	Low or medium Btu producer gas	Burn gas in boiler w/ Steam Turbine	Electricity
Pyrolysis	Kilns or retorts	Charcoal	Cook stoves and furnaces	Heat
Pyrolysis	Pryolysis units (for slow, fast or flash pyrolysis)	Synthetic fuel oil , gas and charcoal	Diesel engines, bioler/turbine, furnace	Power, electricity, heat
Anerobic digestion	Digesters, landfills	Low to medium Btu producer gas	Furnace, gas engine, gas turbine	Heat, electricity, power

Source:
Compiled by Lynn Wright, Oak Ridge, TN.

Note: See Glossary for definitions of terms found under the "Technology Category" column.
The following references are suggested for further reading:

Overend, Ralph. 2003. Heat, power and combined heat and power. Chapter 3 in: Sims, R. Bioenergy Options for a Cleaner Environment: In Developed and Developing Countries, Elsiver, ISBN: 0-08-044351-6. 193 pages

Broek, R. van den, Faaij, A., and van Wijk, J. 1995, Biomass Combustion Power Generation Technologies, Study performed within the framework of the extended JOULE-IIA programme of CECDGXII, project “Energy from biomass: an assessment of two promising systems for energy production”, Department of Science, Technology and Society, Utrech University, Utrecht (Report no. 95029). Available at website: http://www.chem.uu.nl/nws/www/publica/95029.htm

Table 3.2
Biomass Power Technology Fuel Specifications and Capacity Range

Biomass Conversion Technology	Commonly used fuel types[a]	Particle Size Requirements	Moisture Content Requirements (wet basis)[b]	Average capacity range / link to examples
Stove/Furnace	solid wood, pressed logs, wood chips and pellets	Limited by stove size and opening	10 – 30%	15 kWt to ?
Pile burners	Virtually any kind of wood residues[c] or agricultural residues[d] except wood flour	Limited by grate size and feed opening	< 65%	4 to 110 MWe
Pile burner fed with underfire stoker (biomass fed by auger below bed)	Sawdust, non-stringy bark, shavings, chips, hog fuel	0.25-2 in (6-38 mm)	10-30%	4 to 110 MWe
Stoker grate boilers	Sawdust, non-stringy bark, shavings, end cuts, chips, chip rejects, hog fuel	0.25 – 2 in (6 -50 mm)	10-50% (keep within 10% of design rate)	20 to 300 Mwe many in 20 to 50 MWe range
Suspension boilers Cyclonic	Sawdust. Non-stringy bark, shavings, flour, sander dust	0.25 in (6 mm) max	< 15%	many < 30 MWe
Suspension boilers, Air spreader-stoker	Wood flour, sander dust, and processed sawdust, shavings	0.04 in -0.06 in (1-1.6 mm)	< 20%	1.5 MWe to 30 Mwe
Fluidized-bed combustor (FB- bubbling or CFB- circulating)	Low alkali content fuels, mostly wood residues or peat no flour or stringy materials	< 2 in (<50 mm)	< 60%	Many at 20 to 25 MWe, up to 300 Example 1 Example 2
Co-firing: pulverized coal boiler	Sawdust, non-stringy bark, shavings, flour, sander dust	<0.25 in (<6 mm)	< 25%	Up to 1500 MWe[e] Example
Co-firing: cyclones	Sawdust, non-stringy bark, shavings, flour, sander dust	<0.5 in (<12 mm)	10 – 50%	40 to 1150 MWe[e] Example
Co-firing: stokers, fluidized bed	Sawdust, non-stringy bark, shavings, flour, hog fuel	< 3 in (<72 mm)	10 – 50%	MWe[e] Example
Counter current, fixed bed (updraft) atmospheric	Chipped wood or hog fuel, rice hulls, dried sewage sludge	0.25 – 4 in (6 – 100 mm)	< 20%	5 to 90 MWt, + up to 12 MWe Example
Downdraft, moving bed atmospheric gasifier	Wood chips, pellets, wood scrapes, nut shells	< 2 in (<50 mm)	<15%	~ 25-100 kWe Example
Circulating fluidized bed (CFB), dual vessel, gasifier	Most wood and chipped agricultural residues but no flour or stringy materials	0.25 – 2 in (6 -50 mm)	15-50%	~ 5 to 10 Mwe Example
Fast pryolysis	Variety of wood and agricultural resources	0.04-0.25 in (1-6 mm)	< 10%	~ 2.5 Mwe Example 1 Example 2
Anerobic digesters	Animal manures & bedding, food processing residues, brewery by-products, other industry organic residues	NA	65 to 99.9% liquid depending on type, i.e., 0.1 to 35% solids	145 to 1700 x 103 kwhr/yr Example 1 Example 2

Source:
Compiled by Lynn Wright, Oak Ridge, TN.

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[a] Primary source for fuel types is: Badger, Phillip C. 2002. *Processing Cost Analysis for Biomass Feedstocks*. ORNL/TM-2002/199. Available at http://bioenergy.ornl.gov/main.aspx (search by title or author).

[b] Most primary biomass, as harvested, has a moisture content (MC) of 50 to 60% (by wet weight) while secondary or tertiary sources of biomass may be delivered at between 10 and 30%. A lower MC always improves efficiency and some technologies require low MC biomass to operate properly while others can handle a range of MC.

[c] Wood residues may include forest logging residues and storm damaged trees (hog fuel), primary mill residues (e.g. chipped bark and chip rejects), secondary mill residues (e.g. dry sawdust), urban wood residues such as construction and demolition debris, pallets and packaging materials, tree trimmings, urban land clearing debris, and other wood residue components of municipal solid waste (as wood chips).

[d] Agricultural residues may include straws and dried grasses, nut hulls, orchard trimmings, fruit pits, etc. Slagging may be more of a problem in some types of combustion units with high alkali straws and grasses, unless the boilers have been specially designed to handle these type fuels.

[e] The biomass component of a co-firing facility will usually be less than the equivalent of 50MWe.

There are three distinct markets for green power in the United States. In regulated markets, a single utility may provide a green power option to its customers through "green pricing," which is an optional service or tariff offered to customers. These utilities include investor-owned utilities, rural electric cooperatives, and other publicly-owned utilities. More than 500 utilities in 34 states offer green pricing or are in the process of preparing programs.

In restructured (or competitive) electricity markets, retail electricity customers can choose from among multiple electricity suppliers, some of which may offer green power. Electricity markets are now open to full competition in a number of states, while others are phasing in competition.

Finally, consumers can purchase green power through "renewable energy certificates." These certificates represent the environmental attributes of renewable energy generation and can be sold to customers in either type of market, whether or not they already have access to a green power product from their existing retail power provider.

Utility market research shows that majorities of customer respondents are likely to state that they would pay at least $5 more per month for renewable energy. And business and other nonresidential customers, including colleges and universities, and government entities, are increasingly interested in green power.

Table 3.3
New Renewable Capacity Supplying Green Power Markets, 2004

Source	MW in Place	%	MW Planned	%
Wind	2045.6	91.6	364.5	80.1
Biomass	**135.6**	**6.1**	**58.8**	**12.9**
Solar	8.1	0.4	0.4	0.1
Geothermal	35.5	1.6	0	0
Small Hydro	8.5	0.4	31.3	6.9
Total	**2233.3**	**100**	**455**	**100**

Source:
National Renewable Energy Laboratory, *Power Technologies Energy Data Book*, Chapter 3, Table 3.6.5. http://www.nrel.gov/analysis/power_databook/chapter3.html

Note: MW = megawatt.

Green pricing is an optional utility service that allows customers an opportunity to support a greater level of utility company investment in renewable energy technologies. Participating customers pay a premium on their electric bill to cover the extra cost of the renewable energy. Many utilities are offering green pricing to build customer loyalty and expand business lines and expertise prior to electric market competition. As of 2003, 36 utilities in 19 states had implemented green pricing options that used or included biomass feedstocks.

Table 3.4
New Renewable Capacity Supported through Utility Green Pricing Programs, 2004

Source	MW in Place	%	MW Planned	%
Wind	584.0	82.8	139.7	61.1
Biomass	76.3	10.8	57.5	25.1
Solar	6.1	0.9	0.2	0.1
Geothermal	30.5	4.3	0.0	0.0
Small Hydro	8.5	1.2	31.3	13.7
Total	**705.5**	**100.0**	**228.7**	**100.0**

Source:
National Renewable Energy Laboratory, *Power Technology Energy Data Book*, Table 3.7.1, http://www.nrel.gov/analysis/power_databook/chapter3.html

Note: MW = megawatt.

There are a growing number of utilities offering green pricing programs that utilize biomass resources.

Table 3.5
Utility Green Pricing Programs Using Biomass and Biomass Based Resources

State	Utility Name	Program Name	Resource Type	Start Date	Premium
Alabama	Alabama Power	Renewable Energy Rate	biomass co-firing	2003 / 2000	6.0¢/ kWh
	TVA	Green Power Switch	wind, landfill gas, solar	2000	2.67¢/ kWh
Arizona	Salt River Project	EarthWise Energy	central PV,landfill gas, small hydro	1998 / 2001	3.0¢/kWh
	Tucson Electric	GreenWatts	landfill gas, PV, wind	2000	7.5-10¢/ kWh
California	Los Angeles Dept. of Water and Power	Green Power for a Green LA	wind, landfill gas	1999	3.0¢/kWh
	Sacramento Municipal Utility District	Greenergy	wind, landfill gas, hydro	1997	1.0¢/kWh
Colorado	Tri-State Generation & Transmission	Renewable Resource Power Service	wind, landfill gas	1999	2.5¢/kWh
Florida	City of Tallahassee / Sterling Planet	Green for You	biomass, solar	2002	1.6¢/kWh
	Florida Power & Light / Green Mountain Energy	Sunshine Energy	biomass, wind, solar	2004	0.975¢/kWh
	Gainesville Regional Utilities	GRUgreen Energy	landfill gas, wind, solar	2003	2.0¢/kWh
	Tampa Electric Company (TECO)	Tampa Electric's Renewable Energy	PV, landfill gas	2000	10.0¢/kWh
Georgia	Georgia Electric Membership Corporation	Green Power EMC	landfill gas	2001	TBD
	Georgia Power	Green Energy	landfill gas, wind, solar	TBD	5.5¢/kWh
	Savannah Electric	Green Energy	landfill gas, wind, solar	TBD	6.0¢/kWh
	TVA	Green Power Switch	wind, landfill gas, solar	2000	2.67¢/ kWh
Iowa	Alliant Energy	Second Nature	wind, landfill gas	2001	2.0¢/kWh
	Farmers Electric Cooperative	Green Power Project	biodiesel, wind	2004	Contribution
	Iowa Association of Municipal Utilities	Green City Energy	wind, biomass, solar	2003	Varies by utility

Continued on next page

Table 3.5 (Continued)
Utility Green Pricing Programs Using Biomass and Biomass Based Resources

State	Utility Name	Program Name	Resource Type	Start Date	Premium
Illinois	City of St. Charles / ComEd and Community Energy, Inc.	TBD	wind, landfill gas	2003	Contribution
Indiana	Hoosier Energy	EnviroWatts	landfill gas	2001	2.0¢/kWh-4.0¢/kWh
	PSI Energy/Cinergy	Green Power Rider	wind, solar, landfill gas, digester gas	2001	Contribution
	Wabash Valley Power Association	EnviroWatts	landfill gas	2000	0.9-1.0¢/kWh
Kentucky	East Kentucky Power Cooperative	EnviroWatts	landfill gas	2002	2.75¢/kWh
	TVA	Green Power Switch	landfill gas, solar, wind	2000	2.67¢/kWh
Michigan	Lansing Board of Water and Light	GreenWise Electric Power	landfill gas, small hydro	2001	3.0¢/kWh
	We Energies	Energy for Tomorrow	wind, landfill gas, hydro	2000	2.04¢/kWh
Minnesota	Alliant Energy	Second Nature	wind, landfill gas	2002	2.0¢/kWh
Mississippi	TVA	Green Power Switch	wind, landfill gas, solar	2000	2.67¢/kWh
North Carolina	Dominion North Carolina Power, Power, Progress Energy/CP&L *Plus* 7 cities and 14 cooperatives	NC GreenPower	biomass, wind, solar	2003	4.0¢/kWh
	TVA	Green Power Switch	landfill gas, solar, wind	2000	2.67¢/kWh
Nebraska	Omaha Public Power District	Green Power Program	landfill gas, wind	2002	3.0¢/kWh
	Tri-State: Chimney Rock Public Power District,	Renewable Resource Power Service	wind, landfill gas	2001	2.5¢/kWh
New Mexico	Tri-State: Kit Carson Electric Cooperative	Renewable Resource Power Service	wind, landfill gas	2001	2.5¢/kWh
Ohio	City of Bowling Green	Bowling Green Power	small hydro, wind, landfill gas	1999	1.35¢/kWh
Oregon	Pacific Northwest Generating Cooperative	Green Power	landfill gas	1998	1.8-2.0¢/kWh
South Carolina	Eight different cooperatives	Green Power Program	landfill gas	2001	3.0¢/kWh

Source:
National Renewable Energy Laboratory, *Power Technologies Energy Data Book*, Table 3.8.2, http://www.nrel.gov/analysis/power_databook/chapter3.html

A growing number of states have companies that offer a range of green power products that allow consumers to purchase electricity generated in part or entirely from biomass resources.

Table 3.6
Competitive Electricity Markets Retail Green Power Product Offerings, October 2005

State	Company	Product Name	Residential Price Premium[a]	Fee	Resource Mix[b]	Certification
Connecticut	Community Energy (CT Clean Energy Options Program)	CT Clean Energy Options 50% or 100% of usage	1.1¢/kWh	—	50% new wind, 50% landfill gas	—
	Levco	100% Renewable Electricity Program	0.0¢/kWh	—	98% waste-to-energy and hydro (Class II), 2% new solar, wind, fuel cells, and landfill gas	—
	Sterling Planet (CT Clean Energy Options Program)	Sterling Select 50% or 100% of usage	1.15¢/kWh	—	33% new wind, 33% existing small low impact hydro, 34% new landfill gas	—
District of Columbia	PEPCO Energy Services[c]	Green Electricity 10%, 51% or 100% of usage	1.35¢/kWh (for 100% usage)	—	landfill gas	—
Maryland	PEPCO Energy Services[d]	Green Electricity 10%, 51% or 100% of usage	2.75¢/kWh (for 100% usage)	—	landfill gas	—
	PEPCO Energy Services[d]	Non-residential product	NA	—	50% to 100% eligible renewables	Green-e
Massachusetts	Cape Light Compact[e]	Cape Light Compact Green 50% or 100%	1.768¢/kWh (for 100% usage)	—	75% small hydro, 24% new wind or landfill gas, 1% new solar	—
	Massachusetts Electric/Nantucket Electric/Mass Energy Consumers Alliance	New England GreenStart 50% or 100% of usage	2.4¢/kWh (for 100% usage)	—	75% small hydro, 19% biomass, 5% wind, 1% solar (≥25% of total is new)	—
	Massachusetts Electric/Nantucket Electric/Sterling Planet	Sterling Premium 50% or 100% of usage	1.35¢/kWh	—	50% small hydro, 30% bioenergy, 15% wind, 5% new solar	Environmental Resources Trust
New Jersey	Green Mountain Energy Company[f]	Enviro Blend	1.0¢/kWh	$3.95/mo.	5% new wind, 0.4% solar, 44.6% captured methane, 50% large hydro	—
	PSE&G/JCP&L/ Sterling Planet	Clean Power Choice Program	1.2¢/kWh	—	33% wind, 33% small hydro, 34% bioenergy	Environmental Resources Trust
New York	Energy Cooperative of New York[g]	Renewable Electricity	0.5¢/kWh to 0.75¢/kWh	—	25% new wind, 75% existing landfill gas	—
	Long Island Power Authority / EnviroGen	Green Power Program	1.0¢/kWh	—	75% landfill gas, 25% small hydro	—
	Long Island Power Authority / Sterling Planet	New York Clean	1.0¢/kWh	—	55% small hydro, 35% bioenergy, 10% wind	—
	Long Island Power Authority / Sterling Planet	Sterling Green	1.5¢/kWh	—	40% wind, 30% small hydro, 30% bioenergy	—
	Niagara Mohawk / EnviroGen	Think Green!	1.0¢/kWh	—	75% landfill gas, 25% hydro	—
	Niagara Mohawk / Sterling Planet	Sterling Green	1.5¢/kWh	—	40% wind, 30% small hydro, 30% bioenergy	Environmental Resources Trust
	Suburban Energy Services /Sterling Planet	Sterling Green Renewable Electricity	1.5¢/kWh	—	40% new wind, 30% small hydro, 30% bioenergy	—
Pennsylvania	Energy Cooperative of Pennsylvania[h]	EcoChoice 100	2.78¢/kWh	—	89% landfill gas, 10% wind, 1% solar	Green-e
	PEPCO Energy Services[h]	Green Electricity 10%, 51% or 100% of usage	3.7¢/kWh (for 100% usage)	—	100% renewable	—
Rhode Island	Narragansett Electric / Sterling Planet	Sterling Supreme 100%	1.98¢/kWh	—	40% small hydro, 25% biomass, 25% new solar, 10% wind	Environmental Resources Trust
TX	Gexa Energy[i]	Gexa Green	-1.1¢/kWh	—	100% renewable	—
VA	PEPCO Energy Services[j]	Green Electricity 10%, 51% or 100% of usage	4.53¢/kWh (for 100% usage)	—	landfill gas	—

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Table 3.6 (Continued)
Competitive Electricity Markets Retail Green Power Product Offerings, October 2005

Source:
National Renewable Energy Laboratory, *Power Technologies Energy Data Book*, Table 3.8.8, http://www.nrel.gov/analysis/power_databook/chapter3.html.

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[a] Prices updated as of July 2005 and may also apply to small commercial customers. Prices may differ for large commercial/industrial customers and may vary by service territory.

[b] New is defined as operating or repowered after January 1, 1999 based on the Green-e TRC certification standards.

[c] Offered in PEPCO service territory. Product prices are for renewal customers based on annual average costs for customers in PEPCO's service territory (6.8¢/kWh).

[d] Product offered in Baltimore Gas and Electric and PEPCO service territories. Price is for PEPCO service territory based on price to compare of 6.55¢/kWh.

[e] Price premium is based on a comparison to the Cape Light Compact's standard electricity product.

[f] Green Mountain Energy offers products in Conectiv, JCPL, and PSE&G service territories. Product prices are for PSE&G (price to compare of 6.503¢/kWh).

[g] Price premium is for Niagara Mohawk service territory. Program only available in Niagara Mohawk service territory. Premium varies depending on energy taxes and usage.

[h] Product prices are for PECO service territory (price to compare of 6.21¢/kWh).

[i] Product prices are based on price to beat of 12.1¢/kWh for TXU service territory (specifically Dallas, Texas) (Except where noted). Except for Gexa Green, which is listed in price per kWh, prices based on 1000 kWh of usage monthly, and include monthly fees.

[j] Products are available in Dominion Virginia Power service territory.

Renewable energy certificates (RECs)—also known as green tags, renewable energy credits, or tradable renewable certificates—represent the environmental attributes of power generated from renewable electric plants. A number of organizations offer green energy certificates separate from electricity service (i.e., customers do not need to switch from their current electricity supplier to purchase these certificates). Organizations that offer green certificate products using biomass resources are listed below.

Table 3.7
Renewable Energy Certificate Product Offerings, October 2005

Certificate Marketer	Product Name	Renewable Resources	Location of Renewable Resources	Residential Price Premium	Certification
Blue Sky Energy Corp	Greener Choice™ Green Tags	Landfill Gas	Utah	1.95¢/kWh	—
Bonneville Environmental Foundation	Green Tags	≥98% new wind, ≤ 1% new solar, ≤ 1% new biomass	Washington, Oregon, Wyoming, Montana, Alberta	2.0¢/kWh	Green-e
Clean Energy Partnership/Sterling Planet	National New Clean Energy MIx	24% wind, 25% biomass, 50% landfill gas, 1% solar	National	0.6¢/kWh	Environmental Resources Trust
Maine Interfaith Power & Light/BEF	Green Tags (supplied by BEF)	≥98% new wind, ≤ 1% new solar, ≤ 1% new biomass	Washington, Oregon, Wyoming, Montana, Alberta	2.0¢/kWh	—
NativeEnergy	CoolHome	New biogas and new wind	Vermont and Pennsylvania (biomass), South Dakota (wind)	0.8¢/kWh - 1.0¢/kWh	[a]
Sterling Planet	Green America	45% new wind 50% new biomass 5% new solar	Nationwide	1.6¢/kWh	Green-e
TerraPass Inc.	TerraPass	Various (including efficiency and CO2 offsets)	Nationwide	~$11/ton CO2	—

Source:
National Renewable Energy Laboratory, Power Technologies Energy Data Book, Table 3.8.9, http://www.nrel.gov/analysis/power_databook/chapter3.html

Note: — = Information not available.
New is defined as operating or repowered after January 1, 1999, based on the Green-e TRC certification standards. Most product prices are as of July 2005.

[a] The Climate Neutral Network certifies the methodology used to calculate the CO_2 emissions offset.

Table 3.8
Current Biomass Power Plants

Plant Name	Boiler/Generator/ Committed Unit	State Name	County	Capacity MW	Heat Rate	Cogeneration	On-line Year
Florida Coast Paper Co LLC	G	Florida	GULF	0.128873283	8538.991465	Yes	1937
Florida Coast Paper Co LLC	G	Florida	GULF	0.128873283	8538.991465	Yes	1937
Florida Coast Paper Co LLC	G	Florida	GULF	0.128873283	8538.991465	Yes	1947
Florida Coast Paper Co LLC	G	Florida	GULF	0.180422596	8538.991465	Yes	1952
Florida Coast Paper Co LLC	G	Florida	GULF	0.214788805	8538.991465	Yes	1952
Great Northern Paper	G	Maine	PENOBSCOT	0.044617579	8538.991465	Yes	1954
Great Northern Paper	G	Maine	PENOBSCOT	0.044617579	8538.991465	Yes	1956
Fort Bragg Western Wood Products	G	California	MENDOCINO	1.448629561	8538.991465	Yes	1961
Stone Container Corporation Florence	G	South Carolina	FLORENCE	3.280605752	8538.991465	Yes	1963
Fort Bragg Western Wood Products	G	California	MENDOCINO	1.448629561	8538.991465	Yes	1969
Florida Coast Paper Co LLC	G	Florida	GULF	0.365140968	8538.991465	Yes	1974
Stone Container Corporation Florence	G	South Carolina	FLORENCE	4.199175363	8538.991465	Yes	1974
Somerset Plant	G	Maine	SOMERSET	0.673694411	8538.991465	Yes	1976
Fort Bragg Western Wood Products	G	California	MENDOCINO	1.448629561	8538.991465	Yes	1977
Vaagen Brothers Lumber Incorporated	G	Washington	STEVENS	4.00	8538.991465	Yes	1979
Forster Inc Strong Plant	G	Maine	FRANKLIN	0.12519927	8538.991465	Yes	1980
Stone Container Corporation Hopewell	G	Virginia	PRINCE	4.760897033	8538.991465	Yes	1980
Diamond Walnut	G	California	SAN JOAQUIN	3.901181102	15339	Yes	1981
Wheelabrator Hudson Energy Co	G	California	SHASTA	5.841304881	12368.66667	No	1982
Rayonier Inland Wood Products	G	Idaho	BENEWAH	6.25	8538.991465	Yes	1982
Tamarack Energy Partnership	G	Idaho	ADAMS	5.201707828	25416.43077	Yes	1983
Snider Industries Incorporated	G	Texas	HARRISON	1.542490288	12368.66667	Yes	1983
Agrilectric Power Partners Limited	G	Louisiana	CALCASIEU	9.213845328	9224	No	1984
Bio Energy Corporation	G	New Hampshire	MERRIMACK	11.42246966	8538.991465	Yes	1984
Susanville Facility	G	California	LASSEN	1.002430238	9224	No	1985
Collins Pine Company Project	G	California	PLUMAS	4.169269438	8538.991465	Yes	1985
Wheelabrator Martell Inc	G	California	AMADOR	6.487078891	8538.991465	Yes	1985
Susanville Facility	G	California	LASSEN	7.503397937	9224	No	1985
Pacific Oroville Power Inc	G	California	BUTTE	8.53833579	9224	No	1985
Pacific Oroville Power Inc	G	California	BUTTE	8.53833579	9224	No	1985
Mt Lassen Power	G	California	SHASTA	10.33804027	9224	No	1985
Burney Mountain Power	G	California	SHASTA	10.57367613	9224	No	1985
Ultrapower Chinese Station	G	California	TUOLUMNE	21.38108255	9224	No	1985
Biomass One L P	G	Oregon	JACKSON	0.882171777	8538.991465	Yes	1985
Biomass One L P	G	Oregon	JACKSON	13.23257666	8538.991465	Yes	1985
Crestwood Corporation Dothan	G	Alabama	HOUSTON	3.733695627	8538.991465	Yes	1986
Lincoln Facility	G	California	PLACER	2.13531303	9224	No	1986
Quincy Facility	G	California	PLUMAS	10.50316385	9224	No	1986
Burney Facility	G	California	SHASTA	11.96450375	9224	No	1986
Fairhaven Power Co	G	California	HUMBOLDT	15.19195204	9224	No	1986
Timber Energy Resources Incorporated	G	Florida	LIBERTY	13.56859989	9224	No	1986
Sherman Energy Facility	G	Maine	PENOBSCOT	18.45844126	8538.991465	Yes	1986
Pinetree Power Incoporated	G	New Hampshire	GRAFTON	16.35655942	9224	No	1986
Co Gen LLC	G	Oregon	GRANT	6.84375	25416.43077	Yes	1986
Wheelabrator Shasta	G	California	SHASTA	16.35622526	9224	No	1987
Wheelabrator Shasta	G	California	SHASTA	16.35622526	9224	No	1987
Wheelabrator Shasta	G	California	SHASTA	16.35622526	9224	No	1987
Gorbell Thermo Electron Power	G	Maine	SOMERSET	14.0130841	9224	No	1987
Hillman Power Company L L C	G	Michigan	MONTMORENCY	18.10515075	9224	No	1987
Hemphill Power and Light Company	G	New Hampshire	SULLIVAN	14.27220787	9224	No	1987
Bridgewater Power Company LP	G	New Hampshire	GRAFTON	18.05291407	9224	No	1987
Pinetree Power Tamworth Inc	G	New Hampshire	CARROLL	22.69876766	9224	No	1987
Co-Gen II, LLC	G	Oregon	DOUGLAS	6.852791878	25416.43077	Yes	1987
Stone Container Corporation Florence	G	South Carolina	FLORENCE	20.7596732	8538.991465	Yes	1987
The Pacific Lumber Company	G	California	HUMBOLDT	6.001523055	8538.991465	Yes	1988
Greenville Steam Company	G	Maine	PISCATAQUIS	14.59498243	25416.43077	No	1988
Viking Energy of McBain	G	Michigan	MISSAUKEE	16.51695997	9224	No	1988
Whitefield Power and Light Co	G	New Hampshire	COOS	14.51030066	9224	No	1988
Susquehanna Plant	G	Pennsylvania	LYCOMING	10.91578166	7995.373263	Yes	1988
Viking Energy of Northumberland	G	Pennsylvania	NORTHUMBERL	16.94882449	9224	No	1988
The Pacific Lumber Company	G	California	HUMBOLDT	6.001523055	8538.991465	Yes	1989
Loyalton Facility	G	California	SIERRA	15.50036449	8538.991465	Yes	1989
Woodland Biomass Power Limited	G	California	YOLO	24.57285808	9224	No	1989
Mendota Biomass Power Limited	G	California	FRESNO	24.70598521	9224	No	1989
Wadham Energy Limited Partnership	G	California	COLUSA	25.4990433	9224	No	1989
Burney Forest Products	G	California	SHASTA	27.61054735	9082.609668	Yes	1989
HL Power Plant	G	California	LASSEN	31.50214419	9224	No	1989
A R Lavallee Incorporated	G	Maine	YORK	0.447784134	8538.991465	Yes	1989
S D Warren Company 2	G	Maine	CUMBERLAND	4.066280247	8538.991465	Yes	1989
Winslow, Maine	G	Maine	KENNEBEC	10.36716597	8538.991465	Yes	1989
S D Warren Company 2	G	Maine	CUMBERLAND	12.87655412	8538.991465	Yes	1989
Boralex Stratton Energy Inc	G	Maine	FRANKLIN	41.89923255	9224	No	1989
Viking Energy of Lincoln	G	Michigan	ALCONA	16.44424521	9224	No	1989

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Table 3.8 (Continued)
Current Biomass Power Plants

Plant Name	Boiler/Generator/ Committed Unit	State Name	County	Capacity MW	Heat Rate	Cogeneration	On-line Year
Tracy Biomass Plant	G	California	SAN JOAQUIN	20.50248146	9224	No	1990
Delano Energy Company Incorporated	G	California	KERN	27.07152119	9224	No	1990
Great Northern Paper	G	Maine	PENOBSCOT	0.086375057	8538.991465	Yes	1990
Somerset Plant	G	Maine	SOMERSET	0.842118014	8538.991465	Yes	1990
Craven County Wood Energy L P	G	North Carolina	CRAVEN	46.69179392	9224	No	1990
Potlatch Corp Southern Wood Products	G	Arkansas	BRADLEY	7.683280889	8538.991465	Yes	1991
Mecca Plant	G	California	RIVERSIDE	48.30915139	9224	No	1991
Beaver Livermore Falls	G	Maine	ANDROSCOGGI	36.25127717	9224	No	1992
Pinetree Power Fitchburg Inc	G	Massachusetts	WORCESTER	16.07467078	9224	No	1992
Lyonsdale Power Company LLC	G	Michigan	GRATIOT	19.36820024	8538.991465	Yes	1992
Grayling Generating Station	G	Michigan	CRAWFORD	37.99570523	9224	No	1992
Ryegate Power Station	G	Vermont	CALEDONIA	19.50652465	9224	No	1992
Delano Energy Company Incorporated	G	California	KERN	21.48884374	9224	No	1993
Beaver Ashland	G	Maine	AROOSTOOK	36.2184593	9224	No	1993
Cadillac Renewable Energy	G	Michigan	WEXFORD	35.86121164	10013.6	No	1993
KES Chateaugay Power Station	G	New York	FRANKLIN	17.62961823	9224	No	1993
Sauder Power Plant	G	Ohio	FULTON	3.085144462	10891.8	Yes	1993
Sauder Power Plant	G	Ohio	FULTON	3.085144462	10891.8	Yes	1993
Ridge Generating Station	G	Florida	POLK	40.06031261	9224	No	1994
Aroostook Valley	G	Maine	AROOSTOOK	29.50	9224	No	1994
Multitrade of Pittsylvania County L P Pl	G	Virginia	PITTSYLVANIA	41.347412	9224	No	1994
Multitrade of Pittsylvania County L P Pl	G	Virginia	PITTSYLVANIA	41.347412	9224	No	1994
Okeelanta Power Limited Partnership	G	Florida	PALM BEACH	61.33887206	8538.991465	Yes	1995
Cox Waste to Energy	G	Kentucky	TAYLOR	1.075439298	9224	No	1995
Agrilectric Power Partners Limited	G	Louisiana	CALCASIEU	1.139857154	9224	No	1995
Genesee Power Station Limited	G	Michigan	GENESEE	36.03528491	9224	No	1996
Everett Cogen	G	Washington	SNOHOMISH	36.00	8538.991465	Yes	1996
Bioten Operations Inc	G	Tennessee	MACON	0.731874145	10013.6	No	1997
Anderson Facility	G	California	SHASTA	0.679977523	10891.8	No	1998
Washington Veneer	G	Washington	OKANOGAN	0.962570193	8538.991465	Yes	1998
Washington Veneer	G	Washington	OKANOGAN	1.443855289	8538.991465	Yes	1998
Lincoln Facility	G	California	PLACER	0.060566964	8011	Yes	1999
Quincy Facility	G	California	PLUMAS	5.799762734	8011	No	1999
Trigen-Colorado Metro Facility Site	G	Colorado	ADAMS	3.52	29657	Yes	2000
Trigen-Colorado Metro Facility Site	G	Colorado	ADAMS	3.52	29657	Yes	2000
Horry LFG Site	G	South Carolina	HORRY	1.00	29657	No	2001
Horry LFG Site	G	South Carolina	HORRY	1.00	29657	No	2001
Jacobs Energy Corporation	C	Illinois	[a]	4.68	8911	No	2002
St. Paul Cogen, NonMandated	C	Minnesota	[a]	7.60	8911	No	2002
St. Paul Cogen, Mandated	C	Minnesota	[a]	23.75	8911	No	2002
Scott Wood	C	Virginia	[a]	0.90	8911	No	2002
Scott Wood	C	Virginia	[a]	2.80	8911	No	2002
Gorge Energy Div SDS	C	Washington	[a]	5.00	8911	No	2002
Environmental Forest Solutions	C	Arizona	[a]	2.85	8911	No	2003
Jacobs Energy Corporation	C	Illinois	[a]	0.62	8911	No	2003
Ware Biomass Cogen	C	Massachusetts	[a]	7.79	8911	No	2003
Massachusetts RPS 2003 - Biomass	C	Massachusetts	[a]	9.22	8911	No	2003
Aberdeen	C	Washington	[a]	16.00	8911	No	2003

Source:
(National Electric Energy System (NEEDS) Database for IPM 2004, http://www.epa.gov/airmarkets/epa-ipm/#needs.

[a] Data are not available.

Table 3.9
Current Landfill Gas Power Plants

Plant Name	Boiler/Generator/Committed Unit	State Name	County	Capacity MW	Heat Rate	Cogeneration	On-line Year
Puente Hills Energy Recovery	G	California	LOS ANGELES	44.76434101	11000	No	1986
Palos Verdes Gas to Energy Facility	G	California	ORANGE	11.60288061	11000	No	1988
Coyote Canyon Steam Plant	G	California	ORANGE	17.5218204	11000	No	1989
BKK Landfill	G	California	LOS ANGELES	5.984199375	11805	No	1993
O Brien Biogas IV LLC	G	New Jersey	MIDDLESEX	9.986892485	11805	No	1997
North City Cogeneration Facility	G	California	SAN DIEGO	0.933474164	11805	No	1999
North City Cogeneration Facility	G	California	SAN DIEGO	0.933474164	11805	No	1999
North City Cogeneration Facility	G	California	SAN DIEGO	0.933474164	11805	No	1999
North City Cogeneration Facility	G	California	SAN DIEGO	0.933474164	11805	No	1999
Prima Desheha Landfill	G	California	ORANGE	2.65094446	11805	No	1999
Prima Desheha Landfill	G	California	ORANGE	2.65094446	11805	No	1999
Kiefer LF	G	California	SACRAMENTO	2.769899605	11805	No	1999
Kiefer LF	G	California	SACRAMENTO	2.769899605	11805	No	1999
Kiefer LF	G	California	SACRAMENTO	2.769899605	11805	No	1999
BKK Landfill	G	California	LOS ANGELES	4.245327517	11805	No	1999
Tazewell Gas Recovery	G	Illinois	TAZEWELL	0.566133167	11805	No	1999
KMS Joliet Power Partners LP	G	Illinois	WILL	0.754613209	13648	No	1999
Roxana LF	G	Illinois	MADISON	1.000000002	13648	No	1999
Roxana LF	G	Illinois	MADISON	1.000000002	13648	No	1999
Roxana LF	G	Illinois	MADISON	1.000000002	13648	No	1999
Brickyard	G	Illinois	VERMILION	1.000000037	13648	No	1999
Brickyard	G	Illinois	VERMILION	1.000000037	13648	No	1999
Brickyard	G	Illinois	VERMILION	1.000000037	13648	No	1999
Dixon	G	Illinois	LEE	1.000000047	13648	No	1999
Dixon	G	Illinois	LEE	1.000000047	13648	No	1999
Dixon	G	Illinois	LEE	1.000000047	13648	No	1999
Streator	G	Illinois	LA SALLE	1.000000058	13648	No	1999
Streator	G	Illinois	LA SALLE	1.000000058	13648	No	1999
Biodyne Pontiac	G	Illinois	LIVINGSTON	1.54425	11805	No	1999
Deercroft Gas Recovery	G	Indiana	LA PORTE	0.783213037	11805	No	1999
Metro Methane Recovery Facility	G	Iowa	POLK	0.786481001	11805	No	1999
HMDC Kingsland Landfill	G	New Jersey	BERGEN	0.881475967	11805	No	1999
HMDC Kingsland Landfill	G	New Jersey	BERGEN	0.881475967	11805	No	1999
LFG Energy Inc	G	New York	ERIE	0.765217333	11805	No	1999
LFG Energy Inc	G	New York	ERIE	0.765217333	11805	No	1999
LFG Energy Inc	G	New York	ERIE	0.765217333	11805	No	1999
LFG Energy Inc	G	New York	ERIE	0.765217333	11805	No	1999
LFG Energy Inc	G	New York	ERIE	0.765217333	13648	No	1999
High Acres Gas Recovery	G	New York	MONROE	0.778894571	11805	No	1999
Blackburn Co-Generation	G	North Carolina	CATAWBA	0.857569492	11805	No	1999
Blackburn Co-Generation	G	North Carolina	CATAWBA	0.857569492	11805	No	1999
Blackburn Co-Generation	G	North Carolina	CATAWBA	0.857569492	13648	No	1999
Blackburn Co-Generation	G	North Carolina	CATAWBA	0.857569492	13648	No	1999
Charlotte Motor Speedway	G	North Carolina	CABARRUS	4.499151173	11805	No	1999
Cuyahoga Regional Landfill	G	Ohio	CUYAHOGA	1.777833611	11805	No	1999
Cuyahoga Regional Landfill	G	Ohio	CUYAHOGA	1.777833611	11805	No	1999
Roosevelt Biogas 1	G	Washington	KLICKITAT	2.10	11805	No	1999
Roosevelt Biogas 1	G	Washington	KLICKITAT	2.10	11805	No	1999
Roosevelt Biogas 1	G	Washington	KLICKITAT	2.10	11805	No	1999
Roosevelt Biogas 1	G	Washington	KLICKITAT	2.10	11805	No	1999
Tajiguas Landfill	G	California	SANTA BARBARA	2.752165154	11805	No	2000
KMS Joliet Power Partners LP	G	Illinois	WILL	0.759300247	13648	No	2000
Biodyne Pontiac	G	Illinois	LIVINGSTON	0.778130417	11805	No	2000
Upper Rock	G	Illinois	ROCK ISLAND	1.00	13648	No	2000
Upper Rock	G	Illinois	ROCK ISLAND	1.00	13648	No	2000
Upper Rock	G	Illinois	ROCK ISLAND	1.00	13648	No	2000
Roxana LF	G	Illinois	MADISON	1.000000002	13648	No	2000
Fall River Electric	G	Massachusetts	BRISTOL	0.879903479	11805	No	2000
Fall River Electric	G	Massachusetts	BRISTOL	0.879903479	11805	No	2000
Randolph Electric	G	Massachusetts	NORFOLK	0.943396199	11805	No	2000
Randolph Electric	G	Massachusetts	NORFOLK	0.943396199	11805	No	2000
Randolph Electric	G	Massachusetts	NORFOLK	0.943396199	11805	No	2000
Fall River Electric	G	Massachusetts	BRISTOL	4.399517393	11805	No	2000
Grand Blanc Generating Station	G	Michigan	GENESEE	0.767358272	11805	No	2000
M M Nashville	G	Tennessee	DAVIDSON	0.95	11805	No	2000
M M Nashville	G	Tennessee	DAVIDSON	0.95	11805	No	2000
Roosevelt Biogas 1	G	Washington	KLICKITAT	2.10	11805	No	2000
Metro Gas Recovery	G	Wisconsin	MILWAUKEE	0.698586128	13648	No	2000
Metro Gas Recovery	G	Wisconsin	MILWAUKEE	0.698586128	13648	No	2000
Metro Gas Recovery	G	Wisconsin	MILWAUKEE	0.698586128	13648	No	2000
Metro Gas Recovery	G	Wisconsin	MILWAUKEE	0.698586128	13648	No	2000

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Table 3.9 (Continued)
Current Landfill Gas Power Plants

Plant Name	Boiler/Generator/Committed Unit	State Name	County	Capacity MW	Heat Rate	Cogeneration	On-line Year
Pheasant Run Landfill Gas Recovery	G	Wisconsin	KENOSHA	0.75417871	11805	No	2000
Pheasant Run Landfill Gas Recovery	G	Wisconsin	KENOSHA	0.75417871	11805	No	2000
Pheasant Run Landfill Gas Recovery	G	Wisconsin	KENOSHA	0.75417871	13648	No	2000
Pheasant Run Landfill Gas Recovery	G	Wisconsin	KENOSHA	0.75417871	13648	No	2000
Winnebago County Landfill Gas	G	Wisconsin	WINNEBAGO	0.930046772	11805	No	2000
Winnebago County Landfill Gas	G	Wisconsin	WINNEBAGO	0.930046772	11805	No	2000
Winnebago County Landfill Gas	G	Wisconsin	WINNEBAGO	0.930046772	11805	No	2000
Tri - Cities	G	Arizona	MARICOPA	0.80	11805	No	2001
Tri - Cities	G	Arizona	MARICOPA	0.80	11805	No	2001
Tri - Cities	G	Arizona	MARICOPA	0.80	11805	No	2001
Tri - Cities	G	Arizona	MARICOPA	0.80	11805	No	2001
Tri - Cities	G	Arizona	MARICOPA	0.80	11805	No	2001
Badlands	G	California	RIVERSIDE	1.10	11805	No	2001
Biodyne Congress	G	Illinois	COOK	1.794993515	11805	No	2001
Biodyne Congress	G	Illinois	COOK	1.794993515	11805	No	2001
Biodyne Congress	G	Illinois	COOK	1.794993515	11805	No	2001
Biodyne Pontiac	G	Illinois	LIVINGSTON	3.60325	11805	No	2001
Model City Energy	G	New York	NIAGARA	0.686324989	11805	No	2001
Model City Energy	G	New York	NIAGARA	0.686324989	11805	No	2001
Model City Energy	G	New York	NIAGARA	0.686324989	11805	No	2001
Model City Energy	G	New York	NIAGARA	0.686324989	11805	No	2001
Model City Energy	G	New York	NIAGARA	0.686324989	11805	No	2001
Model City Energy	G	New York	NIAGARA	0.686324989	11805	No	2001
Model City Energy	G	New York	NIAGARA	0.686324989	11805	No	2001
Green Knight	G	Pennsylvania	NORTHAMPTON	2.494937456	11805	No	2001
Green Knight	G	Pennsylvania	NORTHAMPTON	2.494937456	11805	No	2001
Green Knight	G	Pennsylvania	NORTHAMPTON	2.494937456	11805	No	2001
Superior Glacier Ridge Landfil	G	Wisconsin	DODGE	0.90	11805	No	2001
Superior Glacier Ridge Landfil	G	Wisconsin	DODGE	0.90	11805	No	2001
Omega Hills Gas Recovery	G	Wisconsin	WASHINGTON	2.50	11805	No	2001
Jamacha LFG	C	California	[a]	0.27	13648	No	2002
Operating Industries LFG	C	California	[a]	0.40	13648	No	2002
Lopez Canyon LFG	C	California	[a]	1.43	13648	No	2002
Central Disposal Sonoma Phase	C	California	[a]	1.52	13648	No	2002
AB1890City/Cty San F	C	California	[a]	1.95	13648	No	2002
Quad Cities	C	Illinois	[a]	0.90	13648	No	2002
Morris	C	Illinois	[a]	1.30	13648	No	2002
Morris	C	Illinois	[a]	1.30	13648	No	2002
Morris	C	Illinois	[a]	1.30	13648	No	2002
Biodyne Pontiac	C	Illinois	[a]	4.20	13648	No	2002
Onyx Zion LFG	C	Illinois	[a]	5.04	13648	No	2002
BioEnergy Com-Ed Biogas	C	Illinois	[a]	5.16	13648	No	2002
South Side LFG	C	Indiana	[a]	4.75	13648	No	2002
Brent Run	C	Michigan	[a]	0.80	13648	No	2002
Elk River	C	Minnesota	[a]	2.28	13648	No	2002
Douglas County LFG	C	Nebraska	[a]	3.04	13648	No	2002
Brookhaven Facility	C	New York	[a]	1.20	13648	No	2002
Brookhaven Facility	C	New York	[a]	1.20	13648	No	2002
Blackburn Co-Generat	C	North Carolina	[a]	0.99	13648	No	2002
Bradford	C	Pennsylvania	[a]	0.76	13648	No	2002
Rolling Hills	C	Pennsylvania	[a]	2.50	13648	No	2002
Rolling Hills	C	Pennsylvania	[a]	2.50	13648	No	2002
Reliant Energy Renew	C	Texas	[a]	1.02	13648	No	2002
Reliant Energy Renew	C	Texas	[a]	1.02	13648	No	2002
Reliant Energy Renew	C	Texas	[a]	1.02	13648	No	2002
Reliant Energy Renew	C	Texas	[a]	1.02	13648	No	2002
Reliant Energy Renew	C	Texas	[a]	1.02	13648	No	2002
Reliant Energy Renew	C	Texas	[a]	1.30	13648	No	2002
Reliant Energy Renew	C	Texas	[a]	1.36	13648	No	2002
Reliant Energy Renew	C	Texas	[a]	1.36	13648	No	2002
Reliant Energy Renew	C	Texas	[a]	1.36	13648	No	2002
Reliant Energy Renew	C	Texas	[a]	1.36	13648	No	2002
Reliant Energy Renew	C	Texas	[a]	1.36	13648	No	2002
Reliant Energy Renew	C	Texas	[a]	1.36	13648	No	2002
Reliant Energy Renew	C	Texas	[a]	1.36	13648	No	2002
Reliant Energy Renew	C	Texas	[a]	1.36	13648	No	2002
Reliant Energy Renew	C	Texas	[a]	1.36	13648	No	2002
Reliant Energy Renew	C	Texas	[a]	1.36	13648	No	2002
Reliant Energy Renew	C	Texas	[a]	1.36	13648	No	2002
Reliant Energy Renew	C	Texas	[a]	1.36	13648	No	2002
Reliant Energy Renew	C	Texas	[a]	1.36	13648	No	2002
Reliant Energy Renew	C	Texas	[a]	1.36	13648	No	2002
Reliant Energy Renew	C	Texas	[a]	1.36	13648	No	2002

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Table 3.9 (Continued)
Current Landfill Gas Power Plants

Plant Name	Boiler/Generator/Committed Unit	State Name	County	Capacity MW	Heat Rate	Cogeneration	On-line Year
Tessman Road Project LFG, Phas	C	Texas	a	4.94	13648	No	2002
Covel Gardens	C	Texas	a	6.65	13648	No	2002
Arlington LF	C	Texas	a	8.55	13648	No	2002
Chesterfield County LFG	C	Virginia	a	0.52	13648	No	2002
Amelia Landfill LFG	C	Virginia	a	3.99	13648	No	2002
Va Beach Mt Trashmore II LFG	C	Virginia	a	11.97	13648	No	2002
Pheasant Run Landfil	C	Wisconsin	a	0.80	13648	No	2002
Pheasant Run Landfil	C	Wisconsin	a	0.80	13648	No	2002
Ridgeview	C	Wisconsin	a	0.80	13648	No	2002
Ridgeview	C	Wisconsin	a	0.80	13648	No	2002
Ridgeview	C	Wisconsin	a	0.80	13648	No	2002
Acme Landfill	C	California	a	0.27	13648	No	2003
AB1890RiversideCty,C	C	California	a	0.90	13648	No	2003
California Street	C	California	a	0.95	13648	No	2003
AB1890Colton (NEO Co	C	California	a	1.14	13648	No	2003
AB1890Milliken(NEO C	C	California	a	2.38	13648	No	2003
AB1890Mid-Valley(NEO	C	California	a	2.38	13648	No	2003
Keller Canyon LFG	C	California	a	2.66	13648	No	2003
AB1890EgyDevelopment	C	California	a	3.71	13648	No	2003
AB1890BFI, Newby Isl	C	California	a	5.23	13648	No	2003
Bradley	C	California	a	6.18	13648	No	2003
SW Alachua	C	Florida	a	2.38	13648	No	2003
Beecher LFG	C	Illinois	a	4.94	13648	No	2003
Bavarian Waste	C	Kentucky	a	4.75	13648	No	2003
Massachusetts RPS 2003 - LFG	C	Massachusetts	a	3.90	13648	No	2003
Plainville LFG	C	Massachusetts	a	5.32	13648	No	2003
Chicopee II LFG	C	Massachusetts	a	5.42	13648	No	2003
Grand Blanc	C	Michigan	a	0.78	13648	No	2003
3 Landfill Gas Projects	C	New York	a	4.94	13648	No	2003
Palmetto	C	South Carolina	a	4.75	13648	No	2003
Reliant Energy Renew	C	Texas	a	0.99	13648	No	2003
Reliant Energy Renew	C	Texas	a	0.99	13648	No	2003
Blue Bonnet LFG	C	Texas	a	2.00	13648	No	2003
Tessman Road LFG - Added Capac	C	Texas	a	2.47	13648	No	2003
Hutchins LFG	C	Texas	a	2.47	13648	No	2003
City of Conroe LFG	C	Texas	a	2.76	13648	No	2003
Sanifill - Baytown	C	Texas	a	3.80	13648	No	2003
Security Recycling LFG	C	Texas	a	5.99	13648	No	2003
Coastal Plains	C	Texas	a	6.37	13648	No	2003
Coastal Plains	C	Texas	a	9.50	13648	No	2003
WMI Atascocit LFG	C	Texas	a	9.98	13648	No	2003
Essex Junction Wastewater Trea	C	VERMONT	a	0.06	13648	No	2003
Janesville Landfill (WI)	C	Wisconsin	a	2.91	13648	No	2003

Source:

National Electric Energy System (NEEDS) Database for IPM 2004, http://www.epa.gov/airmarkets/epa-ipm/#needs.

Table 3.10
Total Net Generation of Electricity by State from Wood and Wood Waste, 2002
(Thousand Kilowatt Hours)

State	Wood/Wood Waste	Percent of all Renewables	Total from all Renewables
Alabama	3,727,493	29.6%	12,575,137
Alaska	1,031	0.1%	1,451,506
Arkansas	1,580,608	31.5%	5,021,095
California	3,957,589	7.2%	54,821,196
Florida	1,552,891	29.1%	5,327,515
Georgia	6,218,978	68.1%	9,130,809
Idaho	508,303	5.5%	9,277,624
Iowa	91	0.0%	1,963,785
Kentucky	365,465	8.3%	4,390,214
Louisiana	2,748,900	73.2%	3,754,232
Maine	3,723,759	51.7%	7,197,599
Maryland	182,904	7.5%	2,437,654
Massachusetts	106,687	3.7%	2,913,724
Michigan	1,474,552	35.4%	4,170,656
Minnesota	377,392	13.1%	2,886,179
Mississippi	936,593	98.7%	948,724
Missouri	143	0.0%	1,423,273
Montana	63,470	0.7%	9,630,379
New Hampshire	699,767	33.9%	2,065,997
New York	412,218	1.5%	27,671,006
North Carolina	1,682,804	31.7%	5,310,327
Ohio	126,067	19.7%	639,640
Oklahoma	239,045	10.7%	2,226,889
Oregon	624,086	1.8%	35,500,087
Pennsylvania	766,289	15.4%	4,968,055
South Carolina	1,228,895	46.7%	2,634,168
Tennessee	750,892	8.6%	8,776,126
Texas	1,073,462	21.0%	5,116,927
Vermont	355,599	24.0%	1,480,893
Virginia	1,407,922	41.6%	3,386,411
Washington	1,126,145	1.4%	79,955,049
West Virginia	51	0.0%	1,097,110
Wisconsin	644,947	17.5%	3,676,150
Total	**38,665,038**	**11.9%**	**323,826,136**

Source:
Energy Information Administration, Renewable *Energy Annual 2004*, Table C6.
http://www.eia.doe.gov/cneaf/solar.renewables/page/rea_data/rea_sum.html.

Note: States not listed contained no data for wood/wood waste.

Table 3.11
Net Generation and Fuel Consumption at Power Plants Consuming Coal and Biomass by State and Plant Name, 2003

State	County	Plant Name	Net Electricity Generation (Thousand Kilowatthours)	Total Energy Consumed (MMBtu)	Energy Consumed from Biomass (MMBtu)	Percent of Energy Consumed from		
						Biomass	Coal	Other
Alabama	Talladega	U S Alliance Coosa Pines	173,254	13,134,273	5,911,501	45.01	54.99	
	Choctaw	Georgia Pacific Naheola Mill	428,406	17,123,967	12,892,753	75.29	14.18	10.53
	Marengo	Gulf States Paper	144,742	10,488,058	8,689,654	82.85	7.30	9.85
	Autauga	International Paper Prattville	496,108	20,716,033	16,225,436	78.32	8.78	12.89
	Mobile	Mobile Energy Services LLC	416,485	6,961,111	3,033,258	43.57	52.68	3.75
	Wilcox	Weyerhaeuser Pine Hill Operati	477,473	6,352,999	3,621,355	57.00	10.01	32.99
Alaska	Fairbanks North Star	Eielson AFB Central Heat & Pow	82,455	2,919,023	26,599	0.91	97.77	1.32
Arizona	Pima	Irvington	1,048,187	11,086,805	154,014	1.39	56.56	42.05
Arkansas	Little River	Ashdown	849,495	41,001,419	36,029,685	87.87	8.03	4.10
California	San Joaquin	Stockton Cogen	452,689	5,741,432	528,273	9.20	54.29	36.50
	Kern	Mt Poso Cogeneration	450,228	5,125,472	12,237	0.24	69.44	30.32
Connecticut	Hartford	Covanta Mid-Connecticut Energy	450,215	8,664,367	8,512,216	98.24	1.76	
Florida	Escambia	Crist	6,413,151	66,408,961	2,080	0.00	99.79	0.21
	Escambia	International Paper Pensacola	463,167	19,758,653	14,615,865	73.97	13.54	12.48
	Duval	Northside Generating Station	4,724,993	48,641,433	76,943	0.16	15.18	84.67
	Nassau	Jefferson Smurfit Fernandina B	593,529	18,167,538	11,360,666	62.53	30.73	6.74
	Polk	C D McIntosh Jr	4,271,266	39,831,464	62,406	0.16	59.17	40.67
	Orange	Stanton Energy Center	6,054,342	59,081,269	1,007,967	1.71	98.14	0.16
	Bay	Stone Container Panama City Mi	236,641	20,068,826	17,409,869	86.75	7.52	5.73
	Duval	Cedar Bay Generating LP	1,833,539	23,812,502	60,039	0.25	99.54	0.21
Georgia	Early	Georgia Pacific Cedar Springs	701,709	37,200,341	28,956,649	77.84	18.10	4.06
	Effingham	Savannah River Mill	616,517	9,999,695	55,381	0.55	9.12	90.33
	Floyd	Inland Paperboard Packaging Ro	437,595	21,075,416	12,717,543	60.34	27.61	12.05
	Chatham	International Paper Savanna Mi	819,569	22,625,484	13,597,613	60.10	30.75	9.15
	Richmond	International Paper Augusta Mi	499,834	23,164,308	15,929,560	68.77	22.49	8.74
	Bibb	Riverwood International Macon	272,388	12,444,817	9,829,168	78.98	9.98	11.04
	Laurens	SP Newsprint	257,674	8,242,895	5,876,174	71.29	19.73	8.98
Hawaii	Oahu	AES Hawaii	1,558,310	15,768,698	197,811	1.25	98.03	0.72
	Maui	Hawaiian Comm and Sugar Puunen	196,437	6,327,592	5,073,883	80.19	18.02	1.80
Illinois	Macon	Archer Daniels Midland Decatur	1,285,911	35,123,776	379,235	1.08	98.92	
	Randolph	Baldwin Energy Complex	13,090,406	133,957,397	1,082,779	0.81	99.10	0.09
Iowa	Story	Ames Electric Services Power P	417,670	5,042,727	351,818	6.98	92.46	0.56
	Linn	Prairie Creek	988,852	10,404,803	126,754	1.22	97.23	1.55
	Linn	Sixth Street	147,644	3,280,837	20,616	0.63	77.34	22.03
	Johnson	University of Iowa Main Power	96,154	3,493,728	303,494	8.69	80.71	10.60
Kentucky	Daviess	Elmer Smith	2,576,356	26,232,220	315,669	1.20	97.60	1.20
Louisiana	De Soto	Mansfield Mill	823,390	25,267,624	20,284,572	80.28	5.28	14.44
	Morehouse	International Paper Louisiana	573,028	20,240,021	17,793,018	87.91	1.44	10.65
Maine	Oxford	Rumford Cogeneration	761,994	14,988,922	10,674,204	71.21	28.79	
	Cumberland	S D Warren Somerset	405,698	6,776,035	3,981,923	58.76	37.70	3.54
Maryland	Allegany	Luke Mill	479,094	17,525,830	7,452,148	42.52	57.48	
Michigan	Dickinson	International Paper Quinnesec	220,975	10,079,834	9,772,982	96.96	0.18	2.86
	Alpena	Louisiana Pacific	44,646	739,198	57,597	7.79	60.85	31.36
	Delta	Mead Paper	684,599	18,935,467	12,154,663	64.19	22.06	13.75
	Muskegon	S D Warren Muskegon	250,591	7,668,122	2,867,940	37.40	58.72	3.87
	Manistee	TES Filer City Station	458,857	6,101,760	501,018	8.21	91.79	
	Wayne	Wyandotte	270,603	3,951,663	305,851	7.74	91.39	0.87
Minnesota	St Louis	Hibbing	45,670	1,531,495	78	0.01	99.99	0.00
	Itasca	Rapids Energy Center	130,699	3,608,215	2,769,301	76.75	16.16	7.09
Mississippi	Lowndes	Weyerhaeuser Columbus MS	613,650	20,090,225	18,705,609	93.11	3.83	3.06
Missouri	St Louis City	Anheuser Busch St Louis	120,498	4,094,333	278,326	6.80	88.85	4.35
	Jackson	Sibley	3,170,801	32,841,421	314,186	0.96	99.01	0.04
	Jasper	Asbury	1,301,578	14,793,004	298,172	2.02	97.72	0.27
	Pike	Hercules Missouri Chemical Wor	84,970	2,864,296	3,573	0.12	98.92	0.95
	Saline	Marshall	35,538	571,009	4,734	0.83	94.14	5.03
	St Charles	Sioux	6,332,833	60,585,566	631,649	1.04	98.15	0.81
	Boone	University of Missouri Columbi	127,509	3,444,927	76,558	2.22	91.00	6.78

Continued on next page.

Table 3.11 (Continued)
Net Generation and Fuel Consumption at Power Plants Consuming Coal and Biomass by State and Plant Name, 2003

State	County	Plant Name	Net Electricity Generation (Thousand Kilowatthours)	Total Energy Consumed (MMBtu)	Energy Consumed from Biomass (MMBtu)	Percent of Energy Consumed from		
						Biomass	Coal	Other
New York	Yates	AES Greenidge LLC	1,040,354	11,705,155	99,328	0.85	98.90	0.25
	Jefferson	Black River Power LLC	355,861	4,539,007	9,635	0.21	74.06	25.73
	Niagara	WPS Power Niagara	251,890	3,353,781	28,760	0.86	98.21	0.94
North Carolina	Haywood	Canton North Carolina	344,245	20,265,972	9,641,230	47.57	52.12	0.30
	Forsyth	Corn Products Winston Salem	56,591	3,948,209	3,441,379	87.16	11.73	1.11
	Halifax	International Paper Roanoke Ra	174,563	12,732,892	8,624,055	67.73	23.23	9.04
	Columbus	International Paper Riegelwood	503,301	25,783,234	18,114,256	70.26	5.22	24.52
	Bladen	Elizabethtown Power LLC	117,590	1,659,872	383,987	23.13	76.87	
	Robeson	Lumberton	83,280	1,075,248	201,011	18.69	81.31	
	Martin	Weyerhaeuser Plymouth NC	806,280	39,957,341	32,330,211	80.91	17.27	1.81
	Pickaway	Picway	402,519	4,674,846	29,550	0.63	98.86	0.51
Ohio	Ross	Mead Custom Paper	532,453	15,151,763	8,077,827	53.31	45.29	1.40
Pennsylvania	Delaware	Chester Operations	389,779	6,591,803	23,657	0.36	54.54	45.10
	Northampton	Northhampton Generating LP	820,274	8,762,273	205,553	2.35	56.42	41.24
	Schuylkill	Kline Township Cogen Facility	393,564	5,978,255	423,384	7.08	92.01	0.91
	York	P H Glatfelter	680,328	17,422,344	8,766,181	50.32	48.75	0.94
	Elk	Johnsonburg Mill	279,550	8,572,138	4,801,100	56.01	38.92	5.07
South Carolina	Richland	International Paper Eastover F	529,454	21,208,564	16,189,319	76.33	16.94	6.72
	Georgetown	International Paper Georgetown	527,894	21,735,489	17,702,311	81.44	10.33	8.23
	Florence	Stone Container Florence Mill	710,340	20,402,914	12,541,662	61.47	27.28	11.25
Tennessee	McMinn	Bowater Newsprint Calhoun Oper	525,280	21,325,300	15,574,553	73.03	25.16	1.81
	Sullivan	Tennessee Eastman Operations	1,239,569	40,812,321	300,054	0.74	98.39	0.88
	Hardin	Packaging Corp of America	373,340	22,112,700	18,034,060	81.56	9.63	8.82
	Sullivan	Weyerhaeuser Kingsport Mill	101,154	6,722,666	5,825,213	86.65	13.35	
Virginia	Bedford	Georgia Pacific Big Island	52,032	3,357,369	1,720,872	51.26	46.83	1.91
	Isle of Wight	International Paper Franklin M	776,727	25,587,752	14,481,554	56.60	22.09	21.32
	King William	St Laurent Paper West Point	525,859	17,126,189	12,851,000	75.04	17.05	7.92
	Portsmouth City	SPSA Waste To Energy Power Pla	173,116	5,415,699	5,388,534	99.50	0.00	0.50
	Hopewell City	Stone Container Hopewell Mill	319,104	8,636,244	6,255,293	72.43	25.30	2.27
	Covington	Covington Facility	671,771	29,004,636	13,064,973	45.04	42.23	12.72
Washington	Cowlitz	Weyerhaeuser Longview WA	327,661	18,235,976	14,422,210	79.09	7.72	13.19
West Virginia	Preston	Albright	1,669,380	18,709,260	1,806	0.01	99.79	0.20
	Pleasants	Willow Island	1,095,678	12,279,409	196,900	1.60	98.02	0.37
	Kanawha	Union Carbide South Charleston	21,488	3,309,914	73,163	2.21	64.49	33.30
Wisconsin	Wood	Georgia Pacific Nekoosa Mill	203,635	5,584,402	3,224,101	57.73	36.09	6.17
	Price	Fraser Paper	36,422	334,360	113,361	33.90	66.10	
	Outagamie	International Paper Kaukauna M	211,943	7,634,467	3,344,608	43.81	39.06	17.13
	Dane	Blount Street	451,308	6,299,195	180,864	2.87	80.63	16.50
	Manitowoc	Manitowoc	315,087	4,761,246	23,264	0.49	66.17	33.34
	Ashland	Bay Front	296,711	4,529,448	1,795,854	39.65	58.60	1.75
	Lincoln	Packaging of America Tomahawk	133,041	10,575,641	7,959,582	75.26	23.01	1.72
	Dane	Univ of Wisc Madison Charter S	42,282	3,947,769	323,026	8.18	82.18	9.64
	Dodge	Waupun Correctional Central He	4,130	288,951	20,665	7.15	88.90	3.95
	Wood	Biron Mill	246,244	4,614,572	326,216	7.07	91.64	1.29
	Marinette	Niagara Mill	114,749	3,000,275	196,181	6.54	71.80	21.66
	Portage	Whiting Mill	25,362	1,572,137	208,755	13.28	78.43	8.29
	Wood	Wisconsin Rapids Pulp Mill	374,930	12,125,962	8,338,658	68.77	26.14	5.10
	Marathon	Wausau Mosinee Paper Pulp	122,059	12,335,121	10,406,885	84.37	13.37	2.26
	Sheboygan	Edgewater	4,893,820	47,746,013	665,280	1.39	98.48	0.12
Total			**95,304,634**	**1,709,675,399**	**630,926,946**	**36.90**	**53.78**	**9.32**

Source:
Energy Information Administration. Derived from Table 9: Net Generation and Fuel Consumption at Power Plants Consuming Coal and Biomass by State and Plant name, 2003, http://www.eia.doe.gov/cneaf/solar.renewables/page/trends/table1.html

Note: MMBtu = One million British thermal units. Blank cell indicates the plant had no consumption or other energy to report.

Table 3.12
Coal Displacement Calculation, 2006

Conversion Formula: Step 1 Capacity (A) x Capacity Factor (B) x Annual Hours (C) = Annual Electricity Generation (D)
Step 2 Annual Electricity Generation (D) x Conversion Efficiency (E) = Total Output (F)
Step 3 Total Output (F) / Fuel Heat Rate (G) = Quantity Fuel (H)

Technology	Wind	Geothermal	Biomass
(A) Capacity (kW)	11,558,205	2,232,495	6,594,096
(B) Capacity Factor (%)	36.0%	90.0%	80.0%
(C) Annual Hours	8,760	8,760	8,760
(D) Annual Electricity Generation (kWh)	36,449,954,187	17,600,991,128	46,211,427,727
(E) Conversion Efficiency (Btu/kWh)	10,107	10,107	10,107
(F) Total Output (Million Btu)	368,399,686	177,893,217	467,058,900
(G) Coal Heat Rate (Btu per short ton)	20,411,000	20,411,000	20,411,000
(H) Coal (short tons)	18,049,076	8,715,556	22,882,705

Technology	Hydropower	PV	Solar Thermal
(A) Capacity (kW)	78,312,583	280,355	388,893
(B) Capacity Factor (%)	44.2%	22.5%	24.4%
(C) Annual Hours	8,760	8,760	8,760
(D) Annual Electricity Generation (kWh)	303,176,455,525	552,579,314	831,235,472
(E) Conversion Efficiency (Btu/kWh)	10,107	10,107	10,107
(F) Total Output (Million Btu)	3,064,204,435	5,584,919	8,401,296
(G) Coal Heat Rate (Btu per short ton)	20,411,000	20,411,000	20,411,000
(H) Coal (short tons)	150,125,150	273,623	411,606

Source:
National Renewable Energy Laboratory, *Power Technologies Energy Data Book*, Table 12.3, http://www.nrel.gov/analysis/power_databook/chapter12.html.
Original Sources: Capacity: EIA, Annual Energy Outlook 2006, DOE/EIA-0383 (2006) (Washington, D.C., February 2006), Table A16.
Capacity Factors: Hydropower calculated from EIA, Annual Energy Outlook 2006, DOE/EIA-0383 (2006) (Washington, D.C., February 2006), Table A16. All others based on DOE, Renewable Energy Technology Characterizations, EPRI TR-109496, 1997 and Program data.
Conversion Efficiency: EIA, Annual Energy Review 2004, DOE/EIA-0384(2004) (Washington, D.C., August 2005), Table A6.
Heat Rate: Annual Energy Outlook 2006, DOE/EIA-0383 (2006) (Washington, D.C., February 2006), Table F1.

Note: Capacity values exclude combined-heat-and-power (CHP) data but include end-use sector (industrial and commercial) non-CHP data.

Table 3.13
Renewable Energy Impacts Calculation, 2006

Conversion Formula: *Step 1* *Capacity (A) x Capacity Factor (B) x Annual Hours (C) = Annual Electricity Generation (D)*
Step 2 *Annual Electricity Generation (D) x Competing Heat Rate (E) = Annual Output (F)*
Step 3 *Annual Output (F) x Emissions Coefficient (G) = Annual Emissions Displaced (H)*

Technology	Wind	Geothermal	Biomass
(A) Capacity (kW)	11,558,205	2,232,495	6,594,096
(B) Capacity Factor (%)	36.0%	90.0%	80.0%
(C) Annual Hours	8,760	8,760	8,760
(D) Annual Electricity Generation (kWh)	36,449,954,187	17,600,991,128	46,211,427,727
(E) Competing Heat Rate (Btu/kWh)	10,107	10,107	10,107
(F) Annual Output (Trillion Btu)	368.4	177.9	467.1
(G) Carbon Coefficient (MMTCB/Trillion Btu)	0.01783	0.01783	0.01783
(H) Annual Carbon Displaced (MMTC)	6.569	3.172	8.328

Technology	Hydropower	PV	Solar Thermal
(A) Capacity (kW)	78,312,583	280,355	388,893
(B) Capacity Factor (%)	44.2%	22.5%	24.4%
(C) Annual Hours	8,760	8,760	8,760
(D) Annual Electricity Generation (kWh)	303,176,455,525	552,579,314	831,235,472
(E) Competing Heat Rate (Btu/kWh)	10,107	10,107	10,107
(F) Annual Output (Trillion Btu)	3,064.2	5.6	8.4
(G) Carbon Coefficient (MMTCB/Trillion Btu)	0.01783	0.01783	0.01783
(H) Annual Carbon Displaced (MMTC)	54.635	0.100	0.128

Source:
National Renewable Energy Laboratory. *Power Technologies Energy Data Book*, Table 12.1, http://www.nrel.gov/analysis/power_databook/chapter12.html
Original sources: Capacity: EIA, *Annual Energy Outlook 2005*, DOE/EIA-0383 (2005) (Washington, DC, February 2005), Table A16, 2005.
Capacity Factors: Hydropower calculated from EIA, *Annual Energy Outlook 2005*, DOE/EIA-0383 (2005) (Washington, DC, February 2005), Table A16. All others based on DOE, Renewable Energy Technology Characterizations, EPRI TR-109496, 1997 and Program data.
Heat Rate: EIA, *Annual Energy Review 2003*, DOE/EIA-0384(2003) (Washington, DC, September 2004), Table A6.
Carbon Coefficient: DOE, GPRA2003 Data Call, Appendix B, page B-16, 2003.

Note: Capacity values exclude combined-heat-and-power (CHP) data but include end-use sector (industrial and commercial) non-CHP data. Competing heat rate from fossil-fueled steam-electric plants heat rate.

Table 3.14
Number of Home Electricity Needs Met Calculation, 2006

Conversion Formula: *Step 1* *Capacity (A) x Capacity Factor (B) x Annual Hours (C) = Annual Electricity Generation (D)*
Step 2 *Annual Electricity Generation (D) / Average Consumption (E) = Number of Households (F)*

Technology	Wind	Geothermal	Biomass	Hydropower	PV	Solar Thermal
(A) Capacity (kW)	11,558,205	2,232,495	6,594,096	78,312,583	280,355	388,893
(B) Capacity Factor (%)	36.0%	90.0%	80.0%	44.2%	22.5%	24.4%
(C) Annual Hours	8,760	8,760	8,760	8,760	8,760	8,760
(D) Annual Electricity Generation (kWh)	36,449,954,187	17,600,991,128	46,211,427,727	303,176,455,525	552,579,314	831,235,472
(E) Average Annual Household Electricity Consumption (kWh)	11,576	11,576	11,576	11,576	11,576	11,576
(F) Number of Households	3,148,804	1,520,497	3,992,068	26,190,515	47,736	71,808

Source:
National Renewable Energy Laboratory, *Power Technologies Data Book*, Table 12.2, http://www.nrel.gov/analysis/power_databook/chapter12.html.
Original sources: Capacity: EIA, Annual Energy Outlook 2006, DOE/EIA-0383 (2006) (Washington, D.C., February 2006), Table A16, 2006.
Capacity Factors: Hydropower calculated from EIA, Annual Energy Outlook 2005, DOE/EIA-0383 (2005) (Washington, D.C., February 2005), Table A16. All others based on DOE, Renewable Energy Technology Characterizations, EPRI TR-109496, 1997 and Program data.
Household electricity Consumption: Calculated from EIA, Annual Energy Outlook 2006, DOE/EIA-0383 (2006) (Washington, D.C., February), Tables A4 and A8, 2006.

Note: Capacity values exclude combined-heat-and-power (CHP) data but include end-use sector (industrial and commercial) non-CHP data.

A tax credit for biomass power production from closed-loop biomass was first enacted as part of the comprehensive Energy Policy Act of 1992. Subsequent acts extended the credit to various other types of renewable energy facilities. Because no biomass power facilities were able to meet the closed-loop biomass definition of the 1992 Act, the tax credit was expanded in 2005 to include open-loop biomass at ½ the tax credit available to a closed-loop facility. Closed and open-loop biomass are defined as follows:

Closed-loop biomass - Crops grown, in a sustainable manner, for the purpose of optimizing their value for bioenergy and bioproduct uses. This includes annual crops such as maize and wheat, and perennial crops such as trees, shrubs, and grasses such as switchgrass.

Open-loop biomass - Biomass that can be used to produce energy and bioproducts even though it was not grown specifically for this purpose. Examples of open-loop biomass include agricultural livestock waste and residues from forest harvesting operations and crop harvesting.

Table 3.15
Major Federal Biomass Power Incentives

Title	Code	Fuel Type	Incentive	Qualifying Period	Limits[c]
Production Tax Credit – extension[a]	IRC §45	Closed-loop biomass	$0.019/kWhr[b] -2005	In service between 2003 - 2007. 10 year max	phase out above 8¢/kWhr (inflation adjusted)
Production Tax Credit – extension[a]	IRC §45	Closed-loop biomass, co-fired with coal or other biomass	$0.019/kWhr[b] -2005	Anytime before 2008, 10 year max from 10/23/2004 or in-service date	Same as above
Production Tax Credit – extension[a]	IRC §45	Open-loop biomass - existing	$0.009/kWhr[b] (2005)	In service before 1/1/2005, 5 year limit	Credit to operator not owner; phase out above 8¢/kWhr; exclusion of biomass co-fired with fossil fuel
Production Tax Credit – extension[a]	IRC §45	Open-loop biomass - new	$0.009/kWhr[b] (2005)	In service between 8/8/2005-12/31/2007, 10 year limit	Same as above
Renewable Energy Production Incentive (REPI)[d]	42 USCS § 13317	Biomass except for MSW combustion	$0.015/kWhr (1993 $ indexed for inflation)	Renewed appropriations for 2006 - 2026	Available to non-profit electrical co-ops, public utilities, government facilities

More information on this can be found at the following websites:
http://www.msi-network.com/content/cmsdoc496.asp
Internal Revenue Code bulletins on §45 at http://www.irs.gov/irb/2004-17_IRB/ar09.html and at: http://www.irs.gov/irb/2005-20_IRB/ar08.html
A business can take the credit by completing Form 8835 (http://www.irs.gov/pub/irs-pdf/f8835.pdf)"Renewable Energy Production Credit."

[a] The 2004 American Jobs Creation Act and the 2005 Energy Policy Act extended the Production Tax Credit §45 so that it now includes wind, open and closed loop biomass, geothermal energy, solar energy, small irrigation power, landfill gas, municipal solid waste, and qualified hydropower production, as well as refined coal production and Indian coal production facilities.

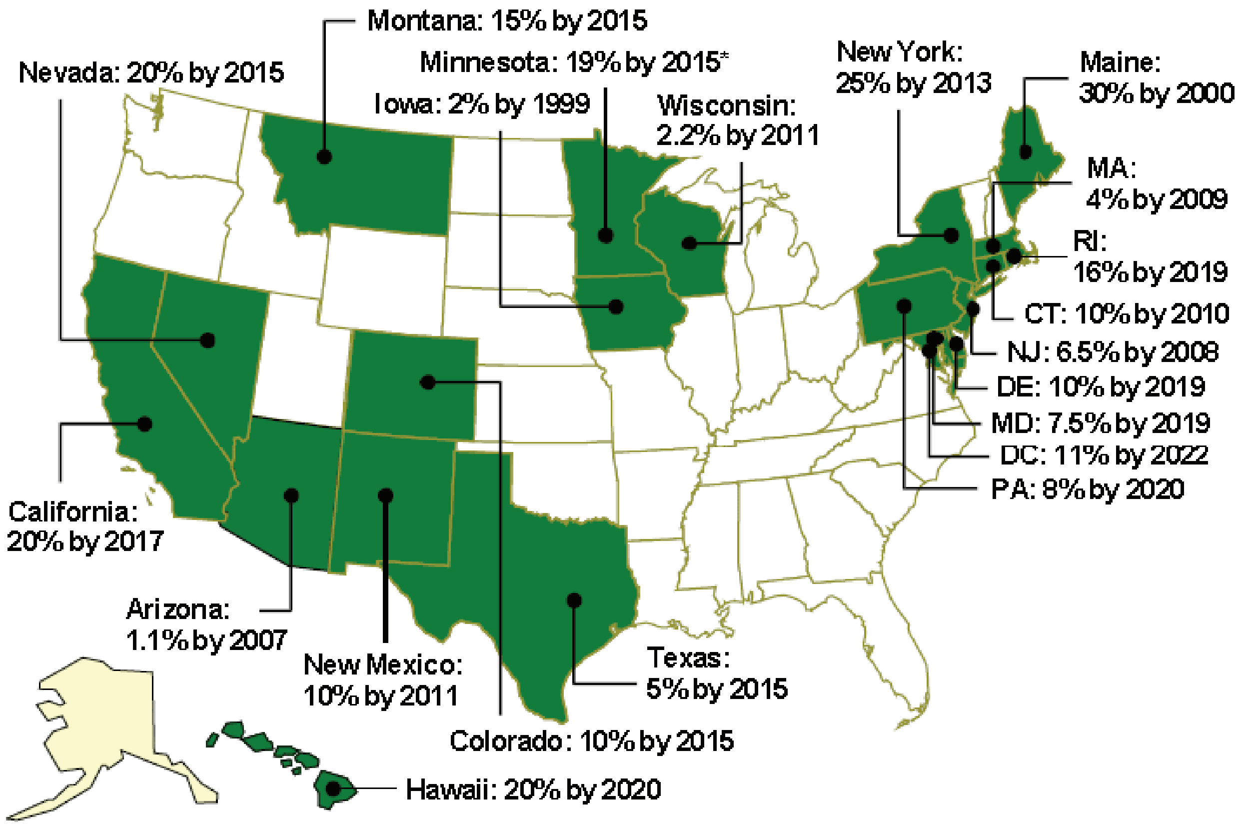
[b] Annual inflation adjusted rate above the base §45 tax credit rate of $0.015/kWhr or ½ the adjusted rate in the case of open-loop biomass, small irrigation power facilities, landfill gas facilities, hydropower facilities. Rates are adjusted annually.

[c] More limits and explanations of limits can be found at http://www.msi-network.com/content/cmsdoc496.asp and in the August 2005 issue of Bioenergy Update.

[d] More information on REPI, including reauthorizing language in Section 202 of the Energy Policy Act of 2005 is available at http://www.dsireusa.org.

A Renewable Portfolio Standard (RPS) is a policy that obligates a retail electricity supplier to include renewable resources in its electricity generation portfolio. Retail suppliers can meet the obligation by constructing or owning eligible renewable resources or purchasing the power from eligible generators. To date, 16 states have adopted RPS policies or renewable purchase obligations. All these states include some type of biomass as a qualifying renewable energy technology. Initially, most states adopted RPS policies as part of electric industry restructuring; but, more recently, a number of states have implemented policies by legislation or proceedings that are separate from restructuring activities. In conjunction with system benefits funds, RPS policies are expected to lead to the development of more than 17,000 MW of new renewable energy capacity by 2017.

Figure 3.1
States with Renewable Portfolio Standards



*Includes requirements adopted in 1994 and 2003 for one utility, Xcel Energy.

Source:
National Renewable Energy Laboratory, *Power Technologies Energy Data Book*, Chapter 3, http://www.nrel.gov/analysis/power_databook/chapter3.html

Almost half of the states have renewable portfolio standards and purchase requirements; the standards and requirements vary widely among those states that do have renewable portfolio requirements.

Table 3.16
State Renewable Portfolio Standards and Purchase Requirements

State	Purchase Requirements	Eligible Resources	Credit Trading	Penalties
Arizona	15% by 2015 (of this 30% must be customer sited)	PV and solar thermal electric, R&D, solar hot water, and in-state **landfill gas**, wind, and **biomass**.	No central credit trading system	Under consideration
California	Investor-owned utilities must add minimum 1% annually to 20% by 2017.	**Biomass**, solar thermal, photovoltaic, wind, geothermal, existing hydro < 30MW, fuel cells using renewable fuels, **digester gas**, **landfill gas**, ocean energy.	WREGIS system under development	At discretion of CPUC
Colorado	10% by 2015	Photovoltaics, **Landfill Gas**, Wind, **Biomass**, Geothermal Electric, **Anaerobic Digestion**, Small Hydroelectric, Fuel Cells (Renewable Fuels)	WREGIS system under development	To be determined
Connecticut	3% Class I or II Technologies by Jan 1, 2004. Class I 1% Jan 1, 2004 increasing to 1.5% by 2005, 2% by 2006, 3.5% by 2007, 5% by 2008, 6% by 2009, and 7% by Jan 1, 2010	Class I: solar, wind, **new sustainable biomass**, **landfill gas**, fuel cells, ocean thermal, wave, tidal, advanced renewable energy conversion technologies, new run of river hydro (<5MW). Class II: licensed hydro, **MSW**, and **other biomass**.	Yes. Using NEPOOL Generation Information System.	Penalty of 5.5¢/kWh paid to the Renewable Energy Investment Fund for the development of Class I renewables
Delaware	10% by 2019	Solar Thermal Electric, Photovoltaics, **Landfill Gas**, Wind, **Biomass**, Hydroelectric, Geothermal Electric, **Anaerobic Digestion**, Tidal Energy, Wave Energy, Ocean Thermal, Fuel Cells (Renewable Fuels)	Yes. GATS	Penalty of 2.5¢/kWh (increases to 5¢/kWh for multi-year noncompliance)
District of Columbia	11% by 2022 (0.386% solar)	Solar Thermal Electric, Photovoltaics, **Landfill Gas**, Wind, **Biomass**, Hydroelectric, Geothermal Electric, Municipal Solid Waste, Cofiring, Tidal Energy, Wave Energy,	Yes. GATS. Electric delivery requirement to PJM	Penalty of 2.5¢/kWh for tier 1 resources, 1¢/kWh for tier II, and 30¢/kWh for PV
Hawaii	8% by end of 2005, 10% by 2010, 15% by 2015 and 20% by 2020	Wind, solar, hydropower, **biomass** including **landfill gas**, **waste to energy**, and **fuels derived from organic sources**, geothermal, ocean energy, fuel cells using hydrogen from renewables	Unspecified	Unspecified: standard to be revisited if utilities can not meet it in cost-effective manner
Iowa	Investor-owned utilities to purchase 105 MW (~2% of 1999 sales)	Solar, wind, **methane recovery,** and **biomass**	No	Unspecified

Continued on next page

Table 3.16 (Continued)
State Renewable Portfolio Standards and Purchase Requirements

State	Purchase Requirements	Eligible Resources	Credit Trading	Penalties
Maine	30% of retail sales in 2000 and thereafter. PUC will revisit within 5 years.	Fuel cells, tidal, solar, wind, geothermal, hydro, **biomass**, and **MSW** (<100MW); high efficiency cogeneration. Selfgeneration is not eligible. Resource supply under this definition exceeds RPS requirement.	Yes. NEPOOL Generation Information System.	Possible sanctions at discretion of PUC
Maryland	3.5% by 2006 with 1% from Tier 1 sources, Tier 1 increasing by 1% every other year from 2007 to 2018, Tier II remains at 2.5%, 7.5% total by 2019 and in subsequent years.	Tier 1: solar, wind, geothermal, **qualifying biomass**, small hydropower (<30MW), and **landfill methane** Tier II: existing large hydropower, **poultry litter incineration**, **existing waste to energy**	Yes	Alternative Compliance fee of 2¢/kWh for Tier 1 and 1.5¢/kWh for Tier 2 paid to Maryland Renewable Energy Fund
Massachusetts	1% of sales to enduse customers from new renewables in 2003, +0.5%/yr to 4% in 2009 1%/yr increase thereafter until determined by Division of Energy Resources	New renewables placed into commercial operation after 1997, including solar, wind, ocean thermal, wave, tidal, fuel cells using renewable fuels, **landfill gas**, and **low-emission advanced biomass**. Excess production from existing generators over historical baseline eligible.	Yes. Using NEPOOL Generation Information System.	Entities may comply by paying 5¢/kWh. Non-complying retailers must submit a compliance plan. Revocation or suspension of license is possible.
Minnesota	(Not true RPS) Applies to Xcel Energy only: 425 MW wind by 2002 and 110 MW biomass. Additional 400 MW wind by 2006 and 300 MW by 2010	**Wind, biomass**	No, other than standard regulatory oversight.	No
Montana	5% in 2008; 10% in 2010; 15% in 2015	Solar Thermal Electric, Photovoltaics, **Landfill Gas**, Wind, **Biomass**, Hydroelectric, Geothermal Electric, **Anaerobic Digestion**, Fuel Cells (Renewable Fuels)	Yes. Electricity must be delivered to MT.	Penalty of 1¢/kWh goes to universal low-income energy assistance fund.
Nevada	6% in 2005, rising to 20% by 2015.	Solar, wind, geothermal, & **biomass (includes agricultural waste, wood, MSW, animal waste and aquatic plants)**. Distributed resources receives extra credit (1.15).	Yes.	Financial penalties may be applied for noncompliance.
New Jersey	Class I or II: 2.5% by 2008 Class I: 4% by 2008, with solar requirement of 0.16% retail sales (90MW) Goal of 20% by 2020.	Class I.: Solar, PV, wind, fuel cells, geothermal, wave, tidal, **landfill methane**, and **sustainable biomass**. Class II: hydro <30 MW and MSW facilities that meet air pollution requirements.	Yes. GATS.	Alternative Compliance Payment of 5¢/kWh, 30¢/kWh for solar.

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Table 3.16 (Continued)
State Renewable Portfolio Standards and Purchase Requirements

State	Purchase Requirements	Eligible Resources	Credit Trading	Penalties
New Mexico	5% of retail sales by 2006. Increase by 1%/yr to 10% by January 1, 2011 and thereafter.	Solar, wind, hydro (<=5 MW), **biomass**, geothermal, and fuel cells. 1 kWh solar =3kWh; **1 kWh biomass**, geothermal, **landfill gas**, or fuel cells =2 kWh toward compliance.	Yes. RECs valid for 4 years from date of issuance.	At discretion of PUC
New York	25% by 2013; 1% voluntary standard; 2% of total incremental RPS requirement (7.71%) is set-aside for customer-sited	Photovoltaics, **Landfill Gas**, Wind, **Biomass**, Hydroelectric, Fuel Cells, CHP/Cogeneration, **Biogas**, **Liquid Biofuel**, **Anaerobic Digestion**, Tidal Energy, Wave Energy, Ocean Thermal	Possibly. Electricity must be delivered to NY.	Unspecified
Pennsylvania	18% by 2020; 8% Tier 1 and 10% Tier II Solar set-aside of 0.5% by 2020	Solar Water Heat, Solar Space Heat, Solar Thermal Electric, Solar Thermal Process Heat, Photovoltaics, **Landfill Gas**, Wind, **Biomass**, Hydroelectric, Geothermal Electric, Fuel Cells, Municipal Solid Waste, CHP/Cogeneration, Waste Coal, Coal Mine Methane, Coal Gasification, **Anaerobic Digestion**, Other Distributed Generation Technologies.	Yes. GATS	Penalty of 4.5¢/kWh, for solar penalty is 200% of PV REC value.
Rhode Island	16% by 2020; 3% by 2003, increasing 0.5% annually 2008-2010, increasing 1% annually 2011-2014, increasing 1.5% annually 2015-2019	Solar, wind, **eligible biomass, including cofiring**, geothermal, small hydropower, ocean, fuel cells using hydrogen derived from renewables.	Yes. Using NEPOOL Generation Information System.	Penalty of 5¢/kWh can be made to Renewable Energy Development Fund.
Texas	5,880 MW by 2015 (5000 MW new) Target of at least 500 MW from renewables other than wind	Solar, wind, geothermal, hydro, wave, tidal, **biomass**, **including landfill gas**. New (operational after Sept. 1, 1999) or small (<2MW) facilities eligible.	Yes. ERCOT REC Trading System.	Lesser of 5¢/kWh or 200% of average market value of renewable energy credits.
Wisconsin	0.5% by 2001 increasing to 2.2% by 2011 (0.6% can come from facilities installed prior to 1998).	Wind, solar, **biomass**, geothermal, tidal, fuel cells that use renewable fuel, & hydro under 60 MW. Eligibility may be xtended by PUC.	Yes. Utilities with excess RECs can trade or bank them.	Penalty of $5,000-$500,000 is allowed in legislation.

Source:
National Renewable Energy Laboratory, *Power Technologies Energy Data Book*, Chapter 3, Table 3.3.1, http://www.nrel.gov/analysis/power_databook/chapter3.html

In addition to State Renewable Portfolio Standards and Purchase Requirements, there are also some nonbinding goals that three states have adopted.

Table 3.17
State Renewable Energy Goals (Nonbinding)

State	Purchase Requirements	Eligible Resources
Illinois	8% by 2013 (75% wind)	Solar Water Heat, Solar Thermal Electric, Photovoltaics, **Landfill Gas**, Wind, **Biomass**, Hydroelectric, CHP/Cogeneration, "Other Such Alternative Sources of Environmentally Preferable Energy"
Minnesota	1% by 2005 increasing by at least 1%/year to 10% by 2015	Wind, solar, hydro (<60 MW), and **biomass**
Vermont	Meet growth in electricity demand from 2005-2013 with renewable energy sources (becomes mandatory in 2013 if not met).	Solar Thermal Electric, Photovoltaics, **Landfill Gas**, Wind, **Biomass**, Hydroelectric, **Anaerobic Digestion**, Fuel Cells (Renewable Fuels)

Source:
National Renewable Energy Laboratory, Power Technologies Energy Data Book, Chapter 3, Table 3.3.2, http://www.nrel.gov/analysis/power_databook/chapter3.html

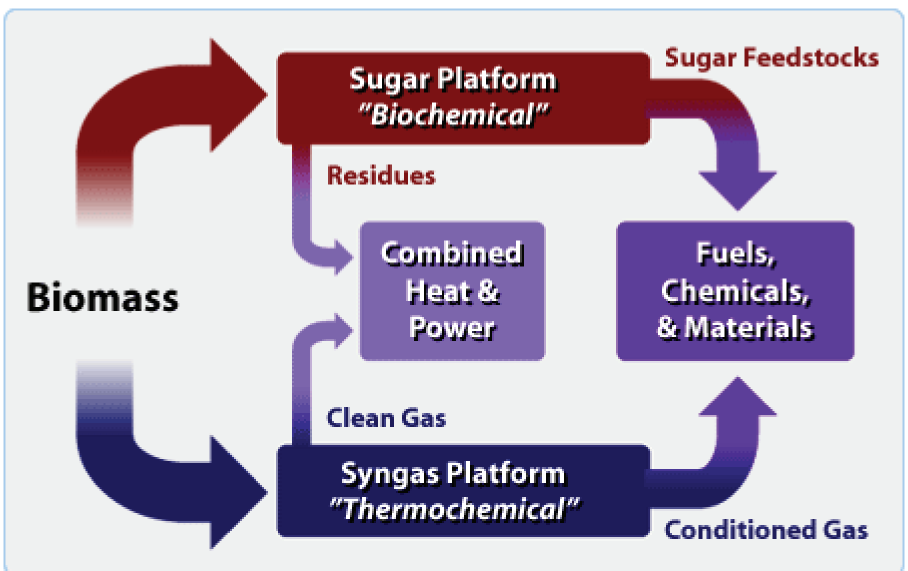
4. BIOREFINERIES

BRIEF OVERVIEW

As a petroleum refinery uses petroleum as the major input and processes it into many different products, a biorefinery uses lignocellulosic biomass as the major input and processes it into many different products. Currently, wet-mill corn processing and pulp and paper mills can be categorized as biorefineries since they produce multiple products from biomass. Research is currently being conducted to foster new industries to convert biomass into a wide range of products, including ones that would otherwise be made from petrochemicals. The idea is for biorefineries to produce both high-volume liquid fuels and high-value chemicals or products in order to address national energy needs while enhancing operation economics.

Two of the most promising emerging biorefinery platforms are the sugar platform and the thermochemical platform (also known as the syngas platform). Sugar platform biorefineries would break biomass down into different types of component sugars for fermentation or other biological processing into various fuels and chemicals. Thermochemical biorefineries would convert biomass to synthesis gas (hydrogen and carbon monoxide) or pyrolysis oil, the various components of which could be directly used as fuel.

The diagram below illustrates the biorefinery concept.



Source:
National Renewable Energy Laboratory, Biomass Program, June 2006,
http://www.nrel.gov/biomass/biorefinery.html

The Department of Energy Biomass Program is currently focusing efforts on two biorefinery platforms – sugar and thermochemical – but other platforms also have potential for expanding the use of biomass energy.

Table 4.1
Biorefinery Platforms

Platform	Description
Sugar Platform	Developing technology to break cellulose and hemicellulose down into their component sugars. Those sugars can then be processed to fuel ethanol or other building block chemicals. Lignin can either be burned to provide process heat and electricity or can itself be converted to fuels and chemicals.
Thermochemical Platform	Converting solid biomass to a gaseous or liquid fuel by heating it with limited oxygen prior to combustion can greatly increase the overall efficiency, and also make it possible to instead convert the biomass to valuable chemicals or materials. Developing thermochemical technologies will allow a more efficient means of tapping the enormous energy potential of lignocellulosic biomass.
Biogas Platform	Decomposing biomass with natural consortia of microorganisms in closed tanks known as anaerobic digesters produces methane (natural gas) and carbon dioxide. This methane-rich biogas can be used as fuel or as a base chemical for biobased products.
Carbon-Rich Chains Platform	Natural plant oils such as soybean, corn, palm, and canola oils are in wide use today for food and chemical applications. Transesterification of vegetable oil or animal fat produces fatty acid methyl ester, commonly known as biodiesel. The glycerin byproduct of biodiesel, and the fatty acids from which it is made, could all be platform chemicals for biorefineries.
Plant Products Platform	Selective breeding and genetic engineering can develop plant strains that produce greater amounts of desirable feedstocks or chemicals or even compounds that the plant does not naturally produce — getting the biorefining done in the biological plant rather than the industrial plant.

Source:
U. S. Department of Energy, Energy Efficiency and Renewable Energy, Biomass Program, June 2006, http://www1.eere.energy.gov/biomass/index.html

Note: This is not an exhaustive list of platforms.

In April 2002 the U.S. Department of Energy solicited projects for "Biomass Research and Development for the Production of Fuels, Power, Chemicals and Other Economical and Sustainable Products." The following six projects, which will be completed in three to four years, were selected to assist in the development of sugar platform research.

Table 4.2
U.S. Department of Energy Sugar Platform Biorefinery Projects

Project name	Partner	Project cost	Project Description
A Second Generation Dry Mill Biorefinery	Broin and Associates	$5.4 million	Separate bran, germ, and endosperm from corn kernels prior to making ethanol from the remaining starch. Investigate making high-value products, as well as ethanol and animal feed from the separated fractions.
A New Biorefinery Platform Intermediate	Cargill, Inc.	$6 million	Develop fermentative organisms and processes to ferment carbohydrates to 3-hydroxypropionic acid (3-HP) and then make a slate of products from the 3-HP.
Making Industrial Biorefining Happen	Cargill-Dow LLC	$26 million	Develop and build a pilot-scale biorefinery that produces sugars and chemicals such as lactic acid and ethanol from grain.
Integrated Corn-Based Biorefinery	E.I. du Pont de Nemours & Co., Inc.	$18.2 million	Development of a biorefinery concept that converts both starch (such as corn) and lignocellulose (such as corn stover) to fermentable sugars for production of value added chemicals (like 1,3 propanediol) and fuel ethanol.
Advanced Biorefining of Distillers' Grain and Corn Stover Blends: Pre-Commercialization of a Biomass-Derived Process Technology	High Plains Corporation (now Abengoa S.A.)	$17.7 million	Develop a process for pretreating a blend of distillers' grain (animal feed co-product from corn ethanol production) and stover to allow ethanol production from both, while leaving a high-protein animal feed. A large-scale pilot facility will be built for integration with High Plains' ethanol plant in York, Nebraska.
Separation of Corn Fiber and Conversion to Fuels and Chemicals Phase II: Pilot-Scale Operation	National Corn Growers Association	$2.4 million	Under a previous DOE-funded project, a process was developed for separation of hemicellulose, protein, and oil from corn fiber. This project will pilot-scale test and validate this process for commercial use.

Source:
U. S. Department of Energy, Energy Efficiency and Renewable Energy, Biomass Program, June 2006, http://www1.eere.energy.gov/biomass/sugar_biorefineries.html

5. FEEDSTOCKS

PRIMARY BIOMASS FEEDSTOCKS

Primary biomass is produced directly by photosynthesis and includes all terrestrial plants now used for food, feed, fiber and fuelwood. All plants in natural and conservation areas (as well as algae and other aquatic plants growing in ponds, lakes, oceans, or artificial ponds and bioreactors) are also considered primary biomass. However, only a small portion of the primary biomass produced will ever be harvested as feedstock material for the production of bioenergy and bioproducts.

Primary biomass feedstocks are thus primary biomass that is harvested or collected from the field or forest where it is grown. Examples of primary biomass feedstocks currently being used for bioenergy include grains and oilseed crops used for transportation fuel production, plus some crop residues (such as orchard trimmings and nut hulls) and some residues from logging and forest operations that are currently used for heat and power production. In the future it is anticipated that a larger proportion of the residues inherently generated from food crop harvesting, as well as a larger proportion of the residues generated from ongoing logging and forest operations, will be used for bioenergy. Additionally, as the bioenergy industry develops, both woody and herbaceous perennial crops will be planted and harvested specifically for bioenergy and bioproducts end-uses.

Because this version of the Data Book is focusing primarily on the bioenergy industry as it exists today, including the biomass feedstocks actually used, only information on the grain and oilseeds crops are included. It would be desirable to include information on the amount and types of crop residues and forest logging, or pulp fiber residues currently being used for energy on a state by state basis, but that information is not readily available. Clearly there is also no nationwide source of information on woody or herbaceous crops being used for energy since this is occurring only on a very small scale in a few isolated experimental situations.

This Data Book covers only current usage of biomass and does not attempt to address the potential for biomass feedstock. Nontheless, other sources of information do exist concerning the future potential of biomass. Tables, maps and explanations for assumptions behind the potential biomass resource calculations that have been performed by Oak Ridge National Laboratory biomass economists can be found on the Bioenergy Feedstock Information Network (BFIN) website at www.bioenergy.ornl.gov.

Source: Lynn Wright, Oak Ridge, TN.

USDA's corn baseline projections show a continuing rise in bushels of corn allocated to fuel alcohol use, a continuing increase in corn yields, a slight increase in corn acreage, and a continuing increase in net returns (over variable costs) through 2014. This analysis is updated annually.

Table 5.1
Corn Baseline Projections, 2004—2015

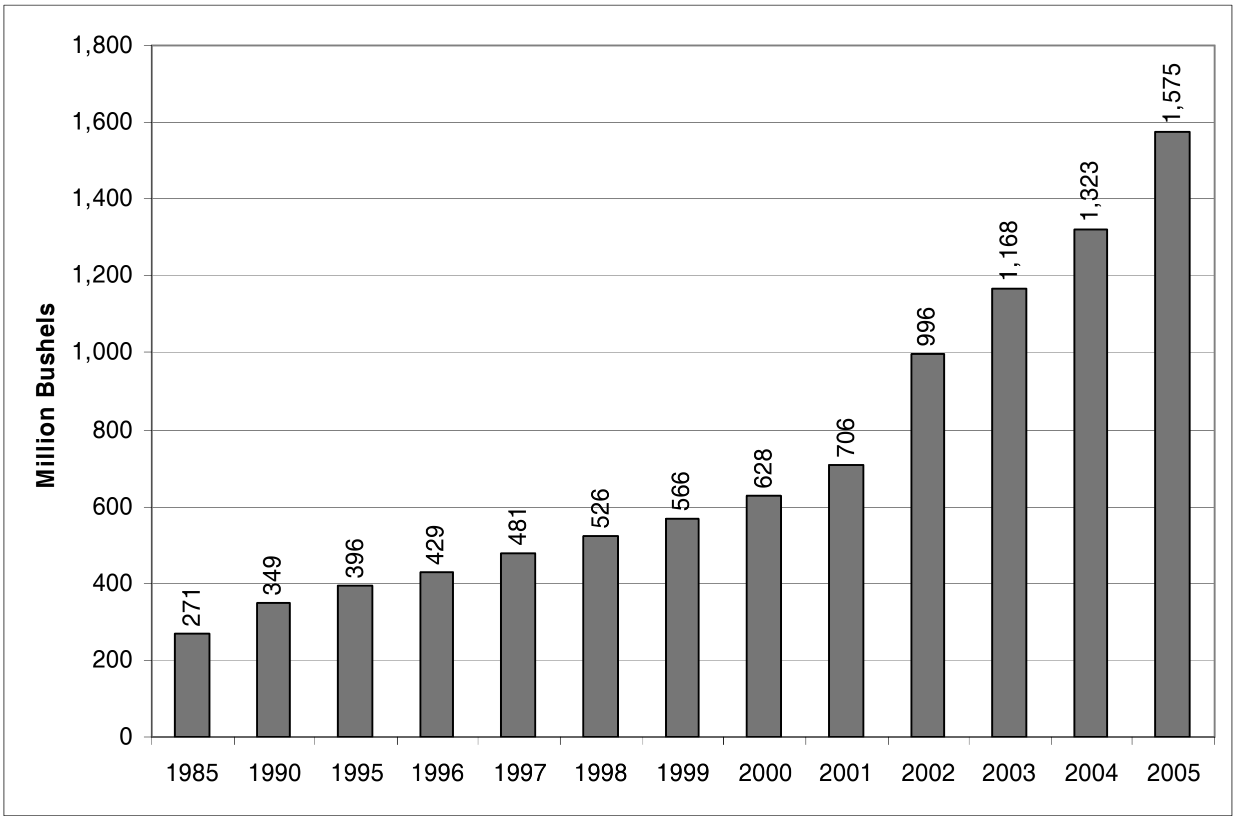
Item	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15
Area (million acres):												
Planted acres	78.7	81.0	81.0	81.0	81.5	82.0	82.5	83.0	83.5	84.0	84.0	84.0
Harvested acres	71.1	73.3	73.6	73.6	74.1	74.6	75.1	75.6	76.1	76.6	76.6	76.6
Yields (bushels per acre):												
Yield/harvested acre	142.2	160.2	145.6	147.4	149.2	151.0	152.8	154.6	156.4	158.2	160.0	161.8
Supply and use (million bushels):												
Beginning stocks	1,087	958	1,819	1,724	1,549	1,394	1,264	1,159	1,109	1,109	1,164	1,194
Production	10,114	11,741	10,715	10,850	11,055	11,265	11,475	11,690	11,900	12,120	12,255	12,395
Imports	14	15	15	15	15	15	15	15	15	15	15	15
Supply	11,215	12,714	12,549	12,589	12,619	12,674	12,754	12,864	13,024	13,244	13,434	13,604
Feed & residual	5,783	6,075	5,800	5,800	5,825	5,850	5,900	5,950	6,000	6,050	6,125	6,200
Food, seed, & industrial	2,577	2,770	2,875	2,965	3,000	3,035	3,070	3,105	3,140	3,180	3,215	3,250
Fuel alcohol use	1,204	1,370	1,470	1,550	1,575	1,600	1,625	1,650	1,675	1,700	1,725	1,750
Domestic	8,360	8,845	8,675	8,765	8,825	8,885	8,970	9,055	9,140	9,230	9,340	9,450
Exports	1,897	2,050	2,150	2,275	2,400	2,525	2,625	2,700	2,775	2,850	2,900	2,975
Total use	10,257	10,895	10,825	11,040	11,225	11,410	11,595	11,755	11,915	12,080	12,240	12,425
Ending stocks	958	1,819	1,724	1,549	1,394	1,264	1,159	1,109	1,109	1,164	1,194	1,179
Stocks/use ratio, percent	9.3	16.7	15.9	14.0	12.4	11.1	10.0	9.4	9.3	9.6	9.8	9.5
Prices (dollars per bushel):												
Farm price	2.42	1.90	2.00	2.15	2.25	2.35	2.40	2.45	2.45	2.45	2.45	2.45
Loan rate	1.98	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95
Variable costs of production (dollars):												
Per acre	158.85	164.93	168.05	170.46	171.98	173.52	175.16	176.96	178.85	180.75	182.67	184.65
Per bushel	1.12	1.03	1.15	1.16	1.15	1.15	1.15	1.14	1.14	1.14	1.14	1.14
Returns over variable costs (dollars per acre):												
Net returns[a]	185.28	179.50	144.99	146.45	163.72	181.33	191.56	201.81	204.33	206.84	209.33	211.76

Source:
USDA Agricultural Baseline Projections to 2014, February 2005 (OCE-2005-1), Table 8 - U.S. corn, http://usda.mannlib.cornell.edu/data-sets/baseline/2005/index.html

[a] Net returns include estimates of marketing loan benefits.

The figure below shows the dramatic rise in demand for corn as a feedstock for ethanol production that has occurred over the last several years.

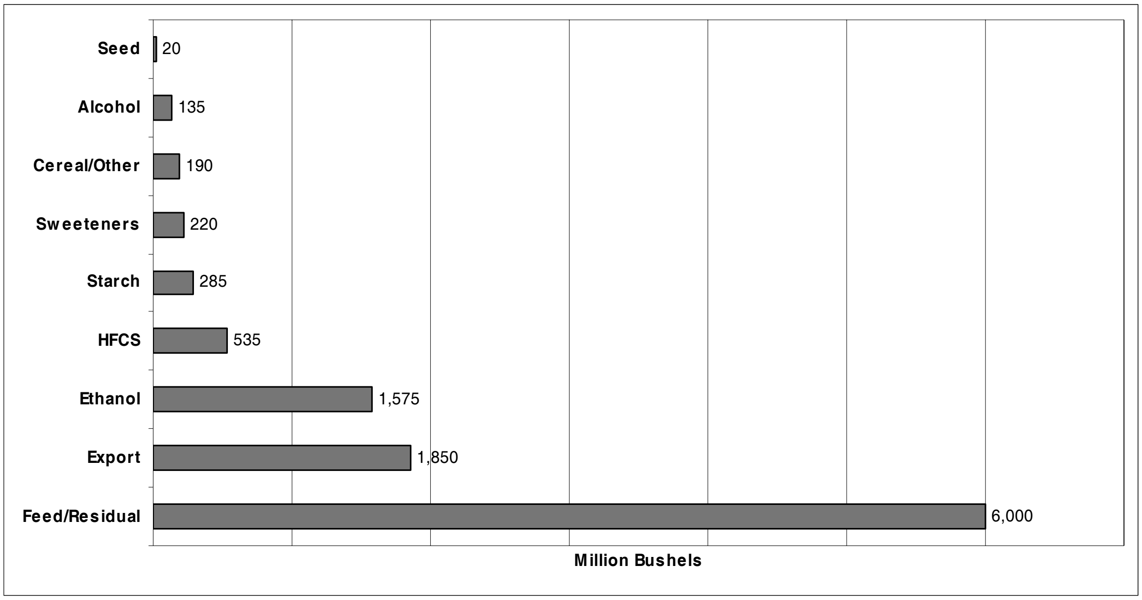
Figure 5.1
Corn Used for Ethanol Production, 1985—2005



Source:
National Corn Growers Association, *The World of Corn*, 2005, http://www.ncga.com, Also found at: http://www.ethanolrfa.org/industry/outlook/

In 2005, ethanol production accounted for about 15% of the overall corn consumption. Corn used for feed/residual is by far the largest usage.

Figure 5.2
Corn Usage by Segment, 2005



Source:
National Corn Growers Association, *The World of Corn*, 2005,
http://www.ncga.com/WorldOfCorn/main/consumption1.asp

In the baseline year of 2001, 7.5% of all corn grain produced was used for ethanol production. Over the past 10 years the corn acres planted have varied between about 71 and 81 million acres; acreage variation is related to feed and export demands, crop subsidy programs, previous year grain prices and animal demand for silage. Yield variation relates to climate variation and improved varieties. The year 2004 provided an unusually favorable climate for high corn yields over much of the corn belt.

Table 5.2
Corn: Area, Yield, Production, and Value, 1996-2005

Year	Area Planted for all purposes	Corn for grain					Corn for silage		
		Area harvested	Yield per harvested acre	Production	Marketing year average price per bushel	Value of production	Area Harvested	Yield per harvested acre	Production
	1,000 Acres	1,000 Acres	Bushels	1,000 Bushels	Dollars	1,000 Dollars	1,000 Acres	Tons	1,000 Tons
1996	79,229	72,644	127.1	9,232,557	2.71	25,149,013	5,607	15.4	86,581
1997	79,537	72,671	126.7	9,206,832	2.43	22,351,507	6,054	16.1	97,192
1998	80,165	72,589	134.4	9,758,685	1.94	18,922,084	5,913	16.1	95,479
1999	77,386	70,487	133.8	9,430,612	1.82	17,103,991	6,037	15.8	95,633
2000	79,551	72,440	136.9	9,915,051	1.85	18,499,002	6,082	16.8	102,156
2001	75,702	68,768	138.2	9,502,580	1.97	18,878,819	6,142	16.6	101,992
2002	78,894	69,330	129.3	8,966,787	2.32	20,882,448	7,122	14.4	102,293
2003	78,603	70,944	142.2	10,089,222	2.42	24,476,803	6,583	16.3	107,378
2004	80,929	73,631	160.4	11,807,086	2.06	24,381,294	6,101	17.6	107,293
2005 [a]	81,759	75,107	147.9	11,112,072	1.90	21,040,707	5,920	18	106,311

Source:
USDA, *2006 Agricultural Statistics*, Table 1-34,
http://www.nass.usda.gov/Publications/Ag_Statistics/index.asp

[a] Preliminary.

Production of sufficient quantities of corn to support ethanol production facilities occurs primarily in the mid-western states. Yields vary considerably across the states, high yields in the western states occur under irrigation.

Table 5.3
Corn: Area, Yield, and Production, by State, 2003—2005

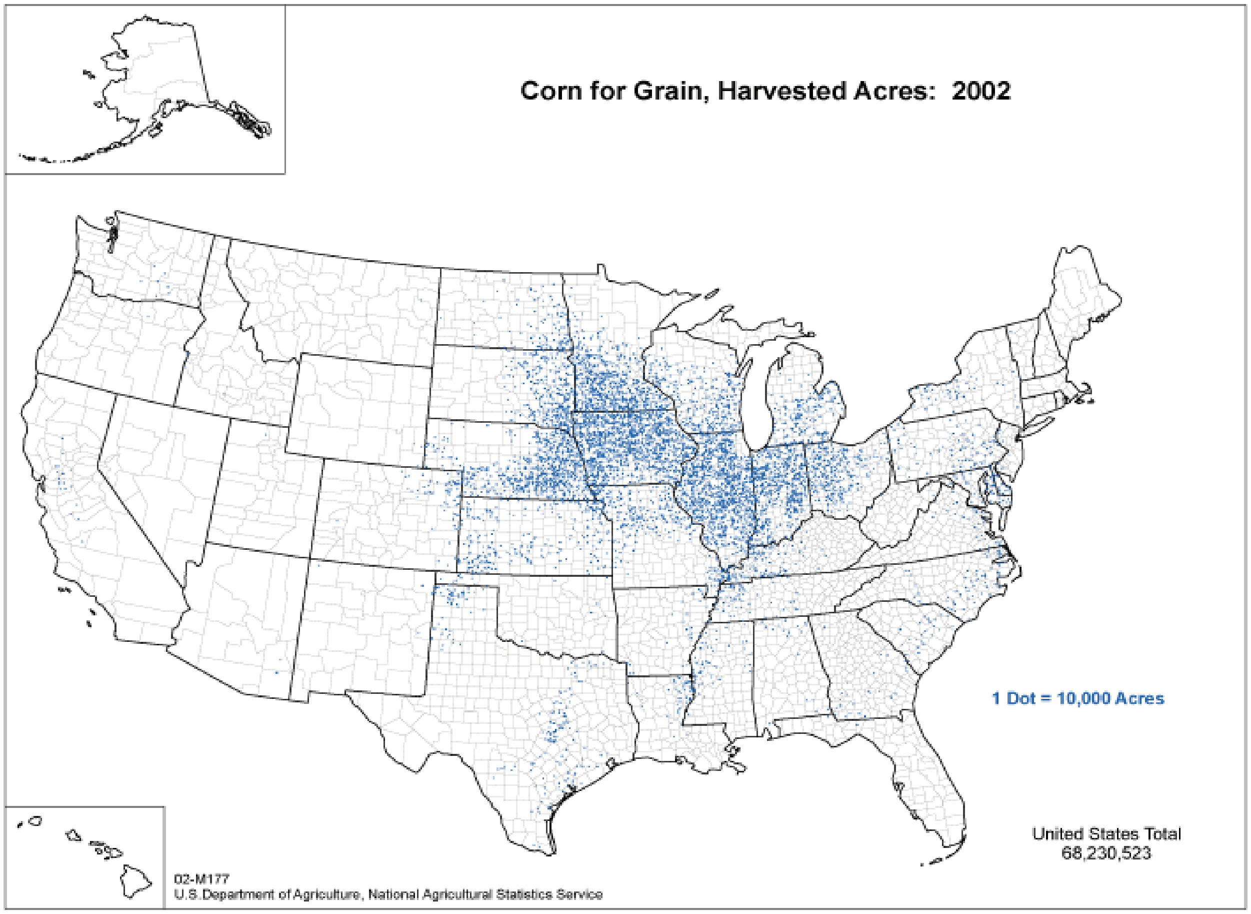
State	Area planted for all purposes			Corn for grain								
				Area harvested			Yield per harvested acre			Production		
	2003	2004	2005[a]	2002	2003	2004[a]	2002	2003	2004[a]	2002	2003	2004[a]
	1,000 Acres	1,000 Acres	1,000 Acres	1,000 Acres	1,000 Acres	1,000 Acres	Bushels	Bushels	Bushels	1,000 Bushels	1,000 Bushels	1,000 Bushels
Alabama	220	220	220	190	195	200	122	123	119	23,180	23,985	23,800
Arizona	47	53	50	22	27	22	190	180	195	4,180	4,860	4,290
Arkansas	365	320	240	350	305	230	140	140	131	49,000	42,700	30,130
California	530	540	540	140	150	110	160	175	172	22,400	26,250	18,920
Colorado	1,080	1,200	1,100	890	1,040	950	135	135	148	120,150	140,400	140,600
Connecticut	30	30	28	b	b	b	b	b	b	b	b	b
Delaware	170	160	160	162	153	154	123	152	143	19,926	23,256	22,022
Florida	75	70	65	39	32	28	82	90	94	3,198	2,880	2,632
Georgia	340	335	270	290	280	230	129	130	129	37,410	36,400	29,670
Idaho	190	230	235	50	75	60	140	170	170	7,000	12,750	10,200
Illinois	11,200	11,750	12,100	11,050	11,600	11,950	164	180	143	1,812,200	2,088,000	1,708,850
Indiana	5,600	5,700	5,900	5,390	5,530	5,770	146	168	154	786,940	929,040	888,580
Iowa	12,300	12,700	12,800	11,900	12,400	12,500	157	181	173	1,868,300	2,244,400	2,162,500
Kansas	2,900	3,100	3,650	2,500	2,880	3,450	120	150	135	300,000	432,000	465,750
Kentucky	1,170	1,210	1,250	1,080	1,140	1,180	137	152	132	147,960	173,280	155,760
Louisiana	520	420	340	500	410	330	134	135	136	67,000	55,350	44,880
Maine	28	28	26	b	b	b	b	b	b	b	b	b
Maryland	480	490	470	410	425	400	123	153	135	50,430	65,025	54,000
Massachusetts	20	20	20	b	b	b	b	b	b	b	b	b
Michigan	2,250	2,200	2,250	2,030	1,920	2,020	128	134	143	259,840	257,280	288,860
Minnesota	7,200	7,500	7,300	6,650	7,050	6,850	146	159	174	970,900	1,120,950	1,191,900
Mississippi	550	460	380	530	440	365	135	136	129	71,550	59,840	47,085
Missouri	2,900	2,950	3,100	2,800	2,880	2,970	108	162	111	302,400	466,560	329,670
Montana	68	70	65	17	15	17	140	143	148	2,380	2,145	2,516
Nebraska	8,100	8,250	8,500	7,700	7,950	8,250	146	166	154	1,124,200	1,319,700	1,270,500
Nevada	4	4	5	b	b	b	b	b	b	b	b	b
New Hampshire	15	15	15	b	b	b	b	b	b	b	b	b
New Jersey	80	86	80	61	72	62	113	143	122	6,893	10,296	7,564
New Mexico	130	125	140	48	58	55	180	180	175	8,640	10,440	9,625
New York	1,000	980	990	440	500	460	121	122	124	53,240	61,000	57,040
North Carolina	740	820	750	680	740	700	106	117	120	72,080	86,580	84,000
North Dakota	1,450	1,800	1,410	1,170	1,150	1,200	112	105	129	131,040	120,750	154,800
Ohio	3,300	3,350	3,450	3,070	3,110	3,250	156	158	143	478,920	491,380	464,750
Oklahoma	230	250	290	190	200	250	125	150	115	23,750	30,000	28,750
Oregon	51	58	53	30	28	25	170	170	160	5,100	4,760	4,000
Pennsylvania	1,450	1,400	1,350	890	980	960	115	140	122	102,350	137,200	117,120
Rhode Island	2	2	2	b	b	b	b	b	b	b	b	b
South Carolina	240	315	300	215	295	285	105	100	116	22,575	29,500	33,060
South Dakota	4,400	4,650	4,450	3,850	4,150	3,950	111	130	119	427,350	539,500	470,050
Tennessee	710	680	650	620	615	595	131	140	130	81,220	86,100	77,350
Texas	1,830	1,830	2,050	1,650	1,680	1,850	118	139	114	194,700	233,520	210,900
Utah	55	55	55	13	12	12	155	155	163	2,015	1,860	1,956
Vermont	100	95	95	b	b	b	b	b	b	b	b	b
Virginia	470	500	490	330	360	360	115	145	118	37,950	52,200	42,480
Washington	130	170	150	70	105	80	195	200	205	13,650	21,000	16,400
West Virginia	48	48	45	27	29	28	115	131	109	3,105	3,799	3,052
Wisconsin	3,750	3,600	3,800	2,850	2,600	2,900	129	136	148	367,650	353,600	429,200
Wyoming	85	90	80	50	50	49	129	131	140	6,450	6,550	6,860
US	**78,603**	**80,929**	**81,759**	**70,944**	**73,631**	**75,107**	**142.2**	**160.4**	**147.9**	**10,089,222**	**11,807,086**	**11,112,072**

Source:
USDA, *2006 Agricultural Statistics*, Table 1-36,
http://www.nass.usda.gov/Publications/Ag_Statistics/index.asp

[a] Preliminary.
[b] Not estimated.

The large majority of U.S. corn grain is produced in just a few mid-western states. The highest concentration of corn production is found in central Illinois, northern Iowa/southern Minnesota, and eastern Nebraska.

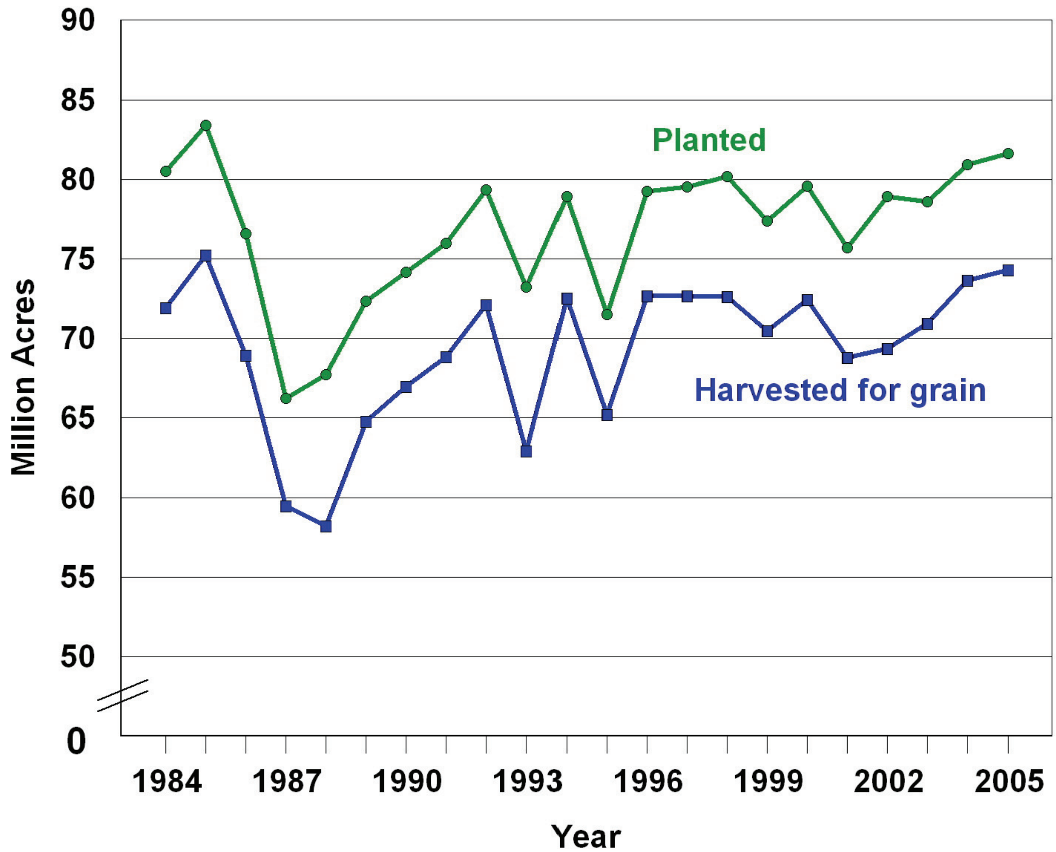
Figure 5.3
Corn for Grain, Harvested Acres, 2002



Source:
U.S. Department of Agriculture, National Agricultural Statistics Service,
www.nass.usda.gov/research/atlas02/atlas-crops.html

Currently, planted acres can be related primarily to anticipated market demand; acres harvested for grain are always less than planted acres due to silage and crop failure.

Figure 5.4
Corn Acres, Planted and Harvested, 1984—2005



Source:
U.S. Department of Agriculture, National Agricultural Statistics Service, www.usda.gov/nass/aggraphs/crops.htm

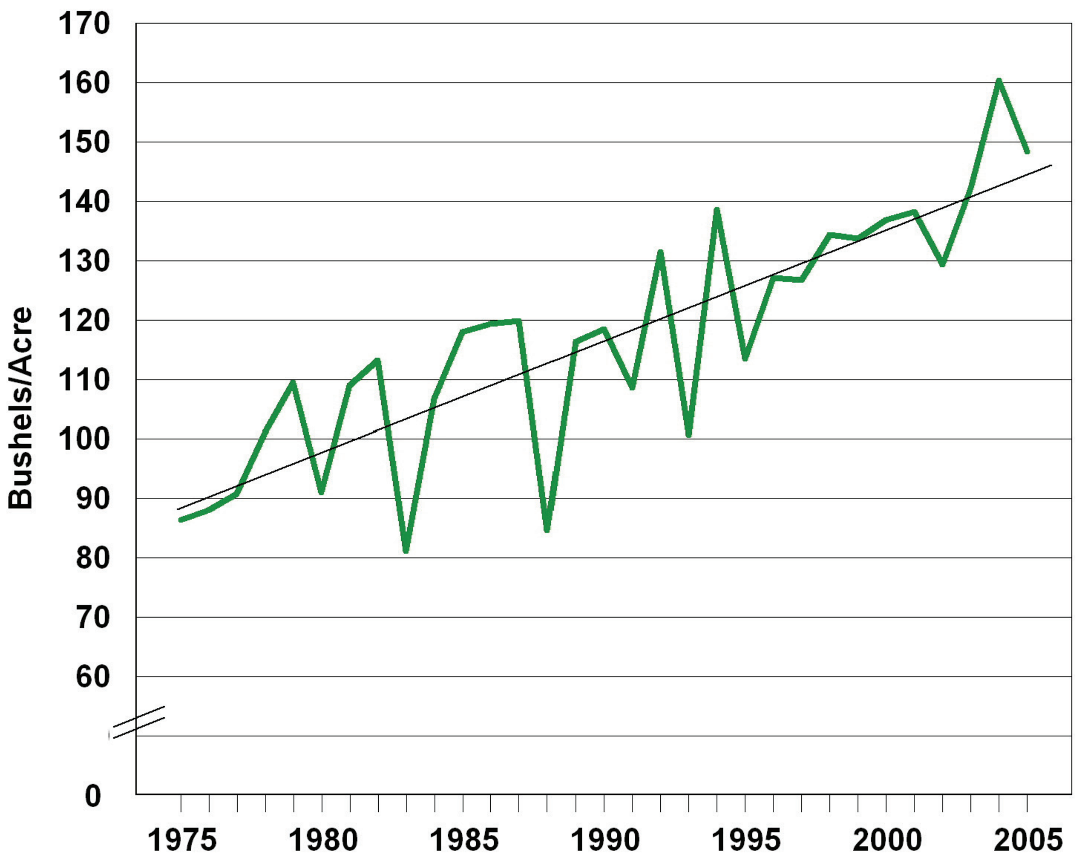
Doberman et. al., noted in 2002 that average corn yields have increased linearly at a rate of 1.7 bushels per acre (bu/ac) per year. At present that translates to a rate of 1.1% per year, but if the same average linear rate continues, the percentage rate will decline. Corn yields must continue to increase at a rate of at least 1% per year to meet the demands created by expected population growth.

In 2002 average corn yields approached 140 bu/ac with progressive farmers routinely harvesting 160 to 220 bu/ac. Yields rose in the 60's and 70's largely due to increasing application of fertilizer to responsive corn hybrids; however, after 1980 yield increases were maintained without continued fertilizer increases due to significant increases in nutrient use efficiency. In the past 15 years, yields have continued to increase due to improved hybrids with greater stress resistance together with improved crop management techniques such as conservation tillage, higher plant densities and improved seed qualities.

Yields at a given site fluctuate as much as 10-15% from year to year due to normal variations in solar radiation and temperature regimes assuming suitable moisture levels. Lack of sufficient moisture is the most important factor reducing yields in most of the U.S. corn belt where most corn is not irrigated. The yield potential of corn continues to be much greater than the average yields currently being obtained in most locations in the United States.

Genetic improvements (particularly in drought resistance) are expected to continue to contribute to yield increases, but continued improvements in crop management will be ever more important. Key references on yield potential.

Figure 5.5
Corn Yield, 1975—2005



Source:
U.S. Department of Agriculture, National Agricultural Statistics Service, www.usda.gov/nass/aggraphs/crops.htm

Figure 5.5 (Continued)
Corn Yield, 1975—2005

Additional References for Corn Yield:

Dobermann, A., T. Arkebauer, K. Cassman, J. Lindquist, J. Specht, D. Walters, and H. Yang. 2002. Understanding and Managing Corn Yield Potential. Proceedings of the Fertilizer Industry Round Table, Charleston, South Carolina. The Fertilizer Industry Round Table, Forest Hill, Maryland, October. Retrieved 5 January 2005 from:

Dobermann, A., T. Arkebauer, K.G. Cassman, R.A. Drijber, J.L. Lindquist, J.E. Specht, D.T. Walters, H. Yang, D. Miller, D.L. Binder, G. Teichmeier, R.B. Ferguson, and C.S. Wortmann. 2003. Understanding corn yield potential in different environments. p. 67-82. In L.S. Murphy (ed.) Fluid focus: the third decade. Proceedings of the 2003 Fluid Forum, Vol. 20. Fluid Fertilizer Foundation, Manhattan, KS.

Both Doberman et al. references can be obtained at the following url: http://soilfertility.unl.edu/Materials%20to%20include/Research%20Pubs/Ecological%20Intensification.htm

Tollenaar, M. and E. A. Lee. Yield potential, yield stability, and stress tolerance in maize. Field Crops Research 75 (2002):161-169.

Duvick, D.N. and K.G. Cassman. 1999. Post-green revolution trends in yield potential of temperature maize in the North-Central United States. Crop Sci. 39:1622-1630.

Production of food for domestic livestock is the largest single use of corn grain, accounting for nearly half of all corn grain produced. Ethanol production is included in the food, seed and industrial category.

Table 5.4
Corn: Supply and Disappearance, 1996—2005
(million bushels)

Year (beginning September 1)	Supply				Disappearance					Ending stocks August 31		
					Domestic use							
	Beginning stocks	Production	Imports	Total	Feed and residual	Food, seed, and industrial	Total	Exports	Total disappear-ance	Privately held [a]	Govern - ment	Total
1996	426	9,233	13	9,672	5,277	1,714	6,991	1,797	8,789	881	2	883
1997	883	9,207	9	10,099	5,482	1,805	7,287	1,504	8,791	1,304	4	1,308
1998	1,308	9,759	19	11,085	5,471	1,846	7,318	1,984	9,298	1,775	12	1,787
1999	1,787	9,431	15	11,232	5,664	1,913	7,578	1,937	9,515	1,704	14	1,718
2000	1,718	9,915	7	11,639	5,842	1,957	7,799	1,941	9,740	1,891	8	1,899
2001	1,899	9,503	10	11,412	5,864	2,046	7,911	1,905	9,815	1,590	6	1,596
2002	1,596	8,967	14	10,578	5,563	2,340	7,903	1,588	9,491	1,083	4	1,087
2003	1,087	10,089	14	11,190	5,795	2,537	8,332	1,900	10,232	958	0	958
2004 [b]	958	11,807	11	12,776	6,162	2,686	8,848	1,814	10,662	2,113	1	2,114
2005 [c]	2,114	11,112	10	13,236	6,000	2,960	8,960	1,850	10,810	2,425	1	2,426

Source:
USDA, *2006 Agricultural Statistics*, Table 1-37,
http://www.nass.usda.gov/Publications/Ag_Statistics/index.asp

[a] Includes quantity under loan and farmer-owned reserve.
[b] Preliminary.
[c] Projected as of January 12, 2006, World Agricultural Supply and Demand Estimates. Totals may not add due to rounding.

Prices of corn used for ethanol production may vary for each mill depending on whether the mills are owned by farmers' cooperatives or whether the corn is purchased on the open market. Prices vary across states considerably.

Table 5.5
Corn for Grain: Marketing Year Average Price and Value, by State

State[a]	Marketing year average price per bushel			Value of production		
	2003	2004	2005	2003	2004	2005[b]
	Dollars	Dollars	Dollars	1,000 Dollars	1,000 Dollars	1,000 Dollars
Alabama	2.36	2.48	2.35	54,705	59,483	55,930
Arizona	3.28	3.03	2.9	13,710	14,726	12,441
Arkansas	2.37	2.39	2.1	116,130	102,053	63,273
California	2.9	2.65	2.75	64,960	69,563	52,030
Colorado	2.49	2.23	2.25	299,174	313,092	316,350
Delaware	2.87	2.19	2.05	57,188	50,931	45,145
Florida	2.55	2.3	2	8,155	6,624	5,264
Georgia	2.45	2.2	2.15	91,655	80,080	63,791
Idaho	2.94	2.82	2.65	20,580	35,955	27,030
Illinois	2.42	2.14	1.95	4,385,524	4,468,320	3,332,258
Indiana	2.53	1.99	1.8	1,990,958	1,848,790	1,599,444
Iowa	2.37	1.99	1.85	4,427,871	4,466,356	4,000,625
Kansas	2.51	2.12	2.1	753,000	915,840	978,075
Kentucky	2.53	2.24	2.05	374,339	388,147	319,308
Louisiana	2.4	2.45	2.25	160,800	135,608	100,980
Maryland	2.83	2.17	2	142,717	141,104	108,000
Michigan	2.37	1.97	1.7	615,821	506,842	491,062
Minnesota	2.35	1.94	1.75	2,281,615	2,174,643	2,085,825
Mississippi	2.28	2.43	2.15	163,134	145,411	101,233
Missouri	2.46	2.03	1.9	743,904	947,117	626,373
Montana	2.65	2.42	2.4	6,307	5,191	6,038
Nebraska	2.39	2.02	1.85	2,686,838	2,665,794	2,350,425
New Jersey	2.81	2.2	2	19,369	22,651	15,128
New Mexico	2.96	2.4	2.5	25,574	25,056	24,063
New York	2.82	2.37	2.05	150,137	144,570	116,932
North Carolina	2.68	2.44	2.25	193,174	211,255	189,000
North Dakota	2.37	1.88	1.8	310,565	227,010	278,640
Ohio	2.45	2.04	1.8	1,173,354	1,002,415	836,550
Oklahoma	2.6	2.53	2.4	61,750	75,900	69,000
Oregon	3.08	2.75	2.6	15,708	13,090	10,400
Pennsylvania	2.96	2.25	2.2	302,956	308,700	257,664
South Carolina	2.7	2.3	2.1	60,953	67,850	69,426
South Dakota	2.28	1.82	1.7	974,358	981,890	799,085
Tennessee	2.37	2.17	1.95	192,491	186,837	150,833
Texas	2.59	2.6	2.5	504,273	607,152	527,250
Utah	2.99	2.56	2.35	6,025	4,762	4,597
Virginia	2.57	2.17	2.1	97,532	113,274	89,208
Washington	3	2.97	2.75	40,950	62,370	45,100
West Virginia	2.72	2.2	2	8,446	8,358	6,104
Wisconsin	2.35	2.15	1.85	863,978	760,240	794,020
Wyoming	2.5	2.48	2.45	16,125	16,244	16,807
US	**2.42**	**2.06**	**1.9**	**24,476,803**	**24,381,294**	**21,040,707**

Source:
USDA, *2006 Agricultural Statistics*. Table 1-39,
http://www.nass.usda.gov/Publications/Ag_Statistics/index.asp

[a] States with no data are not listed.
[b] Preliminary.

These data show that government subsidies are vital to ensuring a profit to farmers, when land and labor opportunity costs are considered. However, many farmers only factor operating costs into the calculation, making corn the most profitable commodity crop in most regions of the country. If the residue from corn production also had a market as a bioenergy feedstock, then farmers in areas of high corn yield may come closer to making a profit without subsidies.

Table 5.6
Corn Production Costs and Returns per Planted Acre, Excluding Government Payments, 2002—2003[a]
(dollars per planted acre)

	United States		Heartland		Northern Crescent		Northern Great Planes	
Item	**2002**	**2003**	**2002**	**2003**	**2002**	**2003**	**2002**	**2003**
Gross value of production								
Primary product: Corn grain	310.88	317.37	326.6	329.7	294.64	296.7	211.85	220.32
Secondary product: Corn silage	1.94	2.25	1.33	1.36	4.73	5.62	4.55	5.4
Total, gross value of production	**312.82**	**319.62**	**327.93**	**331.06**	**299.37**	**302.32**	**216.4**	**225.72**
Operating costs:								
Seed	31.84	34.83	31.6	34.89	33.17	35.48	26.18	32.47
Fertilizer	35.49	43.41	37.24	45	35.51	41.54	23.36	31.31
Soil conditioners	0.12	0.13	0.09	0.09	0.45	0.49	0	0
Manure	2.13	2.47	1.37	1.6	8.78	9.95	2.03	2.22
Chemicals	26.11	26.2	26.22	26.5	25.43	25.77	20.64	20.5
Custom operations[b]	10.79	11.17	9.69	10.09	11.47	12.09	10.38	10.72
Fuel, lube, and electricity	18.93	23.06	15.28	18.81	17.6	22.31	16.65	20.02
Repairs	13.91	14.22	12.35	12.63	14.54	14.9	13.83	14.3
Purchased irrigation water	0.22	0.22	0	0	0	0	2.02	1.94
Interest on operating capital	1.17	0.82	1.13	0.79	1.24	0.86	0.97	0.71
Total, operating costs	**140.71**	**156.53**	**134.97**	**150.4**	**148.19**	**163.39**	**116.06**	**134.19**
Allocated overhead:								
Hired labor	3.06	3.14	2.19	2.3	3.63	3.72	5.26	5.3
Opportunity cost of unpaid labor	25.74	26.53	23.03	23.79	34.17	34.8	21.75	22.62
Capital recovery of machinery and equipment	55.26	56.67	51.87	53.06	59.43	60.99	51.74	53.78
Opportunity cost of land (rental rate)	87.44	89.2	98.83	100.28	67.44	68.88	52.28	53.65
Taxes and insurance	5.42	5.54	5.07	5.19	5.65	5.8	5.01	5.1
General farm overhead	11.91	12.17	10.69	10.93	15.85	16.22	11.07	11.45
Total, allocated overhead	**188.83**	**193.25**	**191.68**	**195.55**	**186.17**	**190.41**	**147.11**	**151.9**
Total, costs listed	**329.54**	**349.78**	**326.65**	**345.95**	**334.36**	**353.8**	**263.17**	**286.09**
Value of production less total costs listed	-16.72	-30.16	1.28	-14.89	-34.99	-51.48	-46.77	-60.37
Value of production less operating costs	172.11	163.09	192.96	180.66	151.18	138.93	100.34	91.53
Supporting information:								
Yield (bushels per planted acre)	134	149	142	157	127	138	95	108
Price (dollars per bushel at harvest)	2.32	2.13	2.3	2.1	2.32	2.15	2.23	2.04
Enterprise size (planted acres) [a]	236	236	270	270	138	138	281	281
Production practices: [a]								
Irrigated (percent)	14	14	5	5	4	4	28	28
Dryland (percent)	86	86	95	95	96	96	72	72

Continued on next page.

Table 5.6 (Continued)
Corn Production Costs and Returns per Planted Acre, Excluding Government Payments, 2002—2003[a]
(dollars per planted acre)

	Prairie Gateway		Eastern Uplands		Southern Seaboard	
Item	**2002**	**2003**	**2002**	**2003**	**2002**	**2003**
Gross value of production						
Primary product: Corn grain	308.7	330.75	172.19	225.4	227.95	298.8
Secondary product: Corn silage	0.89	0.9	15.78	30.54	2	2.23
Total, gross value of production	**309.59**	**331.65**	**187.97**	**255.94**	**229.95**	**301.03**
Operating costs:						
Seed	34.62	35.41	29.67	35.02	31.96	33.36
Fertilizer	31.45	41.3	37.1	45.57	42.19	44.74
Soil conditioners	0.02	0.02	0.75	0.71	0.47	0.49
Manure	0.79	0.95	2.57	3.16	2.1	2.23
Chemicals	28.76	28.04	23.48	24.74	24.91	24.86
Custom operations[b]	15.72	16.16	7.79	9.68	12.22	12.76
Fuel, lube, and electricity	39.16	47.93	6.86	10.54	14.63	20.21
Repairs	20.66	21.6	10.09	10.95	16.42	17.15
Purchased irrigation water	0.59	0.63	0	0	0	0
Interest on operating capital	1.45	1.01	1	0.74	1.22	0.82
Total, operating costs	**173.22**	**193.05**	**119.31**	**141.11**	**146.12**	**156.62**
Allocated overhead:						
Hired labor	5.35	5.48	3.92	4.22	6.51	6.73
Opportunity cost of unpaid labor	31.2	32.74	47.54	48.46	33.94	35.15
Capital recovery of machinery and equipment	70.09	73.28	44.05	47.79	54.06	56.36
Opportunity cost of land (rental rate)	71.02	73.48	48.67	50.12	50.48	51.32
Taxes and insurance	6.54	6.74	6.07	6.2	9.84	10.13
General farm overhead	14.58	14.99	12.22	12.53	16.67	16.96
Total, allocated overhead	**198.78**	**206.71**	**162.47**	**169.32**	**171.5**	**176.65**
Total, costs listed	**372**	**399.76**	**281.78**	**310.43**	**317.62**	**333.27**
Value of production less total costs listed	-62.41	-68.11	-93.81	-54.49	-87.67	-32.24
Value of production less operating costs	136.37	138.6	68.66	114.83	83.83	144.41
Supporting information:						
Yield (bushels per planted acre)	126	147	67	98	97	120
Price (dollars per bushel at harvest)	2.45	2.25	2.57	2.3	2.35	2.49
Enterprise size (planted acres)[a]	346	346	72	72	78	78
Production practices:[a]						
Irrigated (percent)	61	61	1	1	21	21
Dryland (percent)	39	39	99	99	79	79

Source:
Economic Research Service. US Department of Agriculture, http://www.ers.usda.gov/data/costsandreturns/testpick.htm

[a] Developed from survey base year, 2001.
[b] Cost of custom operations, technical services, and commercial drying.

This table shows the historical trends of ups and downs in corn grain prices and the consequent effect on profitability.

Table 5.7
Corn Production Costs and Returns per Planted Acre, Excluding Government Payments, 1996—2003[a]
(dollars per planted acre)

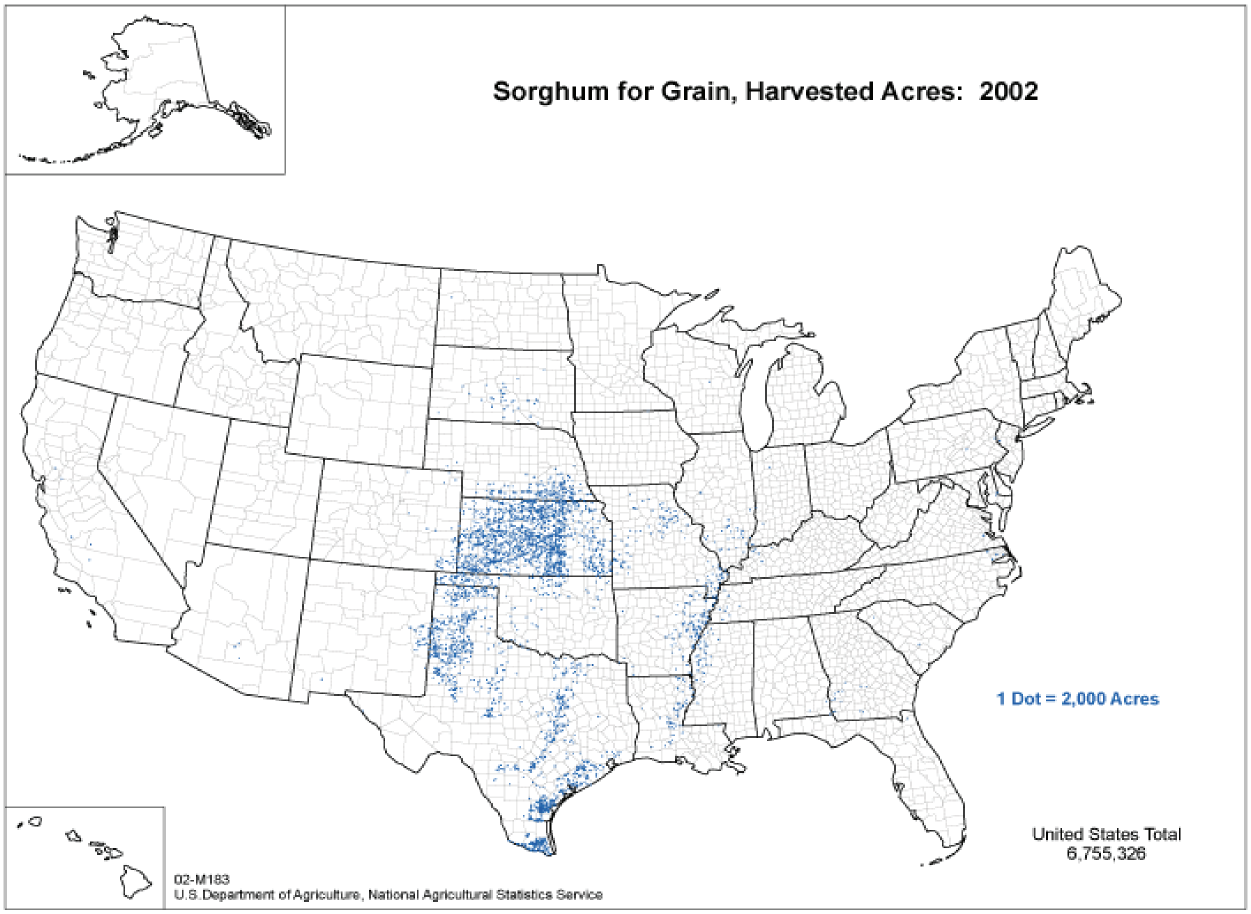
Item	1996	1997	1998	1999	2000	2001	2002	2003
Gross value of production								
Primary product: Corn grain	366.46	327.60	259.76	228.15	244.26	264.96	310.88	317.37
Secondary product: Corn silage	3.47	3.77	3.12	2.55	2.41	1.96	1.94	2.25
Total, gross value of production	**369.93**	**331.37**	**262.88**	**230.70**	**246.67**	**266.92**	**312.82**	**319.62**
Operating costs:								
Seed	26.65	28.71	30.02	30.29	30.02	32.34	31.84	34.83
Fertilizer	47.04	46.21	41.44	38.75	39.04	47.72	35.49	43.41
Soil conditioners	0.16	0.16	0.16	0.17	0.16	0.12	0.12	0.13
Manure	0.60	0.56	0.51	0.49	0.48	2.65	2.13	2.47
Chemicals	27.42	26.87	27.36	28.40	28.82	26.44	26.11	26.20
Custom operations	11.30	11.30	11.29	11.37	11.48	10.94	10.79	11.17
Fuel, lube, and electricity	24.43	24.55	22.96	23.04	29.12	20.88	18.93	23.06
Repairs	15.78	16.17	16.65	17.17	17.55	13.76	13.91	14.22
Purchased irrigation water	0.30	0.32	0.31	0.31	0.31	0.22	0.22	0.22
Interest on operating capital	3.86	3.96	3.61	3.50	4.53	2.60	1.17	0.82
Total, operating costs	**157.54**	**158.81**	**154.31**	**153.49**	**161.51**	**157.67**	**140.71**	**156.53**
Allocated overhead:								
Hired labor	2.83	3.07	3.19	3.28	3.36	2.92	3.06	3.14
Opportunity cost of unpaid labor	28.99	29.89	30.63	31.43	32.21	24.96	25.74	26.53
Capital recovery of machinery and equipment	63.02	64.50	66.46	68.49	70.16	54.69	55.26	56.67
Opportunity cost of land (rental rate)	80.79	84.81	86.35	86.77	89.36	86.50	87.44	89.20
Taxes and insurance	6.98	7.00	7.05	6.96	7.13	5.49	5.42	5.54
General farm overhead	10.38	12.21	11.47	10.88	11.11	11.67	11.91	12.17
Total, allocated overhead	**192.99**	**201.48**	**205.15**	**207.81**	**213.33**	**186.23**	**188.83**	**193.25**
Total, costs listed	**350.53**	**360.29**	**359.46**	**361.30**	**374.84**	**343.90**	**329.54**	**349.78**
Value of production less total costs listed	19.40	-28.92	-96.58	-130.60	-128.17	-76.98	-16.72	-30.16
Value of production less operating costs	212.39	172.56	108.57	77.21	85.16	109.25	172.11	163.09
Supporting information:								
Yield (bushels per planted acre)	130	130	136	135	138	144	134	149
Price (dollars per bushel at harvest)	2.82	2.52	1.91	1.69	1.77	1.84	2.32	2.13
Enterprise size (planted acres)	189	189	189	189	189	236	236	236
Production practices:								
Irrigated (percent)	15	15	15	15	15	14	14	14
Dryland (percent)	85	85	85	85	85	86	86	86

Source:
Economic Research Service. U.S. Department of Agriculture, http://www.ers.usda.gov/data/costsandreturns/testpick.htm

[a] 1996-2000 estimates developed from survey base year, 1996. 2001-03 estimates developed from survey base year, 2001.

Sorghum is currently a small contributor to ethanol production, but because it is largely grown in an area of the country that does not significantly overlap with corn production, it could become important in expanding the range of locations of ethanol production facilities.

Figure 5.6
Sorghum for Grain, Harvested Acres, 2002



Source:
U.S. Department of Agriculture, National Agricultural Statistics Service,
www.nass.usda.gov/research/atlas02/atlas-crops.html

Sorghum is grown in areas that are generally too dry for unirrigated corn, thus potential resource areas for starch based ethanol can be expanded through use of sorghum. Grain weight per bushel is 56 lbs. at assumed harvest moisture content of 14%.

Table 5.8
Sorghum: Area, Yield, Production, and Value, 1996—2005

Year	Area Planted for all purposes[a]	Sorghum for grain[b]					Sorghum for silage		
		Area harvested	Yield per harvested acre	Production	Marketing year average price per cwt[cd]	Value of production[cd]	Area Harvested	Yield per harvested acre	Production
	1,000 Acres	1,000 Acres	Bushels	1,000 Bushels	Dollars	1,000 Dollars	1,000 Acres	Tons	1,000 Tons
1996	13,097	11,811	67.3	795,274	4.17	1,986,316	423	11.8	4,976
1997	10,052	9,158	69.2	633,545	3.95	1,408,534	412	13.1	5,385
1998	9,626	7,723	67.3	519,933	2.97	904,123	308	11.4	3,526
1999	9,288	8,544	69.7	595,166	2.8	937,081	320	11.6	3,716
2000	9,195	7,726	60.9	470,526	3.37	845,755	278	10.5	2,932
2001	10,248	8,579	59.9	514,040	3.46	978,783	352	11	3,860
2002	9,589	7,125	50.6	360,713	4.14	855,140	408	9.6	3,913
2003	9,420	7,798	52.7	411,237	4.26	964,978	343	10.4	3,552
2004	7,486	6,517	69.6	453,654	3.19	843,464	352	13.6	4,776
2005[d]	6,454	5,736	68.7	393,893	3.04	715,327	311	13.6	4,218

Source:
USDA, *2006 Agricultural Statistics*, Table 1-59.

[a] Grain and sweet sorghum for all uses, including syrup.
[b] Includes both grain sorghum for grain, and sweet sorghum for grain or seed.
[c] Based on the reported price of grain sorghum; cwt = 100 pounds.
[d] Preliminary.

Sorghum is used for ethanol production only in the two states that planted over 3 million acres, Kansas and Texas.

Table 5.9
Sorghum: Area, Yield, and Production, by State, 2003—2005

State	Area planted for all purposes			Sorghum for grain: Area harvested			Sorghum for grain: Yield per harvested acre			Sorghum for grain: Production		
	2003	2004	2005[a]	2003	2004	2005[a]	2003	2004	2005[a]	2003	2004	2005[a]
	1,000 Acres	1,000 Acres	1,000 Acres	1,000 Acres	1,000 Acres	1,000 Acres	Bushels	Bushels	Bushels	1,000 Bushels	1,000 Bushels	1,000 Bushels
Alabama	10	10	10	6	6	6	45	43	53	270	258	318
Arizona	17	20	23	6	6	7	90	95	95	540	570	665
Arkansas	225	60	66	210	56	62	82	84	80	17,220	4,704	4,960
California	18	28	26	10	12	10	90	90	90	900	1,080	900
Colorado	270	280	160	160	180	110	27	30	31	4,320	5,400	3,410
Delaware[b]	2	2	....	1	1	....	70	83	....	70	83	....
Georgia	55	45	40	38	25	27	47	47	50	1,786	1,175	1,350
Illinois	110	85	85	105	82	83	82	109	92	8,610	8,938	7,636
Kansas	3,550	3,200	2,750	2,900	2,900	2,600	45	76	75	130,500	220,400	195,000
Kentucky	33	15	25	32	13	24	95	80	90	3,040	1,040	2,160
Louisiana	170	85	90	165	80	88	85	65	99	14,025	5,200	8,712
Maryland[b]	6	5	....	3	4	....	65	84	....	195	336	....
Mississippi	75	20	25	73	18	23	84	79	80	6,132	1,422	1,840
Missouri	215	150	135	210	145	130	77	108	76	16,170	15,660	9,880
Nebraska	660	550	340	500	415	250	62	78	87	31,000	32,370	21,750
New Mexico	140	140	120	62	92	97	27	46	45	1,674	4,232	4,365
North Carolina	18	17	16	14	14	13	50	52	50	700	728	650
Oklahoma	300	270	270	250	240	240	37	60	52	9,250	14,400	12,480
Pennsylvania	15	12	11	5	4	4	87	83	50	435	332	200
South Carolina	7	7	10	5	5	7	52	52	51	260	260	357
South Dakota	270	250	180	150	150	85	45	42	52	6,750	6,300	4,420
Tennessee	45	20	22	40	17	20	82	90	92	3,280	1,530	1,840
Texas	3,200	2,210	2,050	2,850	2,050	1,850	54	62	60	153,900	127,100	111,000
Virginia[b]	9	5	....	3	2	....	70	68	....	210	136	....
US	**9,420**	**7,486**	**6,454**	**7,798**	**6,517**	**5,736**	**52.7**	**69.6**	**68.7**	**411,237**	**453,654**	**393,893**

Source:
USDA, *2006 Agricultural Statistics*, Table 1-62,
http://www.nass.usda.gov/Publications/Ag_Statistics/index.asp

[a] Preliminary.
[b] Estimates discontinued in 2005.

Sorghum is grown primarily for animal feed. About 11% of sorghum grain was used in the production of ethanol in 2004. This would account for most of the grain shown in the food, seed and industrial category in 2004.

Table 5.10
Sorghum: Supply and Disappearance, 1996—2005
(million bushels)

Year (beginning September 1)	Supply			Disappearance					Ending stocks August 31		
				Domestic use							
	Beginning stocks	Production	Total	Feed and residual	Food, seed, and industrial	Total	Exports	Total disappear-ance	Privately owned [a]	Govern-ment	Total
1996	18	795	814	516	45	561	205	766	47	0	47
1997	47	634	681	365	55	420	212	632	49	0	49
1998	49	520	569	262	45	307	197	504	65	0	65
1999	65	595	660	285	55	340	255	595	65	0	65
2000	65	471	536	222	35	258	237	494	41	1	42
2001	42	514	556	230	23	253	242	495	61	0	61
2002	61	361	422	170	24	194	184	379	43	0	43
2003	43	411	454	182	40	222	199	421	34	0	34
2004 [b]	34	454	487	191	55	246	184	430	57	0	57
2005 [c]	57	394	451	150	55	205	170	375	76	0	76

Source:
USDA, *2006 Agricultural Statistics*, Table 1-61,
http://www.nass.usda.gov/Publications/Ag_Statistics/index.asp

Note: Totals may not add due to independent rounding.

[a] Includes quantity under loan and farmer–owned reserve.
[b] Preliminary.
[c] Projected as of January 12, 2006, World Agricultural and Supply Demand Estimates.

The lower yields of sorghum grain results in lower profit in sorghum production compared to corn. Sorghum biomass production can be quite high, making it a potential source of crop residue in some areas of the country.

Table 5.11
Sorghum Production Costs and Returns per Planted Acre, Excluding Government Payments, 2002—2003[a]
(dollars per planted acre)

Item	United States		Eastern Uplands		Heartland		Mississippi Portal		Prairie Gateway	
	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003
Gross value of production:										
Sorghum	95.37	101.25	126.72	135.6	153.78	124.32	176.79	176.28	86.49	96.75
Total, gross value of production	**95.37**	**101.25**	**126.72**	**135.6**	**153.78**	**124.32**	**176.79**	**176.28**	**86.49**	**96.75**
Operating costs:										
Seed	6.63	6.48	7.59	7.77	9.18	9.4	10.99	11.25	6.03	6.17
Fertilizer[b]	15.1	18.17	24.08	29.03	25.32	30.53	24.21	29.19	13.87	16.72
Chemicals	11.22	11.56	11.01	11.2	18.43	18.74	18.65	18.96	10.85	11.03
Custom operations	4.38	3.89	7.15	7.33	5.64	5.78	9.14	9.37	3.43	3.52
Fuel, lube, and electricity	24.92	32.74	38.03	47.54	30.88	38.6	13.01	16.26	25.52	31.9
Repairs	17.48	17.94	20.59	21.06	15.68	16.04	20.09	20.55	17.45	17.85
Interest on operating inputs	0.67	0.48	0.91	0.66	0.88	0.63	0.81	0.56	0.65	0.46
Total, operating costs	**80.4**	**91.26**	**109.36**	**124.59**	**106.01**	**119.72**	**96.9**	**106.14**	**77.8**	**87.65**
Allocated overhead:										
Hired labor	7.45	7.16	3.21	3.29	2.68	2.75	13.17	13.51	7.33	7.52
Opportunity cost of unpaid labor	22.98	23.73	28.98	29.74	21.77	22.34	15.06	15.45	23.04	23.64
Capital recovery of machinery and equipment	60.91	62.55	71.47	72.44	54.52	55.26	65.29	66.17	61.59	62.42
Opportunity cost of land	21.49	23.1	36.53	38.94	65.15	53.16	40.71	40.37	18.02	20.25
Taxes and insurance	5.04	5.35	7.33	7.45	7.5	7.62	7.35	7.47	5	5.08
General farm overhead	4.39	4.59	11.05	11.3	3.23	3.3	4.18	4.28	4.23	4.33
Total, allocated overhead	122.26	126.48	158.57	163.16	154.85	144.43	145.76	147.25	119.21	123.24
Total costs listed	**202.66**	**217.74**	**267.93**	**287.75**	**260.86**	**264.15**	**242.66**	**253.39**	**197.01**	**210.89**
Value of production less total costs listed	-107.29	-116.49	-141.21	-152.15	-107.08	-139.83	-65.87	-77.11	-110.52	-114.14
Value of production less operating costs	14.97	9.99	17.36	11.01	47.77	4.6	79.89	70.14	8.69	9.1
Supporting information:										
Sorghum Yield: bushels per planted acre	33	45	48	60	66	56	71	78	31	43
Price: dollars per bushel	2.89	2.25	2.64	2.26	2.33	2.22	2.49	2.26	2.79	2.25
Production practices:[a]										
Irrigated (percent)	9	9	1	1	2	2	5	5	10	10
Dryland (percent)	91	91	99	99	98	98	95	95	90	90
Land tenure:[a]										
Acres owned (percent)	31	31	30	30	41	41	15	15	32	32
Acres cash rented (percent)	16	16	27	27	11	11	22	22	16	16
Acres share rented (percent)	53	53	43	43	48	48	62	62	53	53
Land rent basis[c]	Composite	Composite	Cash	Cash	Cash	Cash	Share	Share	Share	Share

Source:
Economic Research Service, U.S. Department of Agriculture, http://www.ers.usda.gov/data/costsandreturns/testpick.htm

[a] Developed from survey base year, 1995.
[b] Commercial fertilizer and soil conditioners.
[c] Method used to determine the opportunity cost of land.

Sorghum costs and returns are quite variable, like corn. Sorghum is produced on lower cost, higher risk land, resulting in considerable yield variability.

Table 5.12
Sorghum Production Costs and Returns per Planted Acre, Excluding Government Payments, 1995—2003[a]
(dollars per planted acre)

Item	1995	1996	1997	1998	1999	2000	2001	2002	2003
Gross value of production:									
Sorghum	143	170.1	153.43	96.66	96.66	88.62	93.86	95.37	101.25
Total, gross value of production	**143**	**170.1**	**153.43**	**96.66**	**96.66**	**88.62**	**93.86**	**95.37**	**101.25**
Operating costs:									
Seed	5.42	6	6.57	6.72	6.72	6.33	6.35	6.63	6.48
Fertilizer[b]	19.19	17.99	17.62	13.89	13.89	14.34	21.53	15.1	18.17
Chemicals	12.63	12.29	11.69	11.2	11.2	11.15	11.31	11.22	11.56
Custom operations	5.07	6.23	6.91	6.78	6.78	5.48	5.27	4.38	3.89
Fuel, lube, and electricity	14.13	17.1	17.37	21.92	21.92	26.09	29.99	24.92	32.74
Repairs	12.89	13.81	14.25	14.7	14.7	15.29	16.28	17.48	17.94
Interest on operating inputs	1.91	1.85	1.9	1.77	1.77	2.27	1.53	0.67	0.48
Total, operating costs	**71.24**	**75.27**	**76.31**	**76.98**	**76.98**	**80.95**	**92.26**	**80.4**	**91.26**
Allocated overhead:									
Hired labor	4.98	5.41	5.68	6.36	6.36	6.57	7.06	7.45	7.16
Opportunity cost of unpaid labor	17.58	18.58	19.16	20.38	20.38	20.8	21.32	22.98	23.73
Capital recovery of machinery and equipment	51.49	53.49	55.38	55.79	55.79	56.7	58.23	60.91	62.55
Opportunity cost of land	33.02	39.2	36.18	23.53	23.53	21.02	20.63	21.49	23.1
Taxes and insurance	5.06	4.98	5.02	4.9	4.9	5.07	5.1	5.04	5.35
General farm overhead	3.68	3.76	3.84	3.97	3.97	4.08	4.23	4.39	4.59
Total, allocated overhead	**115.81**	**125.42**	**125.26**	**114.93**	**114.93**	**114.24**	**116.57**	**122.26**	**126.48**
Total costs listed	**187.05**	**200.69**	**201.57**	**191.91**	**191.91**	**195.19**	**208.83**	**202.66**	**217.74**
Value of production less total costs listed	-44.05	-30.59	-48.14	-95.25	-95.25	-106.57	-114.97	-107.29	-116.49
Value of production less operating costs	71.76	94.83	77.12	19.68	19.68	7.67	1.6	14.97	9.99
Supporting information:									
Sorghum Yield: bushels per planted acre	52	63	67	54	54	42	38	33	45
Price: dollars per bushel	2.75	2.7	2.29	1.79	1.79	2.11	2.47	2.89	2.25
Production practices:[a]									
Irrigated (percent)	9	9	9	9	9	9	9	9	9
Dryland (percent)	91	91	91	91	91	91	91	91	91
Land tenure:[a]									
Acres owned (percent)	31	31	31	31	31	31	31	31	31
Acres cash rented (percent)	16	16	16	16	16	16	16	16	16
Acres share rented (percent)	53	53	53	53	53	53	53	53	53
Land rent basis[c]	Composite	Composite	Composite	Composite	Composite	Composite	Composite	Composite	Composite

Source:
Economic Research Service, U.S. Department of Agriculture,
http://www.ers.usda.gov/data/costsandreturns/testpick.htm

[a] Developed from survey base year, 1995.
[b] Commercial fertilizer and soil conditioners.
[c] Method used to determine the opportunity cost of land.

USDA's 2005 soybean baseline projections do not specifically show oil produced for use as a biofuel and do not reflect in the projections the probable increase in demand for soybean oil as a biofuel which is anticipated due to the Energy Policy Act of 2005. It is likely that future USDA soybean baseline projections will reflect the market changes.

Table 5.13
Soybeans and Products Baseline, 2004—2015

Item	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15
Area (million acres):												
Planted	73.4	75.1	74.0	73.8	73.3	73.0	72.8	73.0	73.0	72.8	72.8	72.8
Harvested	72.5	74.0	72.7	72.4	71.9	71.7	71.4	71.7	71.7	71.4	71.4	71.4
Yield/harvested acre (bushels	33.9	42.6	40.0	40.4	40.8	41.2	41.6	42.0	42.4	42.8	43.2	43.6
Supply (million bushels)												
Beginning stocks, Sept 1	178	112	460	400	330	255	230	210	209	210	207	209
Production	2,454	3,150	2,910	2,925	2,935	2,955	2,970	3,010	3,040	3,055	3,085	3,115
Imports	6	6	3	4	4	5	4	4	3	4	5	4
Total supply	2,638	3,269	3,373	3,329	3,269	3,215	3,204	3,224	3,252	3,269	3,297	3,328
Disposition (million bushels)												
Crush	1,530	1,645	1,725	1,745	1,765	1,780	1,810	1,830	1,855	1,880	1,905	1,930
Seed and residual	111	153	148	149	149	150	154	155	157	157	158	159
Exports	885	1,010	1,100	1,105	1,100	1,055	1,030	1,030	1,030	1,025	1,025	1,030
Total disposition	2,525	2,808	2,973	2,999	3,014	2,985	2,994	3,015	3,042	3,062	3,088	3,119
Carryover stocks, August 31												
Total ending stocks	112	460	400	330	255	230	210	209	210	207	209	209
Stocks/use ratio, percent	4.4	16.4	13.5	11.0	8.5	7.7	7.0	6.9	6.9	6.8	6.8	6.7
Prices (dollars per bushel)												
Loan rate	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Soybean price, farm	7.34	4.95	4.50	4.60	4.85	5.25	5.50	5.55	5.60	5.65	5.65	5.70
Variable costs of production (dollars):												
Per acre	79.15	81.26	82.30	83.54	84.22	84.91	85.59	86.29	87.02	87.77	88.55	89.36
Per bushel	2.33	1.91	2.06	2.07	2.06	2.06	2.06	2.05	2.05	2.05	2.05	2.05
Returns over variable costs (dollars per acre):												
Net returns [a]	169.68	140.26	125.70	126.54	127.94	131.39	143.21	146.81	150.42	154.05	155.53	159.16
Soybean oil (million pounds)												
Beginning stocks, Oct. 1	1,491	1,057	1,187	1,487	1,682	1,877	1,962	2,107	2,127	2,077	1,937	1,752
Production	17,077	18,425	19,390	19,630	19,875	20,060	20,415	20,660	20,960	21,265	21,565	21,865
Imports	307	105	110	115	120	125	130	135	140	145	150	155
Total supply	18,875	19,587	20,687	21,232	21,677	22,062	22,507	22,902	23,227	23,487	23,652	23,772
Domestic disappearance	16,881	17,300	17,650	18,000	18,350	18,675	19,025	19,375	19,725	20,100	20,475	20,850
Exports	937	1,100	1,550	1,550	1,450	1,425	1,375	1,400	1,425	1,450	1,425	1,350
Total demand	17,818	18,400	19,200	19,550	19,800	20,100	20,400	20,775	21,150	21,550	21,900	22,200
Ending stocks, Sept. 30	1,057	1,187	1,487	1,682	1,877	1,962	2,107	2,127	2,077	1,937	1,752	1,572
Soybean oil price ($/lb)	0.2997	0.230	0.205	0.198	0.200	0.205	0.208	0.213	0.218	0.223	0.230	0.235
Soybean meal (thousand short tons)												
Beginning stocks, Oct. 1	220	212	250	250	250	250	250	250	250	250	250	250
Production	36,318	39,173	41,035	41,485	41,985	42,385	43,035	43,585	44,135	44,710	45,285	45,985
Imports	270	165	165	165	165	165	165	165	165	165	165	165
Total supply	36,808	39,550	41,450	41,900	42,400	42,800	43,450	44,000	44,550	45,125	45,700	46,400
Domestic disappearance	32,256	33,900	34,500	35,150	35,650	36,150	36,700	37,250	37,800	38,375	38,950	39,550
Exports	4,340	5,400	6,700	6,500	6,500	6,400	6,500	6,500	6,500	6,500	6,500	6,600
Total demand	36,596	39,300	41,200	41,650	42,150	42,550	43,200	43,750	44,300	44,875	45,450	46,150
Ending stocks, Sept. 30	212	250	250	250	250	250	250	250	250	250	250	250
Soybean meal price ($/ton)	256.05	160.00	150.00	155.00	163.00	176.50	185.00	183.50	182.50	181.50	177.00	176.00
Crushing yields (pounds per bushel)												
Soybean oil	11.16	11.20	11.24	11.25	11.26	11.27	11.28	11.29	11.30	11.31	11.32	11.33
Soybean meal	47.48	47.62	47.60	47.60	47.60	47.60	47.60	47.60	47.60	47.60	47.60	47.60
Crush margin ($ per bushel)	2.08	1.44	1.37	1.31	1.28	1.26	1.24	1.22	1.20	1.19	1.17	1.15

Source:
USDA Agricultural Baseline Projections to 2014, February 2005 (OCE-2005-1), Table 13 - U.S. soybean and products, http://usda.mannlib.cornell.edu/data-sets/baseline/2005/index.html

[a] Net returns include estimates of marketing loan benefits.

In 2001, only 5 million gallons of biodiesel fuel was produced requiring a very small amount of all soybeans harvested. By 2005, about 75 million gallons of biodiesel fuel was produced with about 90% being derived from soybeans. At a conversion rate of 1.5 gallons of biodiesel per bushel of soybeans (Source: National Biodiesel Board), the total bushels of soybeans used in biodiesel production was approximately 45 million bushels or about 1.5% of all soybeans produced.

Table 5.14
Soybeans: Area, Yield, Production, and Value, 1996—2005

		Soybeans for beans				
Year	**Area Planted**	**Area harvested**	**Yield per acre**	**Production**	**Marketing year average price per bushel raised by farmers**	**Value of production**
	1,000 Acres	1,000 Acres	Bushels	1,000 Bushels	Dollars	1,000 Dollars
1996	64,195	63,349	37.6	2,380,274	7.35	17,439,971
1997	70,005	69,110	38.9	2,688,750	6.47	17,372,628
1998	72,025	70,441	38.9	2,741,014	4.93	13,493,891
1999	73,730	72,446	36.6	2,653,758	4.63	12,205,352
2000	74,266	72,408	38.1	2,757,810	4.54	12,466,572
2001	74,075	72,975	39.6	2,890,682	4.38	12,605,717
2002	73,963	72,497	38.0	2,756,147	5.53	15,252,691
2003	73,404	72,476	33.9	2,453,665	7.34	18,013,753
2004	75,208	73,958	42.2	3,123,686	5.74	17,894,948
2005	72,142	71,361	43.3	3,086,432	5.50	16,927,898

Source:
USDA, *2006 Agricultural Statistics*, Table 3-26,
http://www.nass.usda.gov/Publications/Ag_Statistics/index.asp

Table 5.15
Soybeans: Supply and Disappearance, 1995—2004
(thousand bushels)

Year beginning September	Supply				
	Stocks by Position				
	Farm	Terminal market, interior mill, elevator, and warehouse	Total	Production	Total[a]
1995	105,130	229,684	334,814	2,174,254	2,513,524
1996	59,523	123,935	183,458	2,380,274	2,572,636
1997	43,600	88,233	131,833	2,688,750	2,825,589
1998	84,300	115,499	199,799	2,741,014	2,944,334
1999	145,000	203,482	348,482	2,653,758	3,006,411
2000	112,500	177,662	290,162	2,757,810	3,051,540
2001	83,500	164,247	247,747	2,890,682	3,140,749
2002	62,700	145,361	208,061	2,756,147	2,968,869
2003	58,000	120,329	178,329	2,453,665	2,637,556
2004	29,400	83,014	112,414	3,123,686	3,241,676

Table continued	Disappearance			
Year beginning September	Crushed[c]	Seed, feed and residual	Exports	Total
1995	1,369,541	111,441	849,084	2,330,066
1996	1,436,961	118,954	885,888	2,440,803
1997	1,596,983	154,476	874,334	2,625,793
1998	1,589,787	201,414	804,651	2,595,852
1999	1,577,650	165,194	973,405	2,716,249
2000	1,639,670	168,252	995,871	2,803,793
2001	1,699,741	169,296	1,063,651	2,932,688
2002	1,615,464	131,380	1,044,372	2,790,540
2003	1,529,699	108,892	886,551	2,525,142
2004[b]	1,696,088	187,386	1,102,695	2,986,169

Source:
USDA, *2006 Agricultural Statistics*, Table 3-29,
http://www.nass.usda.gov/Publications/Ag_Statistics/index.asp

[a] Includes imports, beginning with 1988.
[b] Preliminary.
[c] Reported by the U.S. Department of Commerce.

Soybean production is highly variable by state, with the mid-west producing the largest amount. States with the highest production levels are Illinois and Iowa.

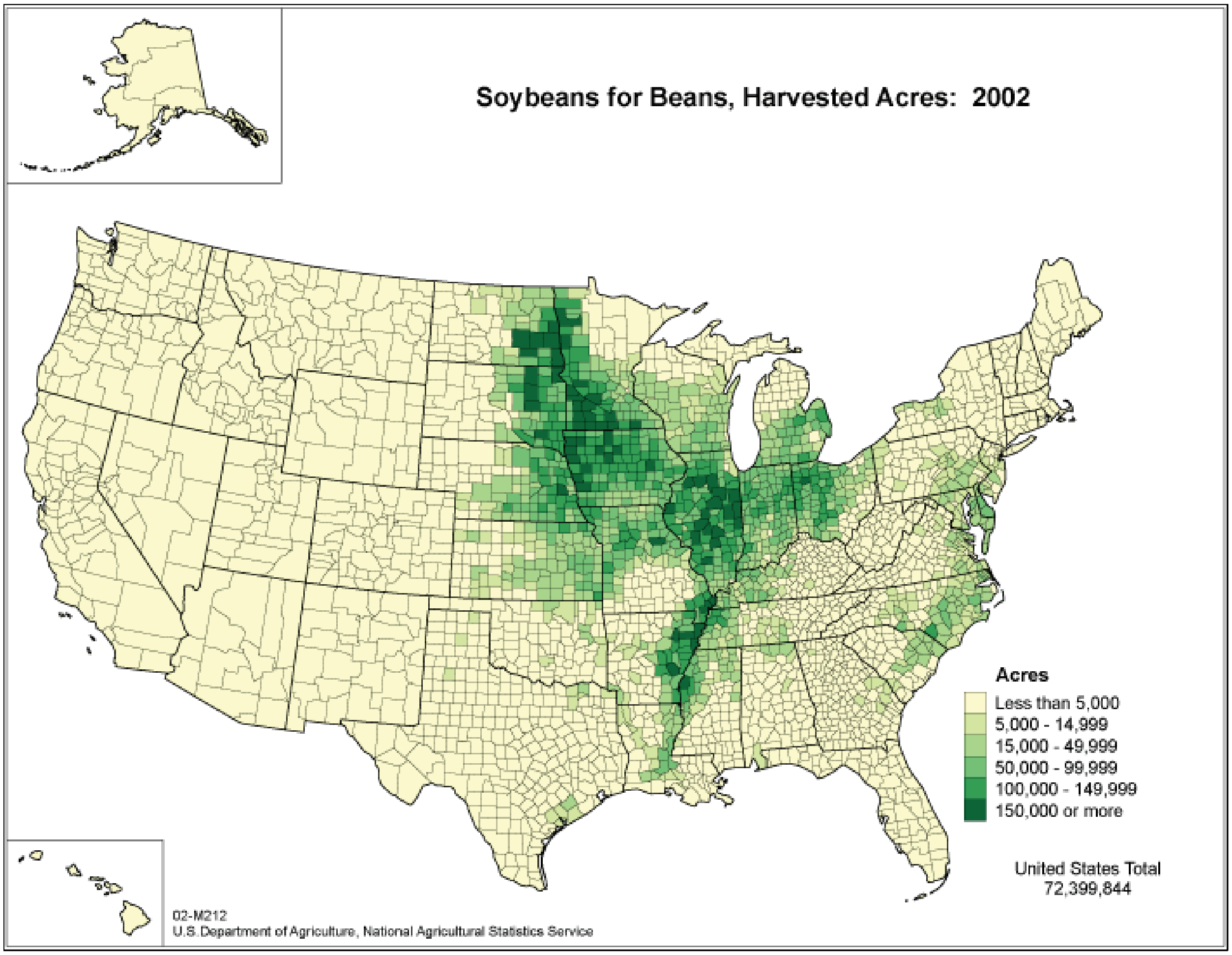
Table 5.16
Soybeans: Area, Yield, and Production, by State, 2003—2005

State	Area planted			Soybeans for beans								
				Area harvested			Yield per harvested acre			Production		
	2003	2004	2005	2003	2004	2005	2003	2004	2005	2003	2004	2005
	1,000 Acres	1,000 Acres	1,000 Acres	1,000 Acres	1,000 Acres	1,000 Acres	Bushels	Bushels	Bushels	1,000 Bushels	1,000 Bushels	1,000 Bushels
Alabama	170	210	150	160	190	145	36	35	33	5,760	6,650	4,785
Arizona	2,920	3,200	3,030	2,890	3,150	3,000	38.5	39	34	111,265	122,850	102,000
Delaware	180	210	185	178	208	182	36	42	26	6,408	8,736	4,732
Florida	13	19	9	12	17	8	30	34	32	360	578	256
Georgia	190	280	180	180	270	175	33	31	26	5,940	8,370	4,550
Illinois	10,300	9,950	9,500	10,260	9,900	9,450	37	50	47	379,620	495,000	444,150
Indiana	5,450	5,550	5,400	5,370	5,520	5,380	38	51.5	49	204,060	284,280	263,620
Iowa	10,600	10,200	10,100	10,550	10,150	10,050	32.5	49	53	342,875	497,350	532,650
Kansas	2,600	2,800	2,900	2,480	2,710	2,850	23	41	37	57,040	111,110	105,450
Kentucky	1,250	1,310	1,260	1,240	1,300	1,250	43.5	44	43	53,940	57,200	53,750
Louisiana	760	1,100	880	740	990	850	34	33	34	25,160	32,670	28,900
Maryland	435	500	480	430	495	470	37	43	34	15,910	21,285	15,980
Michigan	2,000	2,000	2,000	1,990	1,980	1,990	27.5	38	39	54,725	75,240	77,610
Minnesota	7,500	7,300	6,900	7,450	7,050	6,800	32	33	45	238,400	232,650	306,000
Mississippi	1,440	1,670	1,610	1,430	1,640	1,590	39	37.5	37	55,770	61,500	58,830
Missouri	5,000	5,000	5,000	4,950	4,960	4,960	29.5	45	37	146,025	223,200	183,520
Nebraska	4,550	4,800	4,700	4,500	4,750	4,660	40.5	46	50.5	182,250	218,500	235,330
New Jersey	90	105	95	88	103	91	34	42	28	2,992	4,326	2,548
New York	140	175	190	138	172	188	35	39	42	4,830	6,708	7,896
North Carolina	1,450	1,530	1,490	1,400	1,500	1,460	30	34	27	42,000	51,000	39,420
North Dakota	3,150	3,750	2,950	3,050	3,570	2,900	29	23	37	88,450	82,110	107,300
Ohio	4,300	4,450	4,500	4,280	4,420	4,480	38.5	47	45	164,780	207,740	201,600
Oklahoma	270	320	325	245	290	305	26	30	26	6,370	8,700	7,930
Pennsylvania	380	430	430	375	425	420	41	46	41	15,375	19,550	17,220
South Carolina	430	540	430	420	530	420	28	27	20.5	11,760	14,310	8,610
South Dakota	4,250	4,150	3,900	4,200	4,120	3,850	27.5	34	36	115,500	140,080	138,600
Tennessee	1,150	1,210	1,130	1,120	1,180	1,100	42	41	38	47,040	48,380	41,800
Texas	200	290	260	185	270	230	29	32	26	5,365	8,640	5,980
Virginia	500	540	530	480	530	510	34	39	30	16,320	20,670	15,300
West Virginia	16	19	18	15	18	17	41	46	35	615	828	595
Wisconsin	1,720	1,600	1,610	1,670	1,550	1,580	28	34.5	44	46,760	53,475	69,520
US	**73,404**	**75,208**	**72,142**	**72,476**	**73,958**	**71,361**	**33.9**	**42.2**	**43.3**	**2,453,665**	**3,123,686**	**3,086,432**

Source:
USDA, *2006 Agricultural Statistics*, Table 3-31,
http://www.nass.usda.gov/Publications/Ag_Statistics/index.asp

Soybean production area is similar to corn production area, with the addition of more area in North and South Dakota and along the Mississippi Delta.

Figure 5.7
Soybeans for Beans, Harvested Acres, 2002



Source:
U.S. Department of Agriculture, National Agricultural Statistics Service,
http://www.nass.usda.gov/research/atlas02/atlas-crops.html

As with all agricultural crops, soybean costs and returns per acre vary by region. In general, soybean returns are a little less than returns for corn when only operating costs are considered.

Table 5.17
Soybean Production Costs and Returns per Planted Acre, Excluding Government Payments, 2002—2003[a]
(dollars per planted acre)

Item	United States		Heartland		Northern Crescent		Northern Great Plains	
	2002	2003	2002	2003	2002	2003	2002	2003
Gross value of production								
Primary product: Soybeans	210.64	233.61	225.59	237.02	213.96	194.46	175.39	184.84
Total, gross value of production	**210.64**	**233.61**	**225.59**	**237.02**	**213.96**	**194.46**	**175.39**	**184.84**
Operating costs:								
Seed	25.45	27.42	25.72	27.78	25.65	27.46	22.39	26.76
Fertilizer	6.79	7.39	6.47	6.87	10.39	11.00	5.73	7.46
Soil conditioners	0.11	0.12	0.09	0.09	0.23	0.25	0.00	0.00
Manure	0.40	0.46	0.41	0.48	1.48	1.75	0.03	0.03
Chemicals	17.12	16.92	17.29	17.40	17.29	16.96	14.47	13.83
Custom operations	6.16	6.32	5.35	5.48	8.99	9.37	5.72	5.65
Fuel, lube, and electricity	6.98	8.73	5.72	7.16	8.27	10.30	6.46	7.84
Repairs	9.76	9.77	8.62	8.73	11.28	11.14	9.29	9.70
Purchased irrigation water	0.12	0.12	0.00	0.00	0.00	0.00	0.00	0.00
Interest on operating capital	0.61	0.41	0.59	1.39	0.70	0.47	0.54	0.38
Total, operating costs	**73.50**	**77.66**	**70.26**	**75.38**	**84.28**	**88.70**	**64.63**	**71.65**
Allocated overhead:								
Hired labor	1.84	1.90	1.19	1.24	3.14	3.26	1.72	1.84
Opportunity cost of unpaid labor	15.59	16.11	14.57	15.09	21.02	21.76	10.95	11.45
Capital recovery of machinery and equipment	43.30	43.43	40.22	40.68	49.03	48.44	40.59	42.52
Opportunity cost of land(rental rate)	80.74	81.93	94.12	95.93	69.13	69.41	44.87	46.17
Taxes and insurance	5.66	5.80	5.75	5.89	7.18	7.43	4.75	4.91
General farm overhead	11.37	11.66	11.81	12.10	13.61	14.10	9.36	9.65
Total, allocated overhead	158.50	160.83	167.66	170.93	163.11	164.40	112.24	116.54
Total costs listed	**232.00**	**238.49**	**237.92**	**246.31**	**247.39**	**253.10**	**176.87**	**188.19**
Value of production less total costs listed	-21.36	-4.88	-12.33	-9.29	-33.43	-58.64	-1.48	-3.35
Value of production less operating costs	137.14	155.95	155.33	161.64	129.68	105.76	110.76	113.19
Supporting information:								
Yield (bushels per planted acre)	40	36	43	36	41	30	35	30
Price (dollars per bushel at harvest)	5.20	6.56	5.19	6.57	5.18	6.50	5.02	6.17
Enterprise size (planted acres)[a]	268	268	280	280	135	135	460	460
Production practices:[a]								
Irrigated (percent)	9	9	5	5	3	3	3	3
Dryland (percent)	91	91	95	95	97	97	97	97

Continued on the next page.

Table 5.17 (Continued)
Soybean Production Costs and Returns per Planted Acre,
Excluding Government Payments, 2002—2003[a]
(dollars per planted acre)

	Prairie Gateway		Eastern Uplands		Southern Seaboard		Mississippi Portal	
Item	**2002**	**2003**	**2002**	**2003**	**2002**	**2003**	**2002**	**2003**
Gross value of production								
Primary product: Soybeans	169.54	226.37	157.71	242.83	124.46	223.83	201.29	303.21
Total, gross value of production	**169.54**	**226.37**	**157.71**	**242.83**	**124.46**	**223.83**	**201.29**	**303.21**
Operating costs:								
Seed	26.94	25.92	22.76	25.03	26.18	21.72	24.99	29.25
Fertilizer	3.89	4.82	12.24	13.49	11.00	11.43	7.06	7.59
Soil conditioners	0.03	0.03	0.36	0.35	0.91	0.97	0.06	0.07
Manure	0.20	0.24	0.16	0.18	0.18	0.17	0.00	0.00
Chemicals	15.25	14.53	16.52	15.79	17.97	18.20	19.67	18.06
Custom operations	7.20	7.43	6.16	6.31	10.85	11.15	7.87	8.11
Fuel, lube, and electricity	17.21	21.09	5.24	7.13	4.48	6.21	8.99	11.77
Repairs	12.94	13.12	7.85	7.86	7.47	7.39	16.59	15.50
Purchased irrigation water	1.71	1.80	0.00	0.00	0.00	0.00	0.00	0.00
Interest on operating capital	0.72	0.47	0.62	0.44	0.68	0.41	0.72	0.48
Total, operating costs	**86.09**	**89.45**	**71.91**	**76.58**	**79.72**	**77.65**	**85.95**	**90.83**
Allocated overhead:								
Hired labor	0.88	0.88	1.92	1.95	2.94	2.99	6.47	6.51
Opportunity cost of unpaid labor	22.63	23.56	16.41	16.93	19.13	20.02	15.93	16.24
Capital recovery of machinery and equipment	50.13	50.81	38.40	38.54	37.17	36.96	63.40	59.49
Opportunity cost of land(rental rate)	63.03	63.97	53.62	55.11	34.28	34.44	56.85	58.85
Taxes and insurance	4.32	4.44	3.77	3.85	4.50	4.56	6.48	6.64
General farm overhead	8.94	9.19	7.42	7.54	8.36	8.55	11.93	12.21
Total, allocated overhead	149.93	152.85	121.54	123.92	106.38	107.52	161.06	159.94
Total costs listed	**236.02**	**242.30**	**193.45**	**200.50**	**186.10**	**185.17**	**247.01**	**250.77**
Value of production less total costs listed	-66.48	-15.93	-35.74	42.33	-61.64	38.66	-45.72	52.44
Value of production less operating costs	83.45	136.92	85.80	166.25	44.74	146.18	115.34	212.38
Supporting information:								
Yield (bushels per planted acre)	33	34	29	37	23	32	37	45
Price (dollars per bushel at harvest)	5.18	6.59	5.47	6.82	5.41	7.00	5.41	6.68
Enterprise size (planted acres)[a]	246	246	171	171	180	180	538	538
Production practices:[a]								
Irrigated (percent)	32	32	8	8	0	0	43	43
Dryland (percent)	68	68	92	92	100	100	57	57

Source:
Economic Research Service, U.S. Department of Agriculture,
http://www.ers.usda.gov/data/costsandreturns/testpick.htm

[a] Developed from survey base year, 2002.

Secondary Biomass Feedstocks

Residues and byproduct streams from food, feed, fiber, wood, and materials processing plants are the main source of secondary biomass. Secondary biomass feedstocks differ from primary biomass feedstocks in that the secondary feedstocks are a by-product of processing of the primary feedstocks. By “processing” it is meant that there is substantial physical or chemical breakdown of the primary biomass and production of by-products. “Processors” may be factories or animals. Field processes such as harvesting, bundling, chipping or pressing do not cause a biomass resource that was produced by photosynthesis (e.g., tree tops and limbs) to be classified as secondary biomass.

Specific examples of secondary biomass includes sawdust from sawmills, black liquor (which is a by-product of paper making), and cheese whey (which is a by-product of cheese making processes). Manures from concentrated animal feeding operations are collectable secondary biomass resources. Vegetable oils used for biodiesel that are derived directly from the processing of oilseeds for various uses are also a secondary biomass resource.

It is difficult to find good direct sources of information on secondary biomass resources. In most cases, one has to estimate availability based on information and assumptions about the industries or companies generating the biomass. These estimates can be inaccurate because the amount of material that is a by-product to a given process can change over time as processes become more efficient or new uses are found for some by-product components.

The estimates provided in this databook were generated either by industries using secondary biomass to make a marketable fuel (e.g., the pellet fuel industry), or were generated by Forest Service staff using the Timber Product Output database http://www.fia.fs.fed.us/tools-data/tools/. This database is based on wood harvest and use inventories conducted every 5 years; the 2002 inventory is the latest source of information. The wood already used for energy provides insight on current bioenergy produced and the “unused” biomass represents wood that is already collected and potentially very easy to make available for additional energy production. Though a relatively small amount, it would likely be some of the first wood used if bioenergy use is accelerated in the U.S.

Information on black liquor production and use for energy is kept and tracked by the forest products industry but is proprietary. An estimate of black liquor production could be made based on publicly available information on pulp mills. However, any current listing of pulp mills in operation will be out-of-date within a month or two of publication because of the frequent closing of mills that is occurring. Thus, though a very important resource for bioenergy production today, no attempt is made to include a state level estimate of black liquor production in this book.

Source: Lynn Wright, Oak Ridge, TN

About 42% of the residues produced at primary mills are used to produce energy, typically supplying the power needed to operate the mills.

Table 5.18
Residues from Primary Forest Product Mills
(Dry tons)

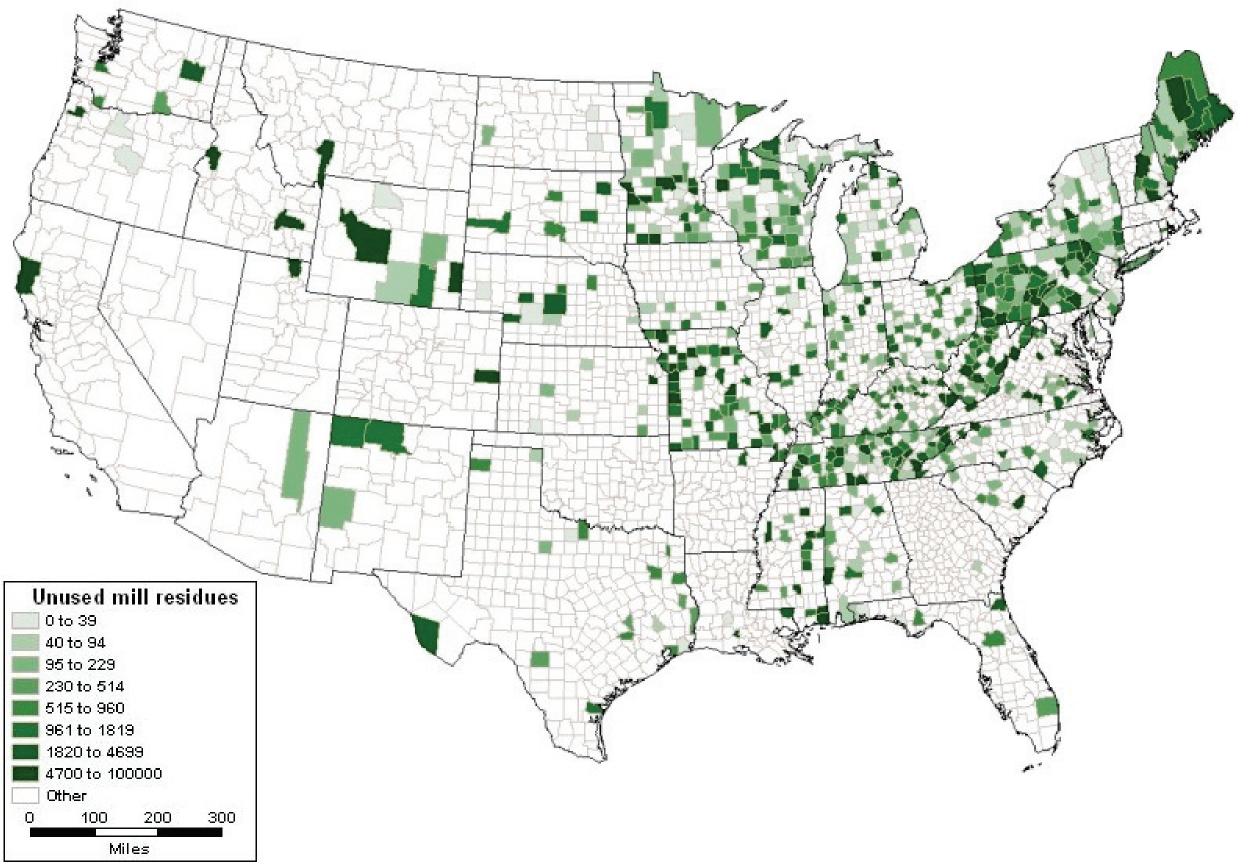
State	Fiber	Energy	Miscellaneous	Unused	Total
Alabama	2,767,320	4,362,130	594,770	13,640	7,737,860
Arizona	58,050	46,830	3,560	150	108,590
Arkansas	2,040,540	2,436,230	291,320	2,790	4,770,880
California	2,146,810	2,285,780	382,280	8,430	4,823,300
Colorado	33,140	35,310	26,260	86,760	181,470
Connecticut	2,710	39,710	47,740	-	90,160
Delaware	910	4,030	11,430	60	16,430
Florida	868,670	1,276,600	386,860	5,200	2,537,330
Georgia	-	-	-	-	-
Idaho	2,602,590	1,557,240	171,180	69,250	4,400,260
Illinois	61,060	97,910	104,920	18,520	282,410
Indiana	198,970	180,300	288,200	28,170	695,640
Iowa	28,190	44,120	82,040	2,660	157,010
Kansas	4,190	3,710	20,430	6,400	34,730
Kentucky	642,230	531,580	635,520	102,800	1,912,130
Louisiana	1,729,960	2,831,950	193,340	18,270	4,773,520
Maine	190,320	166,700	106,190	42,450	505,660
Maryland	44,070	13,160	108,140	230	165,600
Massachusetts	24,910	43,970	66,410	-	135,290
Michigan	243,540	841,890	350,450	49,610	1,485,490
Minnesota	100,950	805,670	82,900	75,090	1,064,610
Mississippi	2,156,610	3,032,540	713,450	103,910	6,006,510
Missouri	171,970	163,100	766,990	160,040	1,262,100
Montana	1,475,950	346,090	74,440	40,580	1,937,060
Nebraska	-	8,940	48,760	11,470	69,170
Nevada	-	-	-	-	-
New Hampshire	274,340	415,780	396,520	23,220	1,109,860
New Jersey	-	7,480	12,720	290	20,490
New Mexico	82,990	37,470	40,530	3,640	164,630
New York	217,340	467,230	562,330	28,250	1,275,150
North Carolina	2,367,310	1,983,530	835,480	18,360	5,204,680
North Dakota	-	190	120	210	520
Ohio	269,050	308,500	343,960	21,430	942,940
Oklahoma	244,360	403,770	187,950	-	836,080
Oregon	4,359,910	1,728,430	736,580	9,910	6,834,830
Pennsylvania	351,080	419,530	686,490	172,790	1,629,890
Rhode Island	920	11,530	13,210	-	25,660
South Carolina	1,346,210	1,600,440	334,470	12,090	3,293,210
South Dakota	106,540	33,700	24,860	5,320	170,420
Tennessee	633,850	846,360	331,510	197,580	2,009,300
Texas	1,512,300	995,850	249,160	10,570	2,767,880
Utah	-	47,140	35,510	19,790	102,440
Vermont	64,940	59,090	-	-	124,030
Virginia	1,232,540	1,053,260	491,900	87,470	2,865,170
Washington	2,944,230	2,257,790	482,840	4,950	5,689,810
West Virginia	312,410	322,810	196,420	136,340	967,980
Wisconsin	412,680	1,071,000	309,810	32,920	1,826,410
Wyoming	72,620	77,380	57,560	47,380	254,940
Total	34,399,280	35,303,750	11,887,510	1,678,990	83,269,530

Source:
Bioenergy Resource and Engineering Systems Program, Oak Ridge National Laboratory.

Note: - No data.
For information on estimation methods used, see: Appendix C - Estimation Methods for Logging Residues, Fuel Treatment Thinnings and Primary Forest Product Mill Residues.

Although the mill residues shown in the map below are currently unused, they represent a source of biomass that could be utilized fairly easily compared with other sources of biomass.

Figure 5.8
Unused Mill Residues by County



Source:
Bioenergy Resource and Engineering Systems Program, Oak Ridge National Laboratory.

Note: For information on estimation methods used, see: Appendix C - Estimation Methods for Logging Residues, Fuel Treatment Thinnings and Primary Forest Product Mill Residues.

Table 5.19
Pellet Fuel Shipments from Pellet Fuel Manufacturers (tons)

Region	1994-1995	1995-1996	1996-1997	1997-1998	1998-1999	1999-2000	2000-2001	2001-2002	2002-2003*	2003-2004*	2004-2005*
Pacific	293,000	262,000	228,000	236,000	231,000	235,500	204,000	229,000	269,000	241,000	183,323
Mountain	120,000	123,000	108,000	108,000	120,000	89,000	121,000	130,000	105,000	131,000	101,509
Central	15,000	19,000	36,000	49,000	31,000	17,500	43,000	39,000	49,000	76,000	49,176
Great Lakes	24,000	36,000	45,000	22,000	27,000	19,100	26,000	44,000	41,000	53,000	56,656
Northeast	84,000	107,000	143,000	154,000	135,000	147,000	197,000	226,000	254,000	272,000	241,344
Southeast	34,000	39,000	49,000	49,000	58,000	62,000	63,000	59,000	43,000	43,000	35,772
Total	**570,000**	**586,000**	**609,000**	**618,000**	**602,000**	**570,100**	**654,000**	**727,000**	**761,000**	**816,000**	**667,780**

Source:
http://www.pelletheat.org/3/industry/marketResearch.html#

Note: * Represents heating season, not annual season. 1st Quarter April-June, 2nd Quarter July-Sept, 3rd Quarter Oct-Dec, 4th Quarter Jan-Mar.

Table 5.20
Pellet Appliance Shipments from Manufacturers

1998	1999	2000	2001	2002	2003	2004
34,000	18,400	31,000	53,500	34,000	48,500	67,000

Source:
Statistics are gathered by Hearth, Patio & Barbecue Association, http://www.pelletheat.org/3/industry/marketResearch.html#

Tertiary Biomass Feedstocks

Tertiary biomass includes post consumer residues and wastes, such as fats, greases, oils, construction and demolition wood debris, other waste wood from the urban environments, as well as packaging wastes, municipal solid wastes, and landfill gases.

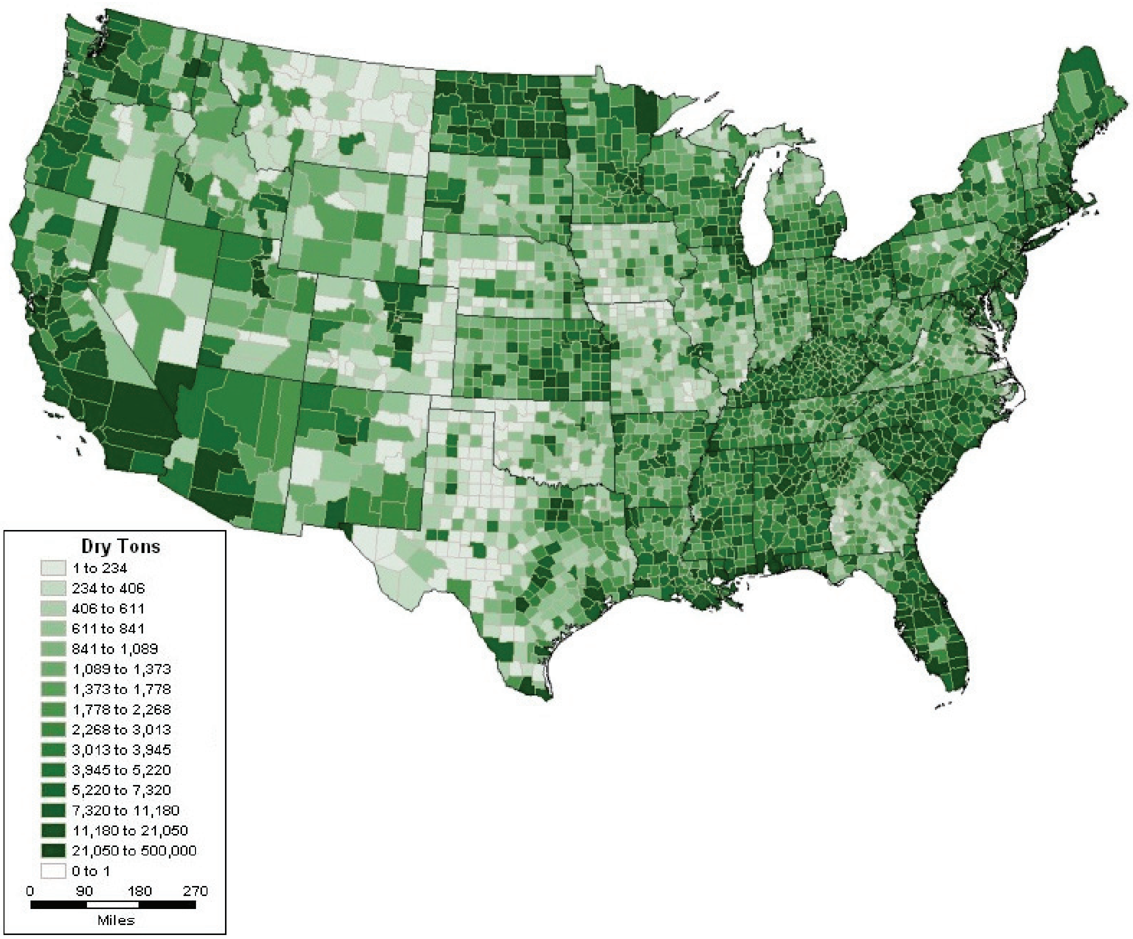
The category "other wood waste from the urban environment" could include trimmings from urban trees, which technically fits the definition of primary biomass. However, because this material is normally handled as a waste stream along with other post-consumer wastes from urban environments (and included in those statistics), it makes the most sense to consider it to be part of the tertiary biomass stream.

The proper categorization of fats and greases may be debatable since those are byproducts of the reduction of animal biomass into component parts. However, since we are considering animals to be a type of biomass processing factory and since most fats and greases, and some oils, are not available for bioenergy use until after they become a post-consumer waste stream, it seems appropriate for them to be included in the tertiary biomass category. Vegetable oils derived from processing of plant components and used directly for bioenergy (e.g., soybean oil used in biodiesel) would be a secondary biomass resource, though amounts being used for bioenergy are most likely to be tracked together with fats, greases and waste oils.

Source: Lynn Wright, Oak Ridge, TN.

Construction and demolition produce a sizeable amount of biomass material, though, recovery and use of those materials pose economic challenges.

Figure 5.9
Total Construction and Demolition Residues



Source:
Bioenergy Resource and Engineering Systems Program, Oak Ridge National Laboratory.

Note: For information on estimation methods used, see: Appendix C - Estimation Methods for Urban Wood Residues.

Table 5.21
Residues from Construction and Demolition by State[a]
(Dry tons)

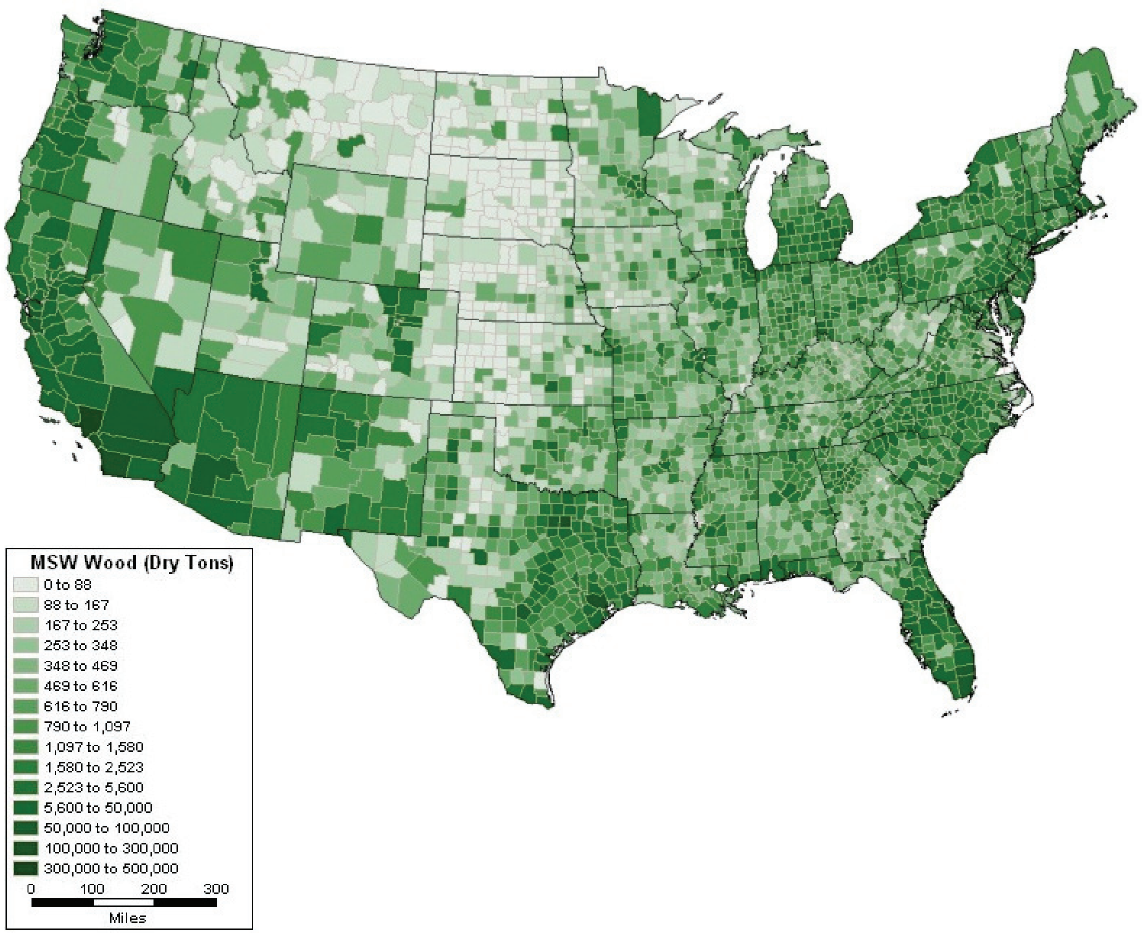
State	Demolition	Construction	Total
Alabama	756,670	97,340	854,010
Arizona	14,410	152,970	167,380
Arkansas	254,800	44,660	299,460
California	11,530	1,288,300	1,299,830
Colorado	12,860	166,950	179,800
Connecticut	19,040	102,160	121,200
Delaware	1,590	28,700	30,290
Florida	710,340	536,140	1,246,480
Georgia	262,520	263,920	526,430
Idaho	83,570	50,100	133,670
Illinois	25,720	439,390	465,100
Indiana	64,290	204,710	269,000
Iowa	25,720	77,150	102,860
Kansas	803,600	79,840	883,440
Kentucky	1,729,530	89,470	1,819,000
Louisiana	424,660	84,960	509,620
Maine	63,470	35,790	99,270
Maryland	15,870	212,560	228,430
Massachusetts	12,690	166,900	179,600
Michigan	38,570	322,840	361,420
Minnesota	507,870	173,520	681,400
Mississippi	509,590	47,130	556,720
Missouri	25,720	161,510	187,230
Montana	12,860	19,960	32,820
Nebraska	122,150	53,460	175,610
Nevada	11,530	102,140	113,660
New Hampshire	1,590	31,680	33,270
New Jersey	1,590	243,210	244,790
New Mexico	46,330	36,980	83,300
New York	155,510	455,070	610,580
North Carolina	470,990	270,110	741,100
North Dakota	1,125,030	14,660	1,139,700
Ohio	469,300	340,690	809,990
Oklahoma	30,880	61,110	92,000
Oregon	17,290	165,790	183,080
Pennsylvania	7,930	303,920	311,860
Rhode Island	6,350	26,600	32,940
South Carolina	972,860	103,250	1,076,110
South Dakota	141,430	20,980	162,410
Tennessee	509,590	145,030	654,620
Texas	370,610	518,760	889,370
Utah	126,790	77,380	204,170
Vermont	1,590	17,050	18,630
Virginia	169,860	238,150	408,010
Washington	97,980	288,580	386,560
West Virginia	223,910	32,980	256,900
Wisconsin	225,010	189,980	414,980
Wyoming	6,430	15,490	21,910
Total	**11,700,000**	**8,600,000**	**20,300,000**

Source:
Bioenergy Resource and Engineering Systems Program, Oak Ridge National Laboratory.

Note: For information on estimation methods used, see: Appendix C - Estimation Methods for Urban Wood Residues.

Although municipal solid wood waste residues constitute a significant amount of biomass material, it is important to note that it may not be available at a cost that is economically viable.

Figure 5.10
Total Municipal Solid Waste Wood Residues



Source:
Bioenergy Resource and Engineering Systems Program, Oak Ridge National Laboratory.

Note: For information on estimation methods used, see: Appendix C - Estimation Methods for Urban Wood Residues.

Table 5.22
Residues from Municipal Solid Waste Landfills by State
(Dry tons)

State	MSW wood	Yard trimmings	Total
Alabama	77,840	21,840	99,680
Arizona	86,060	27,090	113,150
Arkansas	45,020	10,510	55,530
California	1,144,880	308,330	1,453,210
Colorado	72,370	25,310	97,680
Connecticut	14,250	4,820	19,070
Delaware	27,960	8,800	36,750
Florida	400,940	107,570	508,510
Georgia	205,650	52,850	258,500
Idaho	17,900	5,120	23,020
Illinois	170,570	57,900	228,470
Indiana	150,330	50,450	200,780
Iowa	32,740	10,990	43,730
Kansas	32,830	11,500	44,340
Kentucky	85,700	22,600	108,300
Louisiana	58,440	17,350	75,800
Maine	13,490	4,410	17,890
Maryland	64,160	21,090	85,250
Massachusetts	67,640	22,200	89,840
Michigan	191,150	65,960	257,110
Minnesota	50,620	16,800	67,420
Mississippi	75,770	22,720	98,490
Missouri	119,280	39,840	159,130
Montana	8,400	2,930	11,330
Nebraska	20,910	7,160	28,070
Nevada	49,210	15,810	65,020
New Hampshire	11,110	3,780	14,890
New Jersey	99,140	32,530	131,660
New Mexico	54,820	17,650	72,470
New York	358,210	116,590	474,790
North Carolina	252,710	69,010	321,730
North Dakota	6,360	2,220	8,580
Ohio	161,680	55,510	217,190
Oklahoma	50,060	17,600	67,650
Oregon	74,210	20,340	94,550
Pennsylvania	123,940	41,090	165,020
Rhode Island	19,690	6,650	26,340
South Carolina	83,240	21,760	105,000
South Dakota	6,000	1,990	7,990
Tennessee	93,760	23,900	117,660
Texas	905,870	228,970	1,134,840
Utah	31,790	10,890	42,680
Vermont	6,680	2,220	8,900
Virginia	188,360	50,090	238,450
Washington	112,780	31,660	144,440
West Virginia	28,110	7,750	35,850
Wisconsin	41,160	13,790	54,960
Wyoming	6,230	2,180	8,400
Total	**6,000,000**	**1,740,100**	**7,740,100**

Source:
Bioenergy Resource and Engineering Systems Program, Oak Ridge National Laboratory.

Note: For information on estimation methods used, see: Appendix C - Estimation Methods for Urban Wood Residues.

Landfill gas is becoming a more prominent source of energy; all but nine states are using landfill gas to some extent. There are a number of states that are utilizing the majority of landfill sites available to them.

Table 5.23
Landfill Gas Projects and Candidate Landfills by State, January 2006

State	Operational Projects	Candidate Landfills
Alabama	3	21
Alaska	0	1
Arizona	4	13
Arkansas	1	5
California	73	40
Colorado	0	13
Connecticut	2	6
Delaware	1	3
Florida	11	18
Georgia	7	19
Hawaii	0	8
Idaho	1	3
Illinois	36	25
Indiana	17	16
Iowa	3	11
Kansas	4	6
Kentucky	4	18
Louisiana	2	10
Maine	0	2
Maryland	4	12
Massachusetts	18	3
Michigan	27	9
Minnesota	4	8
Mississippi	1	11
Missouri	5	18
Montana	0	5
Nebraska	1	5
Nevada	0	5
New Hampshire	6	[a]
New Jersey	12	3
New Mexico	0	1
New York	16	21
North Carolina	11	38
North Dakota	1	1
Ohio	18	28
Oklahoma	4	13
Oregon	4	7
Pennsylvania	23	19
Rhode Island	2	*
South Carolina	3	20
South Dakota	0	2
Tennessee	6	13
Texas	18	55
Utah	1	5
Vermont	3	1
Virginia	15	16
Washington	6	8
West Virginia	0	7
Wisconsin	18	11
Wyoming	0	1
U.S. Total	**396**	**584**

Source:
EPA's Landfill Methane Outreach Program. January 9, 2006.

[a] No data available.

APPENDIX A

CONVERSIONS

Table A.1
Heat Content for Various Fuels

Automotive gasoline		125,000 Btu/gal(gross) = 115,400 Btu/gal(net)
Hydrogen		134,200 Btu/kg(gross) = 113,400 Btu/kg(net)
Diesel motor fuel		138,700 Btu/gal (gross) = 128,700 Btu/gal (net)
Biodiesel		126,206 Btu/gal (gross) = 117,093 Btu/gal (net)
Methanol		64,600 Btu/gal (gross) = 56,560 Btu/gal (net)
Ethanol		84,600 Btu/gal (gross) = 75,670 Btu/gal (net)
Gasohol		120,900 Btu/gal (gross) = 112,417 Btu/gal (net)
Aviation gasoline		120,200 Btu/gal (gross) = 112,000 Btu/gal (net)
Propane		91,300 Btu/gal (gross) = 83,500 Btu/gal (net)
Butane		103,000 Btu/gal (gross) = 93,000 Btu/gal (net)
Jet fuel (naphtha)		127,500 Btu/gal (gross) = 118,700 Btu/gal (net)
Jet fuel (kerosene)		135,000 Btu/gal (gross) = 128,100 Btu/gal (net)
Lubricants		144,400 Btu/gal (gross) = 130,900 Btu/gal (net)
Waxes		131,800 Btu/gal (gross) = 120,200 Btu/gal (net)
Asphalt and road oil		158,000 Btu/gal (gross) = 157,700 Btu/gal (net)
Petroleum coke		143,400 Btu/gal (gross)
Natural gas		
Wet	1,109	Btu/ft^3
Dry	1,027	Btu/ft^3
Compressed	20,551	Btu/pound
	960	Btu/cubic foot
Liquid	90,800	Btu/gal (gross) = 87,600 Btu/gal (net)
Crude petroleum	138,100	Btu/gal (gross) = 131,800 Btu/gal (net)
Fuel Oils		
Residual	149,700	Btu/gal (gross) = 138,400 Btu/gal (net)
Distillate	138,700	Btu/gal (gross) = 131,800 Btu/gal (net)
Coal		
Anthracite - Consumption		21.711 x 10^6 Btu/short ton
Bituminous and lignite - Consumption		21.012 x 10^6 Btu/short ton
Production average		21.352 x 10^6 Btu/short ton
Consumption average		21.015 x 10^6 Btu/short ton

Table A.2
Approximate Heat Content of Selected Fuels for Electric Power Generation

Fossil Fuels[a]	
Residual Oil (million Btu per barrel)	6.287
Distillate Oil (million Btu per barrel)	5.799
Natural Gas (Btu per million cubic ft)	1,027
Coal (million Btu per Short Ton)	20.411
Biomass Materials[b]	
Switchgrass Btu per pound	7,341
Bagasse, Btu per pound	6,065
Rice Hulls, Btu per pound	6,575
Poultry Litter, Btu per pound	6,187
Solid wood waste, Btu per pound	6,000-8,000

[a] EIA, *Annual Energy Outlook 2006*, DOE/EIA-0383 (2006) (Washington, DC, February 2006), Table G1.

[b] Animal Waste Screening Study, Electrotek Concepts, Inc., Arlington, VA. June 2001.

Table A.3
Alternative Measures of Greenhouse Gases

1 pound methane, measured in carbon units (CH_4)	=	1.333 pounds methane, measured at full molecular weight (CH_4)
1 pound carbon dioxide, measured in carbon units (CO_2-C)	=	3.6667 pounds carbon dioxide, measured at full molecular weight (CO_2)
1 pound carbon monoxide, measured in carbon units (CO-C)	=	2.333 pounds carbon monoxide, measured at full molecular weight (CO)
1 pound nitrous oxide, measured in nitrogen units (N_2O-N)	=	1.571 pounds nitrous oxide, measured at full molecular weight (N_2O)

Table A.4
Area Conversions

1 acre[a]	=	0.405 hectare.
1 are	=	119.599 square yards. 0.025 acre.
1 hectare	=	2.471 acres.
[1 square (building)]	=	100 square feet.
1 square centimeter (cm^2)	=	0.155 square inch.
1 square decimeter (dm^2)	=	15.500 square inches.
1 square foot (ft^2)	=	929.030 square centimeters.
1 square inch (in^2)	=	6.451 6 square centimeters (exactly).
1 square kilometer (km^2)	=	247.104 acres. 0.386 square mile.
1 square meter (m^2)	=	1.196 square yards. 10.764 square feet.
1 square mile (mi^2)	=	258.999 hectares.
1 square millimeter (mm^2)	=	0.002 square inch.
1 square rod (rd^2), sq pole, or sq perch	=	25.293 square meters.
1 square yard (yd^2)	=	0.836 square meter.

Source:
National Institute of Standards and Technology, General Tables of Units and Measurements, http://ts.nist.gov/ts/htdocs/230/235/owmhome.htm

[a] An acre is a unit of area containing 43,560 square feet. It is not necessarily square, or even rectangular. But, if it is square, then the length of a side is equal to the square root of 43,560 or about 208.71 feet.

Table A.5
Areas and Crop Yields

1.0 hectare = 10,000 m^2 (an area 100 m x 100 m, or 328 x 328 ft) = 2.47 acres
1.0 km^2 = 100 hectares = 247 acres
1.0 acre = 0.405 hectares
1.0 US ton/acre = 2.24 t/ha
1.0 metric tonne/hectare = 0.446 ton/acre
100 g/m^2 = 1.0 tonne/hectare = 892 lb/acre

US bushel = 0.0352 m^3 = 0.97 UK bushel = 56 lb, 25 kg (corn or sorghum) = 60 lb, 27 kg (wheat or soybeans) = 40 lb, 18 kg (barley)

A "target" bioenergy crop yield might be:
5.0 US tons/acre (10,000 lb/acre) = 11.2 tonnes/hectare (1120 g/m^2)

Source:
Bioenergy Feedstock Information Network, http://bioenergy.ornl.gov/.

Table A.6
Biomass Energy Conversions

Cord: a stack of wood comprising 128 cubic feet (3.62 m^3); standard dimensions are 4 x 4 x 8 feet, including air space and bark. One cord contains approx. 1.2 U.S. tons (oven-dry) = 2400 pounds = 1089 kg

1.0 metric tonne wood = 1.4 cubic meters (solid wood, not stacked)

Energy content of wood fuel (HHV, bone dry) = 18-22 GJ/t (7,600-9,600 Btu/lb)

Energy content of wood fuel (air dry, 20% moisture) = about 15 GJ/t (6,400 Btu/lb)

Energy content of agricultural residues (range due to moisture content) = 10-17 GJ/t (4,300-7,300 Btu/lb)

Metric tonne charcoal = 30 GJ (= 12,800 Btu/lb)
(but usually derived from 6-12 t air-dry wood, i.e. 90-180 GJ original energy content)

Metric tonne ethanol = 7.94 petroleum barrels = 1262 liters

Ethanol energy content = 11,500 Btu/lb = 75,700 Btu/gallon = 26.7 GJ/t = 21.1 MJ/liter

Ethanol HHV = 84,000 Btu/gallon = 89 MJ/gallon = 23.4 MJ/liter

Ethanol Density (average) = 0.79 g/ml (= metric tonnes/m^3)

Metric tonne biodiesel = 37.8 GJ (33.3 - 35.7 MJ/liter)

biodiesel density (average) = 0.88 g/ml (= metric tonnes/m^3)

Source:
Bioenergy Feedstock Information Network, http://bioenergy.ornl.gov/

Table A.7
Distance and Velocity Conversions

1 in.	= 83.33×10^{-3} ft	1 ft	= 12.0 in.
	= 27.78×10^{-3} yd		= 0.33 yd
	= 15.78×10^{-6} mile		= 189.4×10^{-3} mile
	= 25.40×10^{-3} m		= 0.3048 m
	= 0.2540×10^{-6} km		= 0.3048×10^{-3} km
1 mile	= 63360 in.	1 km	= 39370 in.
	= 5280 ft		= 3281 ft
	= 1760 yd		= 1093.6 yd
	= 1609 m		= 0.6214 mile
	= 1.609 km		= 1000 m

1 ft/sec = 0.3048 m/s = 0.6818 mph = 1.0972 km/h
1 m/sec = 3.281 ft/s = 2.237 mph = 3.600 km/h
1 km/h = 0.9114 ft/s = 0.2778 m/s = 0.6214 mph
1 mph = 1.467 ft/s = 0.4469 m/s = 1.609 km/h

Table A.8
Energy Unit Conversions

1 Btu	= 778.2 ft-lb	1 kWhr	= 3412 Btu[a]
	= 107.6 kg-m		= 2.655×10^{6} ft-lb
	= 1055 J		= 3.671×10^{5} kg-m
	= 39.30×10^{-5} hp-h		= 3.600×10^{6} J
	= 39.85×10^{-5} metric hp-h		= 1.341 hp-h
	= 29.31×10^{-5} kWhr		= 1.360 metric hp-h
1 kg-m	= 92.95×10^{-4} Btu	1 Joule	= 94.78×10^{-5} Btu
	= 7.233 ft-lb		= 0.7376 ft-lb
	= 9.806 J		= 0.1020 kg-m
	= 36.53×10^{-7} hp-h		= 37.25×10^{-8} hp-h
	= 37.04×10^{-7} metric hp-h		= 37.77×10^{-8} metric hp-
	= 27.24×10^{-7} kWhr		= 27.78×10^{-8} kWhr
1 hp-h	= 2544 Btu	1 metric hp-h	= 2510 Btu
	= 1.98×10^{6} ft-lb		= 1.953×10^{6} ft-lb
	= 2.738×10^{6} kgm		= 27.00×10^{4} kg-m
	= 2.685×10^{6} J		= 2.648×10^{6} J
	= 1.014 metric hp-h		= 0.9863 hp-h
	= 0.7475 kWhr		= 0.7355 kWhr

[a]This figure does not take into account the fact that electricity generation and distribution efficiency is approximately 29%. If generation and distribution efficiency are taken into account, 1 kWhr = 11,765 Btu.

Table A.9
Fuel Efficiency Conversions

MPG	Miles/liter	Kilometers/L	L/100 kilometers
10	2.64	4.25	23.52
15	3.96	6.38	15.68
20	5.28	8.50	11.76
25	6.60	10.63	9.41
30	7.92	12.75	7.84
35	9.25	14.88	6.72
40	10.57	17.00	5.88
45	11.89	19.13	5.23
50	13.21	21.25	4.70
55	14.53	23.38	4.28
60	15.85	25.51	3.92
65	17.17	27.63	3.62
70	18.49	29.76	3.36
75	19.81	31.88	3.14
80	21.13	34.01	2.94
85	22.45	36.13	2.77
90	23.77	38.26	2.61
95	25.09	40.38	2.48
100	26.42	42.51	2.35
105	27.74	44.64	2.24
110	29.06	46.76	2.14
115	30.38	48.89	2.05
120	31.70	51.01	1.96
125	33.02	53.14	1.88
130	34.34	55.26	1.81
135	35.66	57.39	1.74
140	36.98	59.51	1.68
145	38.30	61.64	1.62
150	39.62	63.76	1.57
Formula	MPG/3.785	MPG/[3.785/1.609]	235.24/MPG

Table A.10
Mass Conversions

	TO				
FROM	Pound	Kilogram	Short ton	Long ton	Metric ton
Pound	1	0.4536	5.0×10^{-4}	4.4643×10^{-4}	4.5362×10^{-4}
Kilogram	2.205	1	1.1023×10^{-3}	9.8425×10^{-4}	1.0×10^{-3}
Short ton	2000	907.2	1	0.8929	0.9072
Long ton	2240	1016	1.12	1	1.016
Metric ton	2205	1000	1.102	0.9842	1

Table A.11
Power Conversions

	TO					
FROM	Horsepower	Kilowatts	Metric horsepower	Ft-lb per sec	Kilocalories per sec	Btu per sec
Horsepower	1	0.7457	1.014	550	0.1781	0.7068
Kilowatts	1.341	1	1.360	737.6	0.239	0.9478
Metric horsepower	0.9863	0.7355	1	542.5	0.1757	0.6971
Ft-lb per sec	1.36×10^{-3}	1.356×10^{-3}	1.84×10^{-3}	1	0.3238×10^{-3}	1.285×10^{-3}
Kilocalories per sec	5.615	4.184	5.692	3088	1	3.968
Btu per sec	1.415	1.055	1.434	778.2	0.2520	1

Table A.12
Volume and Flow Rate Conversions[a]

1 U.S. gal	= 231 in.^{3}	1 liter	= 61.02 in.^{3}
	= 0.1337 ft^3		= 3.531 x 10^{-2} ft^3
	= 3.785 liters		= 0.2624 U.S. gal
	= 0.8321 imperial gal		= 0.2200 imperial gal
	= 0.0238 bbl		= 6.29 x 10^{-3} bbl
	= 0.003785 m^3		= 0.001 m^3
	A U.S. gallon of gasoline weighs 6.2 pounds		
1 imperial gal	= 277.4 in.^{3}	1 bbl	= 9702 in.^{3}
	= 0.1606 ft^3		= 5.615 ft^3
	= 4.545 liters		= 158.97 liters
	= 1.201 U.S. gal		= 42 U.S. gal
	= 0.0286 bbl		= 34.97 imperial gal
	= 0.004546 m^3		= 0.15897 m^3
1 U.S. gal/hr	= 3.209 ft^3/day		= 1171 ft^3/year
	= 90.84 liter/day		= 33157 liter/year
	= 19.97 imperial gal/day		= 7289 imperial gal/year
	= 0.5712 bbl/day		= 207.92 bbl/year
	For Imperial gallons, multiply above values by 1.201		
1 liter/hr	= 0.8474 ft^3/day		= 309.3 ft^3/year
	= 6.298 U.S. gal/day		= 2299 U.S. gal/year
	= 5.28 imperial gal/day		= 1927 imperial gal/year
	= 0.1510 bbl/day		= 55.10 bbl/year
1 bbl/hr	= 137.8 ft^3/year		= 49187 ft^3 /year
	= 1008 U.S. gal/day		= 3.679 x 10^5 U.S. gal/year
	= 839.3 imperial gal/day		= 3.063 x 10^5 imperial gal/year
	= 3815 liter/day		= 1.393 x 10^6 liter/day

[a] The conversions for flow rates are identical to those for volume measures, if the time units are identical.

Table A.13
International Energy Conversions

To:	Terajoules	Giga-calories	Million tonnes of oil equivalent	Million Btu	Gigawatt-hours
From:	*multiply by:*				
Terajoules	1	238.8	2.388×10^{-5}	947.8	0.2778
Gigacalories	4.1868×10^{-3}	1	10^{-7}	3.968	1.163×10^{-3}
Million tonnes of oil equivalent	4.1868×10^{4}	107	1	3.968×10^{7}	11,630
Million Btu	1.0551×10^{-3}	0.252	$2.52 \text{ X } 10^{-8}$	1	2.931×10^{-4}
Gigawatthours	3.6	860	8.6×10^{-5}	3412	1

Table A.14
SI Prefixes and Their Values

	Value	Prefix	Symbol
One million million millionth	10^{-18}	atto	a
One thousand million millionth	10^{-15}	femto	f
One million millionth	10^{-12}	pico	p
One thousand millionth	10^{-9}	nano	n
One millionth	10^{-6}	micro	µ
One thousandth	10^{-3}	milli	m
One hundredth	10^{-2}	centi	c
One tenth	10^{-1}	deci	d
One	10^{0}		
Ten	10^{1}	deca	da
One hundred	10^{2}	hecto	h
One thousand	10^{3}	kilo	k
One million	10^{6}	mega	M
One billion[a]	10^{9}	giga	G
One trillion[a]	10^{12}	tera	T
One quadrillion[a]	10^{15}	peta	P
One quintillion[a]	10^{18}	exa	E

[a] Care should be exercised in the use of this nomenclature, especially in foreign correspondence, as it is either unknown or carries a different value in other countries. A "billion," for example, signifies a value of 10^{12} in most other countries.

Table A.15
Metric Units and Abbreviations

Quantity	Unit name	Symbol
Energy	joule	J
Specific energy	joule/kilogram	J/kg
Specific energy consumption	joule/kilogram•kilometer	J/(kg•km)
Energy consumption	joule/kilometer	J/km
Energy economy	kilometer/kilojoule	km/kJ
Power	kilowatt	Kw
Specific power	watt/kilogram	W/kg
Power density	watt/meter^3	W/m^3
Speed	kilometer/hour	km/h
Acceleration	meter/second^2	m/s^2
Range (distance)	kilometer	km
Weight	kilogram	kg
Torque	newton•meter	N•m
Volume	meter^3	m^3
Mass; payload	kilogram	kg
Length; width	meter	m
Brake specific fuel consumption	kilogram/joule	kg/J
Fuel economy (heat engine)	liters/100 km	L/100 km

APPENDIX B

BIOMASS CHARACTERISTICS

APPENDIX B

BIOMASS CHARACTERISTICS

Biomass feedstocks and fuels exhibit a wide range of physical, chemical, and agricultural/process engineering properties. Despite their wide range of possible sources, biomass feedstocks are remarkably uniform in many of their fuel properties, compared with competing feedstocks such as coal or petroleum. For example, there are many kinds of coals whose gross heating value ranges from 20 to 30 GJ/tonne (gigajoules per metric tonne; 8,600-12,900 Btu/lb). However, nearly all kinds of biomass feedstocks destined for combustion fall in the range 15-19 GJ/tonne (6,450-8,200 Btu/lb). For most agricultural residues, the heating values are even more uniform – about 15-17 GJ/tonne (6,450-7,300 Btu/lb); the values for most woody materials are 18-19 GJ/tonne (7,750-8,200 Btu/lb). Moisture content is probably the most important determinant of heating value. Air-dried biomass typically has about 15-20% moisture, whereas the moisture content for oven-dried biomass is around 0%. Moisture content is also an important characteristic of coals, varying in the range of 2-30%. However, the bulk density (and hence energy density) of most biomass feedstocks is generally low, even after densification, about 10 and 40% of the bulk density of most fossil fuels. Liquid biofuels have comparable bulk densities to fossil fuels.

Most biomass materials are easier to gasify than coal because they are more reactive with higher ignition stability. This characteristic also makes them easier to process thermochemically into higher-value fuels such as methanol or hydrogen. Ash content is typically lower than for most coals, and sulphur content is much lower than for many fossil fuels. Unlike coal ash, which may contain toxic metals and other trace contaminants, biomass ash may be used as a soil amendment to help replenish nutrients removed by harvest. A few biomass feedstocks stand out for their peculiar properties, such as high silicon or alkali metal contents – these may require special precautions for harvesting, processing and combustion equipment. Note also that mineral content can vary as a function of soil type and the timing of feedstock harvest. In contrast to their fairly uniform physical properties, biomass fuels are rather heterogeneous with respect to their chemical elemental composition.

Among the liquid biomass fuels, biodiesel (vegetable oil ester) is noteworthy for its similarity to petroleum-derived diesel fuel, apart from its negligible sulfur and ash content. Bioethanol has only about 70% the heating value of petroleum distillates such as gasoline, but its sulfur and ash contents are also very low. Both of these liquid fuels have lower vapor pressure and flammability than their petroleum-based competitors – an advantage in some cases (e.g., use in confined spaces such as mines) but a disadvantage in others (e.g., engine starting at cold temperatures).

The following pages contain three tables that show some "typical" values or range of values for selected compositional, chemical and physical properties of biomass feedstocks and liquid biofuels. Figures for fossil fuels are provided for comparison.

References for further information:

US DOE Biomass Feedstock Composition and Property Database
PHYLLIS - database on composition of biomass and waste
Nordin, A. (1994) Chemical elemental characteristics of biomass fuels. Biomass and Bioenergy 6, pp. 339-347.

Source:
Information in Appendix B is from a fact sheet by Jonathan Scurlock, Oak Ridge National Laboratory, Bioenergy Feedstock Development Programs. P.O. Box 2008, Oak Ridge, TN 37831-6407.

Table B.1
Composition of Selected Feedstocks

		Cellulose (%)	Hemi-cellulose (%)	Lignin (%)
Bioenergy Feedstocks	corn stover	35	28	16-21
	sweet	27	25	11
	sorghum	**	**	**
	sugarcane	32-48	19-24	23-32
	bagasse	**	**	**
	sugarcane	**	**	**
	leaves	**	**	**
	hardwood	45	30	20
	softwood	42	21	26
	hybrid	42-56	18-25	21-23
	poplar	**	**	**
	bamboo	41-49	24-28	24-26
	switchgrass	44-51	42-50?	13-20
	miscanthus	44	24	17
	Arundo donax	31	30	21
Liquid Biofuels	bioethanol	N/A	N/A	N/A
	biodiesel	N/A	N/A	N/A
Fossil Fuels	Coal (low rank; lignite/sub-bituminous)	N/A	N/A	N/A
	Coal (high rank bituminous/anthracite)	N/A	N/A	N/A
	Oil (typical distillate)	N/A	N/A	N/A

Source:
Jonathan Scurlock, Oak Ridge National Laboratory, Bioenergy Feedstock Development Programs. P.O. Box 2008, Oak Ridge, TN 37831-6407

Note:
N/A = Not Applicable.
** = Data not available.

Table B.2
Chemical Characteristics of Selected Feedstocks

		Heating value (gross, unless specified; GJ/t)	ash (%)	sulfur (%)	potassium (%)	Ash melting temperature [some ash sintering observed] (C)
Bioenergy Feedstocks	corn stover	17.6	5.6	**	**	**
	sweet	15.4	5.5	**	**	**
	sorghum	**	**	**	**	**
	sugarcane	18.1	3.2-5.5	0.10-	0.73-0.97	**
	bagasse	**	**	0.15	**	**
	sugarcane	17.4	7.7	**	**	**
	leaves	**	**	**	**	**
	hardwood	20.5	0.45	0.009	0.04	[900]
	softwood	19.6	0.3	0.01	**	**
	hybrid	19.0	0.5-1.5	0.03	0.3	1350
	poplar	**	**	**	**	**
	bamboo	18.5-19.4	0.8-2.5	0.03-0.05	0.15-0.50	**
	switchgrass	18.3	4.5-5.8	0.12	**	1016
	miscanthus	17.1-19.4	1.5-4.5	0.1	0.37-1.12	1090 [600]
	Arundo donax	17.1	5-6	0.07	**	**
Liquid Biofuels	bioethanol	28	**	<0.01	**	N/A
	biodiesel	40	<0.02	<0.05	<0.0001	N/A
Fossil Fuels	Coal (low rank; lignite/sub-bituminous)	15-19	5-20	1.0-3.0	0.02-0.3	~1300
	Coal (high rank bituminous/anthracite)	27-30	1-10	0.5-1.5	0.06-0.15	~1300
	Oil (typical distillate)	42-45	0.5-1.5	0.2-1.2	**	N/A

Source:
Jonathan Scurlock, Oak Ridge National Laboratory, Bioenergy Feedstock Development Programs. P.O. Box 2008, Oak Ridge, TN 37831-6407

Note:
N/A = Not Applicable.
** = Data not available.

Table B.3
Physical Characteristics of Selected Feedstocks

		Cellulose fiber length (mm)	Chopped density at harvest (kg/m3)	Baled density [compacted bales] (kg/m3)
Bioenergy Feedstocks	corn stover	1.5	**	**
	sweet	**	**	**
	sorghum	**	**	**
	sugarcane	1.7	50-75	**
	bagasse	**	**	**
	sugarcane	**	25-40	**
	leaves	**	**	**
	hardwood	1.2	**	**
	softwood	**	**	**
	hybrid	1-1.4	150 (chips)	**
	poplar	**	**	**
	bamboo	1.5-3.2	**	**
	switchgrass	**	108	105-133
	miscanthus	**	70-100	130-150 [300]
	Arundo donax	1.2	**	**
Liquid Biofuels				(typical bulk densities or range given below)
	bioethanol	N/A	N/A	790
	biodiesel	N/A	N/A	875
Fossil Fuels	Coal (low rank; lignite/sub-bituminous)	N/A	N/A	700
	Coal (high rank bituminous/anthracite)	N/A	N/A	850
	Oil (typical distillate)	N/A	N/A	700-900

Source:
Jonathan Scurlock, Oak Ridge National Laboratory, Bioenergy Feedstock Development Programs. P.O. Box 2008, Oak Ridge, TN 37831-6407

Note:
N/A = Not Applicable.
** = Data not available.

APPENDIX C

ASSUMPTIONS

APPENDIX C

ASSUMPTIONS

ESTIMATION METHODS FOR PRIMARY MILL RESIDUES

The forestry residue data included in this book are the same as that used in the DOE/USDA publication entitled "Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion Ton Annual Supply." The resource estimates contained in the following tables have been disaggregated to states.

Primary Mill Residues

Primary mill residues include bark, coarse residues (chunks and slabs), and fine residues (shavings and sawdust) generated at sawmills that process harvested wood. The mill residue data were downloaded by state and county from the U.S. Forest Service's Timber Product Output database (http://www.fia.fs.fed.us/tools-data/tools/). Because primary mill residues tend to be clean, uniform, concentrated, and of a low moisture content, most of these materials are already used for products or boiler fuel at the mills. The U.S Forest Service estimates current usage by type as follows:

- Bark – 80% used as fuel and 13% used in products
- Coarse residues – 85% used in products and 13% used as fuel
- Fine residues – 55% used as fuel and 42% used in products

This leaves a very small amount (~2%) of unused primary mill material available for energy. Residues are also generated at secondary processing mills (e.g., millwork, furniture, flooring, containers, etc.). Secondary mill residue data are not collected by the U.S. Forest Service.

ESTIMATION METHODS FOR URBAN WOOD RESIDUES

The state-level estimates provided for urban wood residues are consistent with the estimates found in the DOE/USDA publication entitled "Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion Ton Annual Supply."

Residues for MSW Landfills

MSW consists of a variety of items ranging from organic food scraps to discarded furniture and appliances. Wood and yard and tree trimmings are the two sources within this residue stream that are potentially recoverable for energy use. The wood component includes discarded furniture, pallets, containers, packaging materials, lumber scraps (other than new construction and demolition), and wood residuals from manufacturing. McKeever (2004) estimates the total wood component of the MSW stream at slightly more than 13 million dry tons. About 55% of this material is either recycled as compost, burned for power production, or unavailable for recovery because of excessive contamination. In total about 6 million dry tons of MSW wood is potentially available for energy. The other component of the MSW stream — yard and tree trimmings — is estimated at 9.8 million dry tons. However, only 1.5 million dry tons is considered potentially available for recovery after accounting for what is currently used and what is unusable.

Residues from Construction and Demolition Debris Landfills

The amount of available construction and demolition residue is correlated with economic activity (e.g., housing starts), population, demolition activity, and the extent of recycling and reuse programs. McKeever (2004) estimates annual generation of construction and demolition debris at 11.6 and 27.7 million dry tons, respectively. About 8.6 million dry tons of construction debris and 11.7 million dry tons of demolition debris are considered potentially available for energy. Unlike construction residue, which tends to be relatively clean and can be more easily source-separated, demolition debris is often contaminated, making recovery much more difficult and expensive.

Reference: McKeever, D. 2004. “Inventories of Woody Residues and Solid Wood Waste in the United States, 2002.” Ninth International Conference, Inorganic-Bonded Composite Materials. Vancouver, British Columbia. October 10-13.

GLOSSARY

GLOSSARY

Alcohol - The family name of a group of organic chemical compounds composed of carbon, hydrogen, and oxygen. The molecules in the series vary in chain length and are composed of a hydrocarbon plus a hydroxyl group. Alcohol includes methanol and ethanol.

Anaerobic digestion - Decomposition of biological wastes by micro-organisms, usually under wet conditions, in the absence of air (oxygen), to produce a gas comprising mostly methane and carbon dioxide.

Annual removals - The net volume of growing stock trees removed from the inventory during a specified year by harvesting, cultural operations such as timber stand improvement, or land clearing.

ASABE Standard X593 - The American Society of Agricultural and Biological Engineers (ASABE) in 2005 produced a new standard (Standard X593) entitled "Terminology and Definitions for Biomass Production, Harvesting and Collection, Storage, Processing, Conversion and Utilization." The purpose of the standard is to provide uniform terminology and definitions in the general area of biomass production and utilization. This standard includes many terminologies that are used in biomass feedstock production, harvesting, collecting, handling, storage, pre-processing and conversion, bioenergy, biopower and bioproducts. The terminologies were reviewed by many experts from all of the different fields of biomass and bioenergy before being accepted as part of the standard. The full-text is included on the online Technical Library of ASABE (http://asae.frymulti.com); members and institutions holding a site license can access the online version. Print copies may be ordered for a fee by calling 269-429-0300, e-mailing martin@asabe.org, or by mail at: ASABE, 2950 Niles Rd., St. Joseph, MI 49085.

Asexual reproduction - The naturally occurring ability of some plant species to reproduce asexually through seeds, meaning the embryos develop without a male gamete. This ensures the seeds will produce plants identical to the mother plant.

Barrel of oil equivalent - (boe) The amount of energy contained in a barrel of crude oil, i.e. approximately 6.1 GJ (5.8 million Btu), equivalent to 1,700 kWh. A "petroleum barrel" is a liquid measure equal to 42 U.S. gallons (35 Imperial gallons or 159 liters); about 7.2 barrels are equivalent to one tonne of oil (metric).

Biobased product - The term 'biobased product,' as defined by Farm Security and Rural Investment Act (FSRIA), means a product determined by the U.S. Secretary of Agriculture to be a commercial or industrial product (other than food or feed) that is composed, in whole or in significant part, of biological products or renewable domestic agricultural materials (including plant, animal, and marine materials) or forestry materials.

Biochemical conversion - The use of fermentation or anaerobic digestion to produce fuels and chemicals from organic sources.

Biodiesel - Fuel derived from vegetable oils or animal fats. It is produced when a vegetable oil or animal fat is chemically reacted with an alcohol.

Bioenergy - Useful, renewable energy produced from organic matter - the conversion of the complex carbohydrates in organic matter to energy. Organic matter may either be used directly as a fuel, processed into liquids and gasses, or be a residual of processing and conversion.

Bioethanol - Ethanol produced from biomass feedstocks. This includes ethanol produced from the fermentation of crops, such as corn, as well as cellulosic ethanol produced from woody plants or grasses.

Biorefinery - A facility that processes and converts biomass into value-added products. These products can range from biomaterials to fuels such as ethanol or important feedstocks for the production of chemicals and other materials. Biorefineries can be based on a number of processing platforms using mechanical, thermal, chemical, and biochemical processes.

Biofuels - Fuels made from biomass resources, or their processing and conversion derivatives. Biofuels include ethanol, biodiesel, and methanol.

Biogas - A combustible gas derived from decomposing biological waste under anaerobic conditions. Biogas normally consists of 50 to 60 percent methane. See also landfill gas.

Biomass - Any organic matter that is available on a renewable or recurring basis, including agricultural crops and trees, wood and wood residues, plants (including aquatic plants), grasses, animal manure, municipal residues, and other residue materials. Biomass is generally produced in a sustainable manner from water and carbon dioxide by photosynthesis. There are three main categories of biomass - primary, secondary, and tertiary.

Biomass energy - See Bioenergy.

Biopower - The use of biomass feedstock to produce electric power or heat through direct combustion of the feedstock, through gasification and then combustion of the resultant gas, or through other thermal conversion processes. Power is generated with engines, turbines, fuel cells, or other equipment.

Biorefinery - A facility that processes and converts biomass into value-added products. These products can range from biomaterials to fuels such as ethanol or important feedstocks for the production of chemicals and other materials. Biorefineries can be based on a number of processing platforms using mechanical, thermal, chemical, and biochemical processes.

Bone dry - Having zero percent moisture content. Wood heated in an oven at a constant temperature of 100°C (212°F) or above until its weight stabilizes is considered bone dry or oven dry.

Bottoming cycle - A cogeneration system in which steam is used first for process heat and then for electric power production.

Black liquor - Solution of lignin-residue and the pulping chemicals used to extract lignin during the manufacture of paper.

British thermal unit - (Btu) A non-metric unit of heat, still widely used by engineers. One Btu is the heat energy needed to raise the temperature of one pound of water from 60°F to 61°F at one atmosphere pressure. 1 Btu = 1055 joules (1.055 kJ).

Bunker - A storage tank.

Carbon dioxide (CO2) - A colorless, odorless, non-poisonous gas that is a normal part of the ambient air. Carbon dioxide is a product of fossil fuel combustion.

Closed-loop biomass - Crops grown, in a sustainable manner, for the purpose of optimizing their value for bioenergy and bioproduct uses. This includes annual crops such as maize and wheat, and perennial crops such as trees, shrubs, and grasses such as switchgrass.

Coarse materials - Wood residues suitable for chipping, such as slabs, edgings, and trimmings.

Commercial species - Tree species suitable for industrial wood products.

Conservation reserve program - CRP provides farm owners or operators with an annual per-acre rental payment and half the cost of establishing a permanent land cover in exchange for retiring environmentally sensitive cropland from production for 10 to 15 years. In 1996, Congress reauthorized CRP for an additional round of contracts, limiting enrollment to 36.4 million acres at any time. The 2002 Farm Act increased the enrollment limit to 39 million acres. Producers can offer land for competitive bidding based on an Environmental Benefits Index (EBI) during periodic signups, or can automatically enroll more limited acreages in practices such as riparian buffers, field windbreaks, and grass strips on a continuous basis. CRP is funded through the Commodity Credit Corporation (CCC).

Cord - A stack of wood comprising 128 cubic feet (3.62 m^3); standard dimensions are 4 x 4 x 8 feet, including air space and bark. One cord contains approx. 1.2 U.S. tons (oven-dry) = 2400 pounds = 1089 kg.

Cropland - Total cropland includes five components: cropland harvested, crop failure, cultivated summer fallow, cropland used only for pasture, and idle cropland.

Cropland used for crops - Cropland used for crops includes cropland harvested, crop failure, and cultivated summer fallow. **Cropland harvested** includes row crops and closely sown crops; hay and silage crops; tree fruits, small fruits, berries, and tree nuts; vegetables and melons; and miscellaneous other minor crops. In recent years, farmers have double-cropped about 4 percent of this acreage. **Crop failure** consists mainly of the acreage on which crops failed because of weather, insects, and diseases, but includes some land not harvested due to lack of labor, low market prices, or other factors. The acreage planted to cover and soil improvement crops not intended for harvest is excluded from crop failure and is considered idle. **Cultivated summer fallow** refers to cropland in sub-humid regions of the West cultivated for one or more seasons to control weeds and accumulate moisture before small grains are planted. This practice is optional in some areas, but it is a requirement for crop production in the drier cropland areas of the West. Other types of fallow, such as cropland planted with soil improvement crops but not harvested and cropland left idle all year, are not included in cultivated summer fallow but are included as idle cropland.

Cropland pasture - Land used for long-term crop rotation. However, some cropland pasture is marginal for crop uses and may remain in pasture indefinitely. This category also includes land that was used for pasture before crops reached maturity and some land used for pasture that could have been cropped without additional improvement.

Cull tree - A live tree, 5.0 inches in diameter at breast height (d.b.h.) or larger that is non-merchantable for saw logs now or prospectively because of rot, roughness, or species. (See definitions for rotten and rough trees.)

d.b.h. - The diameter measured at approximately breast high from the ground.

Digester - An airtight vessel or enclosure in which bacteria decomposes biomass in water to produce biogas.

Discount rate - A rate used to convert future costs or benefits to their present value.

Downdraft gasifier - A gasifier in which the product gases pass through a combustion zone at the bottom of the gasifier.

Dutch oven furnace - One of the earliest types of furnaces, having a large, rectangular box lined with firebrick (refractory) on the sides and top. Commonly used for burning wood. Heat is stored in the refractory and radiated to a conical fuel pile in the center of the furnace.

Effluent - The liquid or gas discharged from a process or chemical reactor, usually containing residues from that process.

Emissions - Waste substances released into the air or water. See also Effluent.

Energy crops - Crops grown specifically for their fuel value. These include food crops such as corn and sugarcane, and nonfood crops such as poplar trees and switchgrass. Currently, two energy crops are under development; short-rotation woody crops, which are fast-growing hardwood trees harvested in 5 to 8 years, and herbaceous energy crops, such as perennial grasses, which are harvested annually after taking 2 to 3 years to reach full productivity.

Ethanol - Otherwise known as ethyl alcohol, alcohol, or grain-spirit. A clear, colorless, flammable oxygenated hydrocarbon with a boiling point of 78.5 degrees Celsius in the anhydrous state. In transportation, ethanol is used as a vehicle fuel by itself (E100 – 100% ethanol by volume), blended with gasoline (E85 – 85% ethanol by volume), or as a gasoline octane enhancer and oxygenate (10% by volume).

Externality - A cost or benefit not accounted for in the price of goods or services. Often "externality" refers to the cost of pollution and other environmental impacts.

Feedstock - A product used as the basis for manufacture of another product.

Feller-buncher - A self-propelled machine that cuts trees with giant shears near ground level and then stacks the trees into piles to await skidding.

Fermentation - Conversion of carbon-containing compounds by micro-organisms for production of fuels and chemicals such as alcohols, acids or energy-rich gases.

Fiber products - Products derived from fibers of herbaceous and woody plant materials. Examples include pulp, composition board products, and wood chips for export.

Fine materials - Wood residues not suitable for chipping, such as planer shavings and sawdust.

Firm power - (firm energy) Power which is guaranteed by the supplier to be available at all times during a period covered by a commitment. That portion of a customer's energy load for which service is assured by the utility provider.

Fluidized-bed boiler - A large, refractory-lined vessel with an air distribution member or plate in the bottom, a hot gas outlet in or near the top, and some provisions for introducing fuel. The fluidized bed is formed by blowing air up through a layer of inert particles (such as sand or limestone) at a rate that causes the particles to go into suspension and continuous motion. The super-hot bed material increased combustion efficiency by its direct contact with the fuel.

Fly ash - Small ash particles carried in suspension in combustion products.

Forest land - Land at least 10 percent stocked by forest trees of any size, including land that formerly had such tree cover and that will be naturally or artificially regenerated. Forest land includes transition zones, such as areas between heavily forested and nonforested lands that are at least 10 percent stocked with forest trees and forest areas adjacent to urban and built-up lands. Also included are pinyon-juniper and chaparral areas in the West and afforested areas. The minimum area for classification of forest land is 1 acre. Roadside, streamside, and shelterbelt strips of trees must have a crown width of at least 120 feet to qualify as forest land. Unimproved roads and trails, streams, and clearings in forest areas are classified as forest if less than 120 feet wide.

Forest residues - Material not harvested or removed from logging sites in commercial hardwood and softwood stands as well as material resulting from forest management operations such as precommercial thinnings and removal of dead and dying trees.

Forest health - A condition of ecosystem sustainability and attainment of management objectives for a given forest area. Usually considered to include green trees, snags, resilient stands growing at a moderate rate, and endemic levels of insects and disease. Natural processes still function or are duplicated through management intervention.

Fossil fuel - Solid, liquid, or gaseous fuels formed in the ground after millions of years by chemical and physical changes in plant and animal residues under high temperature and pressure. Oil, natural gas, and coal are fossil fuels.

Fuel cell - A device that converts the energy of a fuel directly to electricity and heat, without combustion.

Fuel cycle - The series of steps required to produce electricity. The fuel cycle includes mining or otherwise acquiring the raw fuel source, processing and cleaning the fuel, transport, electricity generation, waste management and plant decommissioning.

Fuel treatment evaluator (FTE) - A strategic assessment tool capable of aiding the identification, evaluation, and prioritization of fuel treatment opportunities.

Fuelwood - Wood used for conversion to some form of energy, primarily for residential use.

Furnace - An enclosed chamber or container used to burn biomass in a controlled manner to produce heat for space or process heating.

Gasohol - A mixture of 10% anhydrous ethanol and 90% gasoline by volume; 7.5% anhydrous ethanol and 92.5% gasoline by volume; or 5.5% anhydrous ethanol and 94.5% gasoline by volume. There are other fuels that contain methanol and gasoline, but these fuels are not referred to as gasohol.

Gas turbine - (combustion turbine) A turbine that converts the energy of hot compressed gases (produced by burning fuel in compressed air) into mechanical power. Often fired by natural gas or fuel oil.

Gasification - A chemical or heat process to convert a solid fuel to a gaseous form.

Gasifier - A device for converting solid fuel into gaseous fuel. In biomass systems, the process is referred to as pyrolitic distillation. See Pyrolysis.

Genetic selection - Application of science to systematic improvement of a population, e.g. through selective breeding.

Gigawatt - (GW) A measure of electrical power equal to one billion watts (1,000,000 kW). A large coal or nuclear power station typically has a capacity of about 1 GW.

Grassland pasture and range - All open land used primarily for pasture and grazing, including shrub and brush land types of pasture; grazing land with sagebrush and scattered mesquite; and all tame and native grasses, legumes, and other forage used for pasture or grazing. Because of the diversity in vegetative composition, grassland pasture and range are not always clearly distinguishable from other types of pasture and range. At one extreme, permanent grassland may merge with cropland pasture, or grassland may often be found in transitional areas with forested grazing land.

Greenhouse effect - The effect of certain gases in the Earth's atmosphere in trapping heat from the sun.

Greenhouse gases - Gases that trap the heat of the sun in the Earth's atmosphere, producing the greenhouse effect. The two major greenhouse gases are water vapor and carbon dioxide. Other greenhouse gases include methane, ozone, chlorofluorocarbons, and nitrous oxide.

Grid - An electric utility company's system for distributing power.

Growing stock - A classification of timber inventory that includes live trees of commercial species meeting specified standards of quality or vigor. Cull trees are excluded. When associated with volume, includes only trees 5.0 inches in d.b.h. and larger.

Habitat - The area where a plant or animal lives and grows under natural conditions. Habitat includes living and non-living attributes and provides all requirements for food and shelter.

Hardwoods - Usually broad-leaved and deciduous trees.

Heat rate - The amount of fuel energy required by a power plant to produce one kilowatt-hour of electrical output. A measure of generating station thermal efficiency, generally expressed in Btu per net kWh. It is computed by dividing the total Btu content of fuel burned for electric generation by the resulting net kWh generation.

Heat transfer efficiency - useful heat output released / actual heat produced in the firebox.

Heating value - The maximum amount of energy that is available from burning a substance.

Hectare - Common metric unit of area, equal to 2.47 acres. 100 hectares = 1 square kilometer.

Herbaceous - Non-woody type of vegetation, usually lacking permanent strong stems, such as grasses, cereals and canola (rape).

HFCS - High fructose corn syrup.

Higher heating value - (HHV) The maximum potential energy in dry fuel. For wood, the range is from 7,600 to 9,600 Btu/lb (17.7 to 22.3 GJ/t).

Horsepower - (electrical horsepower; hp) A unit for measuring the rate of mechanical energy output, usually used to describe the maximum output of engines or electric motors. 1 hp = 550 foot-pounds per second = 2,545 Btu per hour = 745.7 watts = 0.746 kW

Hydrocarbon - A compound containing only hydrogen and carbon. The simplest and lightest forms of hydrocarbon are gaseous. With greater molecular weights they are liquid, while the heaviest are solids.

Idle cropland - Land in cover and soil improvement crops, and cropland on which no crops were planted. Some cropland is idle each year for various physical and economic reasons. Acreage diverted from crops to soil-conserving uses (if not eligible for and used as cropland pasture) under federal farm programs is included in this component. Cropland enrolled in the Federal Conservation Reserve Program (CRP) is included in idle cropland.

Incinerator - Any device used to burn solid or liquid residues or wastes as a method of disposal. In some incinerators, provisions are made for recovering the heat produced.

Inclined grate- A type of furnace in which fuel enters at the top part of a grate in a continuous ribbon, passes over the upper drying section where moisture is removed, and descends into the lower burning section. Ash is removed at the lower part of the grate.

Incremental energy costs - The cost of producing and transporting the next available unit of electrical energy. Short run incremental costs (SRIC) include only incremental operating costs. Long run incremental costs (LRIC) include the capital cost of new resources or capital equipment.

Independent power producer - A power production facility that is not part of a regulated utility.

Indirect liquefaction - Conversion of biomass to a liquid fuel through a synthesis gas intermediate step.

Industrial wood - All commercial roundwood products except fuelwood.

Joule - Metric unit of energy, equivalent to the work done by a force of one Newton applied over a distance of one meter (= 1 kg m2/s2). One joule (J) = 0.239 calories (1 calorie = 4.187 J).

Kilowatt - (kW) A measure of electrical power equal to 1,000 watts. 1 kW = 3412 Btu/hr = 1.341 horsepower. See also watt.

Kilowatt hour - (kWh) A measure of energy equivalent to the expenditure of one kilowatt for one hour. For example, 1 kWh will light a 100-watt light bulb for 10 hours. 1 kWh = 3412 Btu.

Landfill gas - A type of biogas that is generated by decomposition of organic material at landfill disposal sites. Landfill gas is approximately 50 percent methane. See also biogas.

Levelized life-cycle cost - The present value of the cost of a resource, including capital, financing and operating costs, expressed as a stream of equal annual payments. This stream of payments can be converted to a unit cost of energy by dividing the annual payment amount by the annual kilowatt-hours produced or saved. By levelizing costs, resources with different lifetimes and generating capabilities can be compared.

Lignin - Structural constituent of wood and (to a lesser extent) other plant tissues, which encrusts the cell walls and cements the cells together.

Live cull - A classification that includes live cull trees. When associated with volume, it is the net volume in live cull trees that are 5.0 inches in d.b.h. and larger.

Logging residues - The unused portions of growing-stock and non-growing-stock trees cut or killed by logging and left in the woods.

Megawatt - (MW) A measure of electrical power equal to one million watts (1,000 kW). See also watt.

Mill/kWh - A common method of pricing electricity in the United States. Tenths of a U.S. cent per kilowatt hour.

Mill residue - Wood and bark residues produced in processing logs into lumber, plywood, and paper.

MMBtu - One million British thermal units.

Moisture content - (MC) The weight of the water contained in wood, usually expressed as a percentage of weight, either oven-dry or as received.

Moisture content, dry basis - Moisture content expressed as a percentage of the weight of oven-dry wood, i.e.: [(weight of wet sample - weight of dry sample) / weight of dry sample] x 100

Moisture content, wet basis - Moisture content expressed as a percentage of the weight of wood as-received, i.e.: [(weight of wet sample - weight of dry sample) / weight of wet sample] x 100

Monoculture - The cultivation of a single species crop.

Net present value - The sum of the costs and benefits of a project or activity. Future benefits and costs are discounted to account for interest costs.

Nitrogen fixation - The transformation of atmospheric nitrogen into nitrogen compounds that can be used by growing plants.

Nitrogen oxides (NOx) - A product of combustion of fossil fuels whose production increases with the temperature of the process. It can become an air pollutant if concentrations are excessive.

Noncondensing, controlled extraction turbine - A turbine that bleeds part of the main steam flow at one (single extraction) or two (double extraction) points.

Nonforest land - Land that has never supported forests and lands formerly forested where use of timber management is precluded by development for other uses. (Note: Includes area used for crops, improved pasture, residential areas, city parks, improved roads of any width and adjoining clearings, powerline clearings of any width, and 1- to 4.5-acre areas of water classified by the Bureau of the Census as land. If intermingled in forest areas, unimproved roads and nonforest strips must be more than 120 feet wide, and clearings, etc., must be more than 1 acre in area to qualify as nonforest land.)

Nonattainment area - Any area that does not meet the national primary or secondary ambient air quality standard established by the Environmental Protection Agency for designated pollutants, such as carbon monoxide and ozone.

Nonindustrial private - An ownership class of private lands where the owner does not operate wood-using processing plants.

Old growth- Timber stands with the following characteristics; large mature and over-mature trees in the overstory, snags, dead and decaying logs on the ground, and a multi-layered canopy with trees of several age classes.

Open-loop biomass - Biomass that can be used to produce energy and bioproducts even though it was not grown specifically for this purpose. Examples of open-loop biomass include agricultural livestock waste, residues from forest harvesting operations and crop harvesting.

Organic compounds- Chemical compounds based on carbon chains or rings and also containing hydrogen, with or without oxygen, nitrogen, and other elements.

Other forest land - Forest land other than timberland and reserved forest land. It includes available forest land, which is incapable of annually producing 20 cubic feet per acre of industrial wood under natural conditions because of adverse site conditions such as sterile soils, dry climate, poor drainage, high elevation, steepness, or rockiness.

Other removals - Unutilized wood volume from cut or otherwise killed growing stock, from cultural operations such as precommercial thinnings, or from timberland clearing. Does not include volume removed from inventory through reclassification of timberland to productive reserved forest land.

Other sources - Sources of roundwood products that are not growing stock. These include salvable dead, rough and rotten trees, trees of noncommercial species, trees less than 5.0 inches d.b.h., tops, and roundwood harvested from non-forest land (for example, fence rows).

Oxygenate - A substance which, when added to gasoline, increases the amount of oxygen in that gasoline blend. Includes fuel ethanol, methanol, and methyl tertiary butyl ether (MTBE).

Particulate - A small, discrete mass of solid or liquid matter that remains individually dispersed in gas or liquid emissions. Particulates take the form of aerosol, dust, fume, mist, smoke, or spray. Each of these forms has different properties.

Photosynthesis - Process by which chlorophyll-containing cells in green plants concert incident light to chemical energy, capturing carbon dioxide in the form of carbohydrates.

Pilot scale - The size of a system between the small laboratory model size (bench scale) and a full-size system.

Poletimber trees - Live trees at least 5.0 inches in d.b.h. but smaller than sawtimber trees.

Present value - The worth of future receipts or costs expressed in current value. To obtain present value, an interest rate is used to discount future receipts or costs.

Primary wood-using mill - A mill that converts roundwood products into other wood products. Common examples are sawmills that convert saw logs into lumber and pulp mills that convert pulpwood roundwood into wood pulp.

Process heat - Heat used in an industrial process rather than for space heating or other housekeeping purposes.

Producer gas - Fuel gas high in carbon monoxide (CO) and hydrogen (H2), produced by burning a solid fuel with insufficient air or by passing a mixture of air and steam through a burning bed of solid fuel.

Public utility commissions - State agencies that regulate investor-owned utilities operating in the state.

Public utility regulatory policies act - (PURPA) A federal law requiring a utility to buy the power produced by a qualifying facility at a price equal to that which the utility would otherwise pay if it were to build its own power plant or buy power from another source.

Pulpwood - Roundwood, whole-tree chips, or wood residues that are used for the production of wood pulp.

Pyrolysis - The thermal decomposition of biomass at high temperatures (greater than 400° F, or 200° C) in the absence of air. The end product of pyrolysis is a mixture of solids (char), liquids (oxygenated oils), and gases (methane, carbon monoxide, and carbon dioxide) with proportions determined by operating temperature, pressure, oxygen content, and other conditions.

Quad: One quadrillion Btu (10^15 Btu) = 1.055 exajoules (EJ), or approximately 172 million barrels of oil equivalent.

Recovery boiler - A pulp mill boiler in which lignin and spent cooking liquor (black liquor) is burned to generate steam.

Refractory lining - A lining, usually of ceramic, capable of resisting and maintaining high temperatures.

Refuse-derived fuel - (RDF) Fuel prepared from municipal solid waste. Noncombustible materials such as rocks, glass, and metals are removed, and the remaining combustible portion of the solid waste is chopped or shredded. RDF facilities process typically between 100 and 3,000 tons of MSW per day.

Reserve margin - The amount by which the utility's total electric power capacity exceeds maximum electric demand.

Residues - Bark and woody materials that are generated in primary wood-using mills when roundwood products are converted to other products. Examples are slabs, edgings, trimmings, sawdust, shavings, veneer cores and clippings, and pulp screenings. Includes bark residues and wood residues (both coarse and fine materials) but excludes logging residues.

Return on investment- (ROI) The interest rate at which the net present value of a project is zero. Multiple values are possible.

Rotation - Period of years between establishment of a stand of timber and the time when it is considered ready for final harvest and regeneration.

Rotten tree - A live tree of commercial species that does not contain a saw log now or prospectively primarily because of rot (that is, when rot accounts for more than 50 percent of the total cull volume).

Rough tree - (a) A live tree of commercial species that does not contain a saw log now or prospectively primarily because of roughness (that is, when sound cull, due to such factors as poor form, splits, or cracks, accounts for more than 50 percent of the total cull volume) or (b) a live tree of noncommercial species.

Roundwood products - Logs and other round timber generated from harvesting trees for industrial or consumer use.

Salvable dead tree - A downed or standing dead tree that is considered currently or potentially merchantable by regional standards.

Saplings - Live trees 1.0 inch through 4.9 inches in d.b.h.

Saturated steam- Steam at boiling temperature for a given pressure.

Secondary wood processing mills - A mill that uses primary wood products in the manufacture of finished wood products, such as cabinets, moldings, and furniture.

Shaft horsepower - A measure of the actual mechanical energy per unit time delivered to a turning shaft. See also horsepower.

Silviculture - Theory and practice of controlling the establishment, composition, structure and growth of forests and woodlands. **Sound dead** - The net volume in salvable dead trees.

SRIC - Short rotation intensive culture - the growing of tree crops for bioenergy or fiber, characterized by detailed site preparation, usually less than 10 years between harvests, usually fast-growing hybrid trees and intensive management (some fertilization, weed and pest control, and possibly irrigation).

Stand - (of trees) A tree community that possesses sufficient uniformity in composition, constitution, age, spatial arrangement, or condition to be distinguishable from adjacent communities.

Steam turbine- A device for converting energy of high-pressure steam (produced in a boiler) into mechanical power which can then be used to generate electricity.

Superheated steam - Steam which is hotter than boiling temperature for a given pressure.

Surplus electricity- Electricity produced by cogeneration equipment in excess of the needs of an associated factory or business.

Sustainable- An ecosystem condition in which biodiversity, renewability, and resource productivity are maintained over time.

Synthetic ethanol - Ethanol produced from ethylene, a petroleum by-product.

Therm - A unit of energy equal to 100,000 Btus (= 105.5 MJ); used primarily for natural gas.

Thermochemical conversion - Use of heat to chemically change substances from one state to another, e.g. to make useful energy products.

Timberland - Forest land that is producing or is capable of producing crops of industrial wood, and that is not withdrawn from timber utilization by statute or administrative regulation. Areas qualifying as timberland are capable of producing more than 20 cubic feet per acre per year of industrial wood in natural stands. Currently inaccessible and inoperable areas are included.

Timber Product Output Database Retrieval System (TPO) - Developed in support of the 1997 Resources Planning Act (RPA) Assessment, this system acts as an interface to a standard set of consistently coded TPO data for each state and county in the country. This set of national TPO data consists of 11 data variables that describe for each county the roundwood products harvested, the logging residues left behind, the timber otherwise removed, and the wood and bark residues generated by its primary wood-using mills.

Tipping fee - A fee for disposal of waste.

Ton, Tonne - One U.S. ton (short ton) = 2,000 pounds. One Imperial ton (long ton or shipping ton) = 2,240 pounds. One metric tonne(tonne) = 1,000 kilograms (2,205 pounds). One oven-dry ton or tonne (ODT, sometimes termed bone-dry ton/tonne) is the amount of wood that weighs one ton/tonne at 0% moisture content. One green ton/tonne refers to the weight of undried (fresh) biomass material - moisture content must be specified if green weight is used as a fuel measure.

Topping cycle - A cogeneration system in which electric power is produced first. The reject heat from power production is then used to produce useful process heat.

Topping and back pressure turbines - Turbines which operate at exhaust pressure considerably higher than atmospheric (noncondensing turbines). These turbines are often multistage types with relatively high efficiency.

Transmission- The process of long-distance transport of electrical energy, generally accomplished by raising the electric current to high voltages.

Traveling grate- A type of furnace in which assembled links of grates are joined together in a perpetual belt arrangement. Fuel is fed in at one end and ash is discharged at the other.

Turbine - A machine for converting the heat energy in steam or high temperature gas into mechanical energy. In a turbine, a high velocity flow of steam or gas passes through successive rows of radial blades fastened to a central shaft.

Turn down ratio- The lowest load at which a boiler will operate efficiently as compared to the boiler's maximum design load.

Waste streams - Unused solid or liquid by-products of a process.

Water-cooled vibrating grate - A boiler grate made up of a tuyere grate surface mounted on a grid of water tubes interconnected with the boiler circulation system for positive cooling. The structure is supported by flexing plates allowing the grid and grate to move in a vibrating action. Ashes are automatically discharged.

Watershed - The drainage basin contributing water, organic matter, dissolved nutrients, and sediments to a stream or lake.

Watt - The common base unit of power in the metric system. One watt equals one joule per second, or the power developed in a circuit by a current of one ampere flowing through a potential difference of one volt. One Watt = 3.412 Btu/hr. See also kilowatt.

Wheeling - The process of transferring electrical energy between buyer and seller by way of an intermediate utility or utilities.

Whole-tree harvesting - A harvesting method in which the whole tree (above the stump) is removed.

Yarding - The initial movement of logs from the point of felling to a central loading area or landing.