Biomass Energy Data Book

Edition 4

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy | OAK RIDGE National Laboratory

USEFUL WEB SITES

GOVERNMENT LINKS

U.S. DEPARTMENT OF AGRICULTURE	www.usda.gov
Agricultural Research Service	www.ars.usda.gov
Forest Service	www.fs.fed.us
National Agricultural Library	www.nal.usda.gov
National Agricultural Statistics Service	www.nass.usda.gov
U.S. DEPARTMENT OF ENERGY	www.energy.gov
Energy Efficiency and Renewable Energy	www.eere.energy.gov
Biomass Program	www.eere.energy.gov/biomass
Bioenergy Knowledge Discovery Framework	bioenergykdf.net
Alternative Fuels Data Center	www.eere.energy.gov/afdc
Clean Cities	www.eere.energy.gov/cleancities
Fuel Economy	www.fueleconomy.gov
Biomass Energy Data Book	cta.ornl.gov/bedb
Buildings Energy Data Book	www.btscoredatabook.net
Power Technologies Data Book	www.nrel.gov/analysis/power_databook
Transportation Energy Data Book	cta.ornl.gov/data
Energy Information Administration	www.eia.doe.gov
IDAHO NATIONAL LABORATORY	www.inl.gov
NATIONAL RENEWABLE ENERGY LABORATORY	www.nrel.gov
OAK RIDGE NATIONAL LABORATORY	www.ornl.gov
Bioenergy Feedstock Information	bioenergy.ornl.gov
Center for Transportation Analysis	cta.ornl.gov
PACIFIC NORTHWEST NATIONAL LABORATORY	www.pnl.gov
USA.GOV	www.usa.gov
FEDERAL GOVERNMENT – FEDSTATS	www.fedstats.gov
U.S. BUREAU OF LABOR STATISTICS	www.bls.gov
U.S. CENSUS BUREAU	www.census.gov
U.S. DEPARTMENT OF COMMERCE	www.commerce.gov
Bureau of Economic Analysis	www.bea.gov
U.S. ENVIRONMENTAL PROTECTION AGENCY	www.epa.gov

NON GOVERNMENT LINKS

American Corn Growers Association	www.acga.org
American Soybean Association	www.soygrowers.com
National Biodiesel Board	www.biodiesel.org
National Oilseed Processors Association	www.nopa.org
National Ethanol Vehicle Coalition	www.e85fuel.com
Pellet Fuels Institute	pelletheat.org
Short Rotation Woody Crops Operations Working Group	www.woodycrops.org

Cover Image: Courtesy of the Department of Energy, National Renewable Energy Laboratory.

ORNL/TM-2011/446

BIOMASS ENERGY DATA BOOK:
EDITION 4

Bob Boundy
Roltek, Inc.
Clinton, Tennessee

Susan W. Diegel
Oak Ridge National Laboratory
Oak Ridge, Tennessee

Lynn Wright
WrightLink Consulting
Ten Mile, Tennessee

Stacy C. Davis
Oak Ridge National Laboratory
Oak Ridge, Tennessee

September 2011

Prepared for the
Office of the Biomass Program
Energy Efficiency and Renewable Energy
U.S. Department of Energy

Prepared by the
Oak Ridge National Laboratory
Oak Ridge, Tennessee, 37831-6073
managed by
UT-BATTELLE, LLC
for the
U.S. DEPARTMENT OF ENERGY

Users of the *Biomass Energy Data B ook* are encouraged to send comments on errors, omissions, emphases, and organization of this report to Ms. Stacy Davis, Oak Ridge National Laboratory. The DOE sponsor for this project is also listed below.

Stacy C. Davis
Oak Ridge National Laboratory
National Transportation Research Center
2360 Cherahala Boulevard
Knoxville, Tennessee 37932
Telephone: (865) 946-1256
FAX: (865) 946-1314
E-mail: DAVISSC@ornl.gov
Web Site Location: cta.ornl.gov

Zia Haq
Office of the Biomass Program
Department of Energy, EE-2E
Forrestal Building
1000 Independence Avenue, S.W.
Washington, DC 20585
Telephone: (202) 586-2869
FAX: (202) 586-1640
E-mail: Zia.Haq@ee.doe.gov
Web Site Location:
http://www.eere.energy.gov/

The *Biomass Energy Data Book*
can be found on the Web at:
cta.ornl.gov/bedb

ACRONYMS

AEO	Annual Energy Outlook
ARS	Agricultural Research Service, USDA
ASABE	American Society of Agricultural and Biological Engineers
ASTM	American Society for Testing and Materials
Btu	British thermal unit
CES	Cooperative Extension Service
CO_2	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
Etoh	Ethanol
FTE	Fuel Treatment Evaluator
FY	Fiscal Year
GAO	United States Government Accountability Office
GHG	Greenhouse Gas
GPRA	Government Performance Results Act
GW	Gigawatt
IEA	International Energy Agency
iLUC	Indirect Land-Use Change
LCA	Life-Cycle Analysis
LFG	Landfill Gas
MC	Moisture Content
MGY	Million Gallons per Year
MJ	Megajoule
MMBtu	One Million British thermal units
MPG	Miles per Gallon
MW	Megawatt
MSW	Municipal Solid Waste
NASS	National Agricultural Statistics Service
NEMS	National Energy Modeling System
NOAA	National Oceanic & Atmospheric Administration
NREL	National Renewable Energy Laboratory
NRCS	Natural Resources Conservation Service
ORNL	Oak Ridge National Laboratory
PNNL	Pacific Northwest National Laboratory
PPA	Power Purchase Agreement
REC	Renewable Energy Certificate
RPS	Renewable Portfolio Standard
SEO	State Energy Office
SRIC	Short Rotation Intensive Culture
SRWC	Short Rotation Woody Crops
SSEB	Southern States Energy Board
TBD	To Be Determined
TVA	Tennessee Valley Authority
USDA	United States Department of Agriculture
USFS	United States Forest Service

PREFACE

The Department of Energy, through the Biomass Program 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 fourth edition of the Biomass Energy Data Book and it is only available online in electronic format. Because there are many diverse online sources of biomass information, the Data Book provides links to many of those valuable information sources. 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 most of the types of biomass energy currently being produced in this country. It is certain, however, that not all biomass energy contributions have been identified. With the rapid expansion in biomass technologies that is occurring, bioenergy production information may not yet 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. 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 Biomass Program 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, including discussions on sustainability.

This is the fourth edition of the Biomass Energy Data Book which is 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 bio-oil. 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 two appendices which include frequently needed conversion factors, a table of selected biomass feedstock characteristics, and discussions on sustainability. A glossary of terms and a list of acronyms are also included for the reader's convenience.

INTRODUCTION TO BIOMASS

Contents	Data Type	Updated
Biomass Energy Overview	Text	08/26/2011
Energy Independence and Security Act of 2007	Text	10/02/2012
Biomass Energy Production and Consumption by Source and Sector		
Primary Energy Consumption by Major Fuel Source, 1974-2010	Table	08/30/2011
Energy Production by Source, 1973-2010	Table	08/29/2011
Energy Consumption by Source, 1973-2010	Table	08/29/2011
Renewable Energy Consumption by Source, 1973-2010	Table	10/02/2012
Renewable Energy Consumption for Industrial and Transportation Sectors, 1973-2010	Table	08/29/2011
Renewable Energy Consumption for Residential and Commercial Sectors, 1973-2010	Table	08/29/2011
Industrial Biomass Energy Consumption and Electricity Net Generation by Industry and Energy Source, 2008	Table	10/02/2012
Summary of Biomass Energy Consumption, 2010	*Figure*	08/29/2011
Biomass Energy Sustainability	Text	09/29/2011
Indirect Land Use Change	Text	09/29/2011
A Comparison of Climate Impacts of Various Bioenergy Systems	*Figure*	10/02/2012
Biomass Resources Overview	Text	10/02/2012
Biomass Definitions in Legislation	Text	08/26/2011
Major Uses of Land in the United States, 2007	*Figure*	08/29/2011
Geographic Locations of Major Crops, 2010	*Figure*	08/04/2011
Geographic Distribution of Timberland by County, 2007	*Figure*	10/02/2012
Projected Consumption of Currently Used Biomass Feedstocks by Source	Table	09/07/2011
Summary of Currently Used and Potential Biomass	Table	08/30/2011

Biomass Energy Overview

In 2010, biomass energy production contributed 4.3 quadrillion Btu (British thermal units) of energy to the 75 quadrillion Btu of energy produced in the United States or about 5.7% of total energy production. Since a substantial portion of U.S. energy is imported, the more commonly quoted figure is that biomass consumption amounted to 4.3 quadrillion Btu of energy of the 98 quadrillion Btu of energy consumed in the United States in 2010 or about 4.4%. 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. However, the contribution of biofuels has nearly tripled since 2005 and now accounts for about 43% of all biomass consumed. While most biofuels feedstocks are currently starches, oils and fats derived from the agricultural sector, whole plants and plant residues will soon be an important feedstock for cellulosic biofuels. Algae are being developed as a source of both oil and cellulosic feedstocks. The industrial sector (primarily the wood products industry) used about 2.2 quadrillion Btu in 2010. The residential and commercial sectors consume 0.05 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 now at about 1 quadrillion Btu. This is less than the total amount of biofuels produced because some liquid biofuels are used by other sources.

The tables in the introduction showing the accounting of energy production and consumption are all derived from Energy Information Administration (EIA) reports. Information on assumed Btu content of most fuels and the assumptions used in estimating the total Btus consumed in the US can be found in the EIA Monthly Energy Review at: http://www.eia.gov/totalenergy/data/monthly/pdf/sec13.pdf. A key point is that gross heat contents (higher heating values) of fuels and biomass feedstocks are used rather than the net heat contents (lower heating values) commonly used in Europe. Differences may range from 2 to 10%. The assumptions for the gross heat content of wood and consumption estimation were found under a discussion of “wood conversion to Btu” in the EIA glossary that can be accessed at http://www.eia.gov/tools/glossary/. The EIA glossary explains that many factors can affect wood heat content but EIA calculations always assume 20 million Btu per cord of wood. This is actually slightly higher than the heat content values for wood found from multiple other sources. A table, showing both higher and lower heating values for many biomass fuels, is included in appendix A of the Biomass Energy Data Book. Factors for translating cords to other units of wood are also found in the appendix A. The EIA glossary also notes that EIA biomass waste data includes energy crops grown specifically for energy production. This is likely due to the fact that insufficient amounts of dedicated energy crops are currently being used to warrant separate tracking.

The Renewable Fuels Association characterized 2007 as a year that ushered in a new energy era for America. The enactment of the Energy Independence and Security Act of 2007 (H.R. 6) coupled increased vehicle efficiency with greater renewable fuel use. The law increased the Renewable Fuel Standard (RFS) to 36 billion gallons of annual renewable fuel use by 2022 and required that 60 percent of the new RFS be met by advanced biofuels, including cellulosic ethanol. The recent increase in the percentage of biomass consumed in the U.S. is largely due to the increased production and consumption of biofuels.

Biomass energy production involves the use of a wide range of technologies to produce heat, steam, electricity and transportation fuels from renewable biomass feedstocks. Descriptions of many of the biomass technologies currently in commercial use or being tested are included in the Biomass Energy Data Book. Information on the characteristics and availability of utilized or potential biomass feedstocks as well as information on relevant policies are also included. Information on economics and sustainability is included to a limited extent since the limited information publically available is generally based on estimates rather than factual data.

Legislation passed in December 2007 created a large incentive to increase the total amount of renewable biofuels available in the U.S. with nearly half to be derived from lignocellulosic biomass, but excluded the use of biomass from some sources.

Section: INTRODUCTION
Energy Independence and Security Act (EISA) 2007

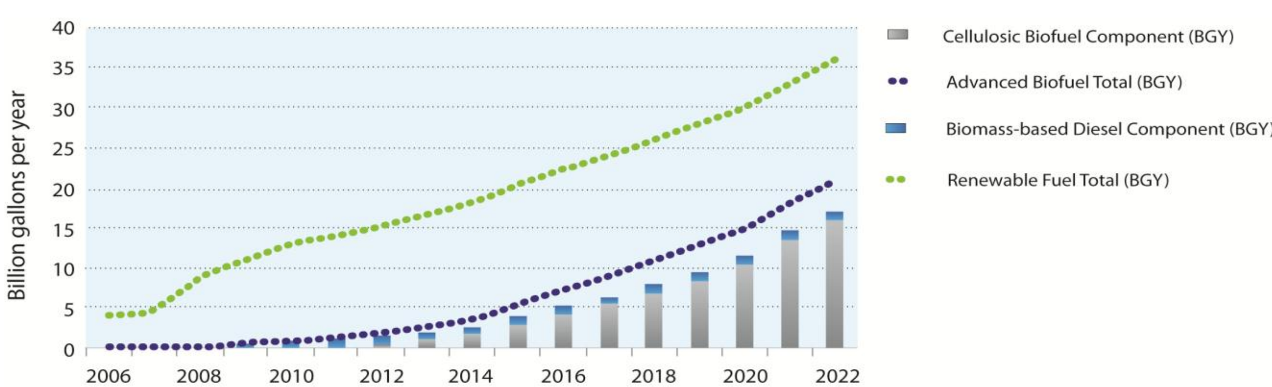
EISA legislation was signed into law on December 19, 2007. The law contains a number of provisions to increase energy efficiency and the availability and use of renewable energy. One key provision of EISA is the setting of a revised Renewable Fuels Standard (RFS). The revised RFS mandates the use of 36 billion gallons per year (BGY) of renewable fuels by 2022. The revised RFS has specific fuel allocations for 2022 that include use of:

- 16 BGY of cellulosic biofuels
- 14 BGY of advanced biofuels
- 1 BGY of biomass-based biodiesel
- 15 BGY of conventional biofuels (e.g., corn starch-based ethanol).

(See, 42 U.S.C. 7545(o)(2)) EISA legislation also established new definitions and criteria for both renewable fuels (e.g., greenhouse gas reduction thresholds) and the renewable biomass used to produce the fuels. Renewable biomass includes, generally:

- Crops from previously cleared non-forested land
- Trees from actively managed plantations on non-federal land
- Residues from non-federal forestland that is deemed not to be critically imperiled or rare
- Biomass from the immediate vicinity of buildings or public infrastructure at risk from wildfires
- Algae
- Separated yard or food waste.

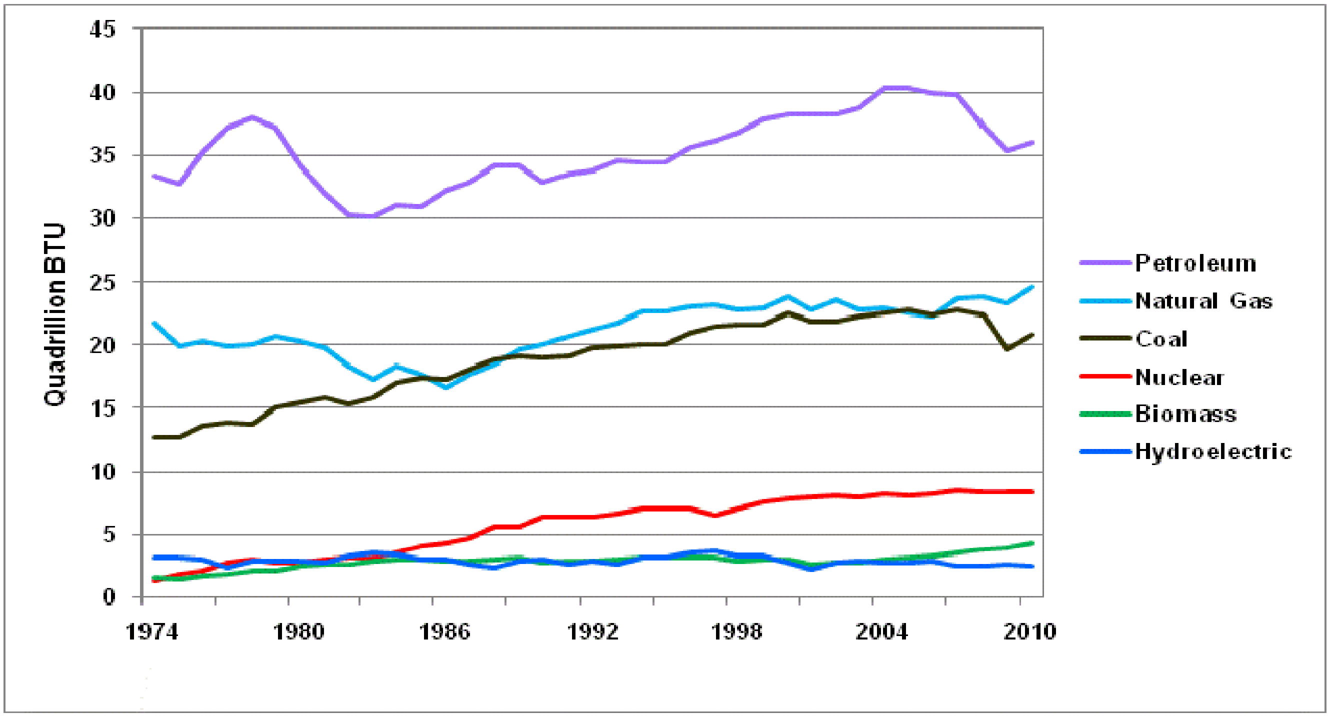
(See, 42 U.S.C. 7545(o)(1)(I)) Excluded from the qualifying renewable biomass are resources from ecologically sensitive or protected lands, biomass from federal forestlands, biomass from newly cleared or cultivated land, and merchantable biomass from naturally regenerated forestlands.



Above write-up extracted from: Perlack, R. D., and B. J. Stokes (leads), *U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and BiproductsIndustry* , ORNL/TM-2010/224, Oak Ridge National Laboratory, Oak Ridge, TN, 2011, p. 227.

A variety of biomass feedstocks are currently used to generate electricity, produce heat, and liquid transportation fuels. According to EIA, biomass contributes nearly 4.3 quadrillion Btu (British thermal unit) and accounts for more than 4% of total U.S. primary energy consumption. In 2009, the share of biomass in total U.S. energy consumption exceeded 4% for the first time. Over the last 30 years, the share of biomass in total primary energy consumption has averaged less that 3.5%. However, as shown in the figure below there has been a gradual increase in biomass consumption that started in the early 2000s. This increase is due to ethanol production. The EIA estimates include the energy content of the biofuels (ethanol and biodiesel) feedstock minus the energy content of liquid fuel produced.

Section: INTRODUCTION
Primary Energy Consumption by Major Fuel Source, 1974 - 2010



Source:
U.S. Department of Energy, Energy Information Administration, *Monthly Energy Review*, July 2011, Washington, D.C., Table 1.3.
http://www.eia.gov/totalenergy/data/monthly/

In 2010 biomass accounted for just over half of the renewable energy production in the United States.

Section: INTRODUCTION
Energy Production by Source, 1973-2010
(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	Geo-thermal	Solar	Wind	Total	Total
1973	13.992	22.187	19.493	2.569	58.241	0.910	2.861	1.529	0.020	NA	NA	4.433	63.585
1974	14.074	21.210	18.575	2.471	56.331	1.272	3.177	1.540	0.026	NA	NA	4.769	62.372
1975	14.989	19.640	17.729	2.374	54.733	1.900	3.155	1.499	0.034	NA	NA	4.723	61.357
1976	15.654	19.480	17.262	2.327	54.723	2.111	2.976	1.713	0.038	NA	NA	4.768	61.602
1977	15.755	19.565	17.454	2.327	55.101	2.702	2.333	1.838	0.037	NA	NA	4.249	62.052
1978	14.910	19.485	18.434	2.245	55.074	3.024	2.937	2.038	0.031	NA	NA	5.039	63.137
1979	17.540	20.076	18.104	2.286	58.006	2.776	2.931	2.152	0.040	NA	NA	5.166	65.948
1980	18.598	19.908	18.249	2.254	59.008	2.739	2.900	2.476	0.053	NA	NA	5.485	67.232
1981	18.377	19.699	18.146	2.307	58.529	3.008	2.758	2.596	0.059	NA	NA	5.477	67.014
1982	18.639	18.319	18.309	2.191	57.458	3.131	3.266	2.664	0.051	NA	NA	6.034	66.623
1983	17.247	16.593	18.392	2.184	54.416	3.203	3.527	2.904	0.064	NA	0.000	6.561	64.180
1984	19.719	18.008	18.848	2.274	58.849	3.553	3.386	2.971	0.081	0.000	0.000	6.522	68.924
1985	19.325	16.980	18.992	2.241	57.539	4.076	2.970	3.016	0.097	0.000	0.000	6.185	67.799
1986	19.509	16.541	18.376	2.149	56.575	4.380	3.071	2.932	0.108	0.000	0.000	6.223	67.178
1987	20.141	17.136	17.675	2.215	57.167	4.754	2.635	2.875	0.112	0.000	0.000	5.739	67.659
1988	20.738	17.599	17.279	2.260	57.875	5.587	2.334	3.016	0.106	0.000	0.000	5.568	69.030
1989	21.360	17.847	16.117	2.158	57.483	5.602	2.837	3.160	0.162	0.055	0.022	6.391	69.476
1990	22.488	18.326	15.571	2.175	58.560	6.104	3.046	2.735	0.171	0.060	0.029	6.206	70.870
1991	21.636	18.229	15.701	2.306	57.872	6.422	3.016	2.782	0.178	0.063	0.031	6.238	70.532
1992	21.694	18.375	15.223	2.363	57.655	6.479	2.617	2.933	0.179	0.064	0.030	5.993	70.127
1993	20.336	18.584	14.494	2.408	55.822	6.410	2.892	2.910	0.186	0.066	0.031	6.263	68.495
1994	22.202	19.348	14.103	2.391	58.044	6.694	2.683	3.030	0.173	0.069	0.036	6.155	70.893
1995	22.130	19.082	13.887	2.442	57.540	7.075	3.205	3.102	0.152	0.070	0.033	6.703	71.319
1996	22.790	19.344	13.723	2.530	58.387	7.087	3.590	3.157	0.163	0.071	0.033	7.167	72.641
1997	23.310	19.394	13.658	2.495	58.857	6.597	3.640	3.111	0.167	0.070	0.034	7.180	72.634
1998	24.045	19.613	13.235	2.420	59.314	7.068	3.297	2.933	0.168	0.070	0.031	6.659	73.041
1999	23.295	19.341	12.451	2.528	57.614	7.610	3.268	2.969	0.171	0.069	0.046	6.683	71.907
2000	22.735	19.662	12.358	2.611	57.366	7.862	2.811	3.010	0.164	0.066	0.057	6.262	71.490
2001	23.547	20.166	12.282	2.547	58.541	8.033	2.242	2.629	0.164	0.065	0.070	5.318	71.892
2002	22.732	19.439	12.163	2.559	56.894	8.143	2.689	2.712	0.171	0.064	0.105	5.899	70.936
2003	22.094	19.691	12.026	2.346	56.157	7.959	2.825	2.815	0.175	0.064	0.115	6.149	70.264
2004	22.852	19.093	11.503	2.466	55.914	8.222	2.690	3.011	0.178	0.065	0.142	6.248	70.384
2005	23.185	18.574	10.963	2.334	55.056	8.160	2.703	3.141	0.181	0.066	0.178	6.431	69.647
2006	23.790	19.022	10.801	2.356	55.968	8.215	2.869	3.226	0.181	0.068	0.264	6.608	70.792
2007	23.493	19.825	10.721	2.409	56.447	8.455	2.446	3.489	0.186	0.076	0.341	6.537	71.440
2008	23.851	20.703	10.509	2.419	57.482	8.427	2.511	3.867	0.192	0.089	0.546	7.205	73.114
2009	21.627	21.095	11.348	2.574	56.644	8.356	2.669	3.915	0.200	0.098	0.721	7.603	72.603
2010	22.077	22.095	11.669	2.686	58.527	8.441	2.509	4.310	0.212	0.109	0.924	8.064	75.031

Source:
U.S. Department of Energy, Energy Information Administration, *Monthly Energy Review,* June 2011. Table 1.2,
www.eia.doe.gov/emeu/mer/overview.html

Note: NA = Not available.

[a]Most data are estimates.
[b]Includes lease condensate.
[c]Conventional hydroelectric power.

Energy Consumption by Source, 1973-2010
(Quadrillion Btu)

Year	Fossil Fuels				Nuclear Electric Power	Renewable Energy[a]						Total[d,h]
	Coal	Natural Gas[b]	Petroleum[c,d]	Total[e]		Hydroelectric Power[f]	Biomass[d,g]	Geothermal	Solar	Wind	Total	
1973	12.971	22.512	34.837	70.314	0.910	2.861	1.529	0.020	NA	NA	4.411	75.684
1974	12.663	21.732	33.454	67.905	1.272	3.177	1.540	0.026	NA	NA	4.742	73.962
1975	12.663	19.948	32.732	65.357	1.900	3.155	1.499	0.034	NA	NA	4.687	71.965
1976	13.584	20.345	35.178	69.107	2.111	2.976	1.713	0.038	NA	NA	4.727	75.975
1977	13.922	19.931	37.124	70.991	2.702	2.333	1.838	0.037	NA	NA	4.209	77.961
1978	13.766	20.000	37.963	71.854	3.024	2.937	2.038	0.031	NA	NA	5.005	79.950
1979	15.040	20.666	37.122	72.891	2.776	2.931	2.152	0.040	NA	NA	5.123	80.859
1980	15.423	20.235	34.205	69.828	2.739	2.900	2.476	0.053	NA	NA	5.428	78.067
1981	15.908	19.747	31.932	67.571	3.008	2.758	2.596	0.059	NA	NA	5.414	76.106
1982	15.322	18.356	30.232	63.888	3.131	3.266	2.663	0.051	NA	NA	5.980	73.099
1983	15.894	17.221	30.052	63.152	3.203	3.527	2.904	0.064	NA	0.000	6.496	72.971
1984	17.071	18.394	31.053	66.506	3.553	3.386	2.971	0.081	0.000	0.000	6.438	76.632
1985	17.478	17.703	30.925	66.093	4.076	2.970	3.016	0.097	0.000	0.000	6.084	76.392
1986	17.260	16.591	32.198	66.033	4.380	3.071	2.932	0.108	0.000	0.000	6.111	76.647
1987	18.008	17.640	32.864	68.521	4.754	2.635	2.875	0.112	0.000	0.000	5.622	79.054
1988	18.846	18.448	34.223	71.557	5.587	2.334	3.016	0.106	0.000	0.000	5.457	82.709
1989	19.070	19.602	34.209	72.911	5.602	2.837	3.159	0.162	0.055	0.022	6.235	84.786
1990	19.173	19.603	33.552	72.332	6.104	3.046	2.735	0.171	0.059	0.029	6.041	84.485
1991	18.992	20.033	32.846	71.880	6.422	3.016	2.782	0.178	0.062	0.031	6.069	84.438
1992	19.122	20.714	33.525	73.396	6.479	2.617	2.932	0.179	0.064	0.030	5.821	85.783
1993	19.835	21.229	33.745	74.836	6.410	2.892	2.908	0.186	0.066	0.031	6.083	87.424
1994	19.909	21.728	34.561	76.256	6.694	2.683	3.028	0.173	0.068	0.036	5.988	89.091
1995	20.089	22.671	34.438	77.259	7.075	3.205	3.101	0.152	0.069	0.033	6.560	91.029
1996	21.002	23.085	35.675	79.785	7.087	3.590	3.157	0.163	0.070	0.033	7.014	94.022
1997	21.445	23.223	36.159	80.873	6.597	3.640	3.105	0.167	0.070	0.034	7.016	94.602
1998	21.656	22.830	36.816	81.369	7.068	3.297	2.927	0.168	0.069	0.031	6.493	95.018
1999	21.623	22.909	37.838	82.427	7.610	3.268	2.963	0.171	0.068	0.046	6.516	96.652
2000	22.580	23.824	38.262	84.731	7.862	2.811	3.008	0.164	0.065	0.057	6.106	98.814
2001	21.914	22.773	38.186	82.902	8.029	2.242	2.622	0.164	0.064	0.070	5.163	96.168
2002	21.904	23.558	38.224	83.747	8.145	2.689	2.701	0.171	0.063	0.105	5.729	97.693
2003	22.321	22.831	38.811	84.014	7.959	2.825	2.807	0.175	0.062	0.115	5.983	97.978
2004	22.466	22.909	40.292	85.805	8.222	2.690	3.010	0.178	0.063	0.142	6.082	100.148
2005	22.797	22.561	40.388	85.790	8.161	2.703	3.116	0.181	0.063	0.178	6.242	100.277
2006	22.447	22.224	39.955	84.687	8.215	2.869	3.276	0.181	0.068	0.264	6.659	99.624
2007	22.749	23.702	39.774	86.251	8.455	2.446	3.502	0.186	0.076	0.341	6.551	101.363
2008	22.385	23.834	37.280	83.540	8.427	2.511	3.852	0.192	0.089	0.546	7.190	99.268
2009	19.692	23.344	35.403	78.415	8.356	2.669	3.899	0.200	0.098	0.721	7.587	94.475
2010	20.817	24.643	35.970	81.425	8.441	2.509	4.295	0.212	0.109	0.924	8.049	98.003

Source:
U.S. Department of Energy, Energy Information Administration, *Monthly Energy Review,* June 2011. Table 1.3, www.eia.doe.gov/emeu/mer/overview.html

Note: NA = Not available.

[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 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.

Biofuels, which are produced mainly from corn and soybeans, made up 43% of all biomass consumed in the U.S. in 2010. The other 57% comes mainly from waste -- wood waste, municipal solid waste, landfill gas, etc.

Section: INTRODUCTION
Renewable Energy Consumption by Source, 1973-2010
(Trillion Btu)

Year	Hydro-electric Power[a]	Biomass				Geo-thermal[e]	Solar[f]	Wind[g]	Total
		Wood[b]	Waste[c]	Biofuels[d]	Total				
1973	2,861	1,527	2	NA	1,529	20	NA	NA	4,411
1974	3,177	1,538	2	NA	1,540	26	NA	NA	4,742
1975	3,155	1,497	2	NA	1,499	34	NA	NA	4,687
1976	2,976	1,711	2	NA	1,713	38	NA	NA	4,727
1977	2,333	1,837	2	NA	1,838	37	NA	NA	4,209
1978	2,937	2,036	1	NA	2,038	31	NA	NA	5,005
1979	2,931	2,150	2	NA	2,152	40	NA	NA	5,123
1980	2,900	2,474	2	NA	2,476	53	NA	NA	5,428
1981	2,758	2,496	88	13	2,596	59	NA	NA	5,414
1982	3,266	2,510	119	34	2,663	51	NA	NA	5,980
1983	3,527	2,684	157	63	2,904	64	NA	0	6,496
1984	3,386	2,686	208	77	2,971	81	0	0	6,438
1985	2,970	2,687	236	93	3,016	97	0	0	6,084
1986	3,071	2,562	263	107	2,932	108	0	0	6,111
1987	2,635	2,463	289	123	2,875	112	0	0	5,622
1988	2,334	2,577	315	124	3,016	106	0	0	5,457
1989	2,837	2,680	354	125	3,159	162	55	22	6,235
1990	3,046	2,216	408	111	2,735	171	59	29	6,041
1991	3,016	2,214	440	128	2,782	178	62	31	6,069
1992	2,617	2,313	473	145	2,932	179	64	30	5,821
1993	2,892	2,260	479	169	2,908	186	66	31	6,083
1994	2,683	2,324	515	188	3,028	173	68	36	5,988
1995	3,205	2,370	531	198	3,099	152	69	33	6,560
1996	3,590	2,437	577	141	3,155	163	70	33	7,014
1997	3,640	2,371	551	186	3,108	167	70	34	7,016
1998	3,297	2,184	542	202	2,929	168	69	31	6,493
1999	3,268	2,214	540	211	2,965	171	68	46	6,516
2000	2,811	2,262	511	233	3,006	164	65	57	6,106
2001	2,242	2,006	364	254	2,624	164	64	70	5,163
2002	2,689	1,995	402	308	2,705	171	63	105	5,729
2003	2,825	2,002	401	402	2,805	175	62	115	5,983
2004	2,690	2,121	389	487	2,998	178	63	142	6,082
2005	2,703	2,136	403	564	3,104	181	63	178	6,242
2006	2,869	2,109	397	720	3,226	181	68	264	6,659
2007	2,446	2,098	413	978	3,489	186	76	341	6,551
2008	2,511	2,044	436	1,387	3,867	192	89	546	7,190
2009	2,669	1,881	452	1,583	3,915	200	98	721	7,587
2010	2,509	1,986	454	1,870	4,310	212	109	924	8,049

Source:
U.S. Department of Energy, Energy Information Administration, *Monthly Energy Review,* June 2011, Table 10.1, www.eia.doe.gov/emeu/mer/renew.html

Note: NA = Not available.

[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] Fuel ethanol and biodiesel consumption, plus losses and co-products from the production of ethanol and biodiesel.
[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 97% of the renewable transportation fuels consumed in the United States in 2010 while biodiesel accounted for less than 3%. In the industrial sector, biomass accounted for nearly all of the renewable energy consumed.

Section: INTRODUCTION

Renewable Energy Consumption for Industrial and Transportation Sectors, 1973-2010

(Trillion Btu)

	Industrial Sector[a]								Transportation Sector		
		Biomass							Biomass		
Year	Hydro-electric Power[b]	Wood[c]	Waste[d]	Fuel Ethanol[e]	Losses and Co-products[f]	Total	Geo-thermal[g]	Total	Fuel Ethanol[h]	Biodiesel[f]	Total
1973	35	1,165	NA	NA	NA	1,165	NA	1,200	NA	NA	NA
1974	33	1,159	NA	NA	NA	1,159	NA	1,192	NA	NA	NA
1975	32	1,063	NA	NA	NA	1,063	NA	1,096	NA	NA	NA
1976	33	1,220	NA	NA	NA	1,220	NA	1,253	NA	NA	NA
1977	33	1,281	NA	NA	NA	1,281	NA	1,314	NA	NA	NA
1978	32	1,400	NA	NA	NA	1,400	NA	1,432	NA	NA	NA
1979	34	1,405	NA	NA	NA	1,405	NA	1,439	NA	NA	NA
1980	33	1,600	NA	NA	NA	1,600	NA	1,633	NA	NA	NA
1981	33	1,602	87	0	6	1,695	NA	1,728	7	NA	7
1982	33	1,516	118	0	16	1,650	NA	1,683	18	NA	18
1983	33	1,690	155	0	29	1,874	NA	1,908	34	NA	34
1984	33	1,679	204	1	35	1,918	NA	1,951	41	NA	41
1985	33	1,645	230	1	42	1,918	NA	1,951	50	NA	50
1986	33	1,610	256	1	48	1,915	NA	1,948	57	NA	57
1987	33	1,576	282	1	55	1,914	NA	1,947	66	NA	66
1988	33	1,625	308	1	55	1,989	NA	2,022	67	NA	67
1989	28	1,584	200	1	56	1,841	2	1,871	68	NA	68
1990	31	1,442	192	1	49	1,684	2	1,717	60	NA	60
1991	30	1,410	185	1	56	1,652	2	1,684	70	NA	70
1992	31	1,461	179	1	64	1,705	2	1,737	80	NA	80
1993	30	1,484	181	1	74	1,741	2	1,773	94	NA	94
1994	62	1,580	199	1	82	1,862	3	1,927	105	NA	105
1995	55	1,652	195	2	86	1,934	3	1,992	112	NA	112
1996	61	1,683	224	1	61	1,969	3	2,033	81	NA	81
1997	58	1,731	184	1	80	1,996	3	2,057	102	NA	102
1998	55	1,603	180	1	86	1,872	3	1,929	113	NA	113
1999	49	1,620	171	1	90	1,882	4	1,934	118	NA	118
2000	42	1,636	145	1	99	1,881	4	1,928	135	NA	135
2001	33	1,443	129	3	108	1,681	5	1,719	141	1	142
2002	39	1,396	146	3	130	1,676	5	1,720	168	2	170
2003	43	1,363	142	4	169	1,679	3	1,726	228	2	230
2004	33	1,476	132	6	203	1,817	4	1,853	286	3	290
2005	32	1,452	148	7	230	1,837	4	1,873	327	12	339
2006	29	1,472	130	10	285	1,897	4	1,930	442	33	475
2007	16	1,413	144	10	377	1,944	5	1,964	557	46	602
2008	17	1,344	144	12	532	2,031	5	2,053	786	40	826
2009	18	1,198	154	13	617	1,982	4	2,005	894	40	934
2010	16	1,307	168	16	738	2,229	4	2,249	1,070	28	1,098

Source:

U.S. Department of Energy, Energy Information Administration, *Monthly Energy Review*, June 2011, Table 10.2b, www.eia.doe.gov/emeu/mer/renew.html

Note: NA = Not available.

[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] Ethanol blended into motor gasoline.

[f] Losses and co-products from the production of fuel ethanol and biodiesel. Does not include natural gas, electricity, and other non-biomass energy used in the production of fuel ethanol and biodiesel—these are included in the industrial sector consumption statistics for the appropriate energy source.

[g] Geothermal heat pump and direct use energy.

[h] The ethanol portion of motor fuels (such as E10 and E85) consumed by the transportation sector.

In 2010, biomass accounted for about 76% of the renewable energy used in the residential sector and about 85% of the renewable energy used in the commercial sector.

Section: INTRODUCTION

Renewable Energy Consumption for Residential and Commercial Sectors, 1973-2010

(Trillion Btu)

	Residential Sector				Commercial Sector[a]						
	Biomass					Biomass					
Year	Wood[b]	Geo-thermal[c]	Solar[d]	Total	Hydro-electric	Wood[b]	Waste[e]	Fuel Ethanol	Total	Geo-thermal[c]	Total
1973	354	NA	NA	354	NA	7	NA	NA	7	NA	7
1974	371	NA	NA	371	NA	7	NA	NA	7	NA	7
1975	425	NA	NA	425	NA	8	NA	NA	8	NA	8
1976	482	NA	NA	482	NA	9	NA	NA	9	NA	9
1977	542	NA	NA	542	NA	10	NA	NA	10	NA	10
1978	622	NA	NA	622	NA	12	NA	NA	12	NA	12
1979	728	NA	NA	728	NA	14	NA	NA	14	NA	14
1980	850	NA	NA	850	NA	21	NA	NA	21	NA	21
1981	870	NA	NA	870	NA	21	NA	0	21	NA	21
1982	970	NA	NA	970	NA	22	NA	0	22	NA	22
1983	970	NA	NA	970	NA	22	NA	0	22	NA	22
1984	980	NA	NA	980	NA	22	NA	0	22	NA	22
1985	1010	NA	NA	1010	NA	24	NA	0	24	NA	24
1986	920	NA	NA	920	NA	27	NA	0	27	NA	27
1987	850	NA	NA	850	NA	29	NA	1	30	NA	30
1988	910	NA	NA	910	NA	32	NA	1	33	NA	33
1989	920	5	52	977	1	76	22	1	99	3	102
1990	580	6	56	641	1	66	28	0	94	3	98
1991	610	6	57	673	1	68	26	0	95	3	100
1992	640	6	59	706	1	72	32	0	105	3	109
1993	550	7	61	618	1	76	33	0	109	3	114
1994	520	6	63	589	1	72	35	0	106	4	112
1995	520	7	64	591	1	72	40	0	113	5	118
1996	540	7	65	612	1	76	53	0	129	5	135
1997	430	8	64	502	1	73	58	0	131	6	138
1998	380	8	64	452	1	64	54	0	118	7	127
1999	390	9	63	461	1	67	54	0	121	7	129
2000	420	9	60	489	1	71	47	0	119	8	128
2001	370	9	59	438	1	67	25	0	92	8	101
2002	380	10	57	448	0	69	26	0	95	9	104
2003	400	13	57	470	1	71	29	1	101	11	113
2004	410	14	57	481	1	70	34	1	105	12	118
2005	430	16	58	504	1	70	34	1	105	14	119
2006	390	18	63	472	1	65	36	1	102	14	117
2007	430	22	70	522	1	69	31	2	102	14	118
2008	450	26	80	556	1	73	34	2	109	15	125
2009	430	33	89	552	1	72	36	3	112	17	129
2010	420	37	97	554	1	70	34	3	108	19	127

Source:

U.S. Department of Energy, Energy Information Administration, *Monthly Energy Review*, June 2011, 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.

[e] Municipal solid waste, landfill gas, sludge waste, tires, agricultural byproducts, and other biomass.

Total industrial biomass energy consumption was approximately 2,031 trillion Btu in 2008. The bulk of industrial biomass energy consumption is derived from forestlands (lumber, paper and allied products); 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.

Section: INTRODUCTION

Industrial Biomass Energy Consumption and Electricity Net Generation by Industry and Energy Source, 2008

		Biomass Energy Consumption (Trillon Btus)			
Industry	**Energy Source**	**Total**	**For Electricity**	**For Useful Thermal Output**	**Net Generation (Million Kilowatthours)**
Total	**Total**	**2,031.193**	**183.953**	**1,847.240**	**27,462**
Agriculture, Forestry, and Mining	**Total**	**16.159**	**1.231**	**14.928**	**229**
	Agricultural Byproducts/Crops	16.159	1.231	14.928	229
Manufacturing	**Total**	**1,908.531**	**182.721**	**1,725.810**	**27,233**
Food and Kindred Industry Products	**Total**	**21.328**	**0.631**	**20.697**	**107**
	Agricultural Byproducts/Crops	15.819	0.160	15.659	33
	Other Biomass Gases	0.289	0.095	0.194	7
	Other Biomass Liquids	0.044	0.044	-	5
	Sludge Waste	0.243	0.055	0.188	8
	Wood/Wood Waste Solids	4.933	0.277	4.657	54
Lumber	**Total**	**225.729**	**10.682**	**215.047**	**1,287**
	Sludge Waste	0.052	0.006	0.046	1
	Wood/Wood Waste Solids	225.676	10.676	215.001	1,286
Paper and Allied Products	**Total**	**1,116.304**	**170.909**	**945.396**	**25,774**
	Agricultural Byproducts/Crops	1.335	0.036	1.300	5
	Black Liquor	787.380	112.361	675.019	17,152
	Landfill Gas	0.034	0.004	0.029	1
	Other Biomass Gases	0.183	0.015	0.168	3
	Other Biomass Liquids	0.122	0.015	0.107	3
	Other Biomass Solids	9.477	1.762	7.715	326
	Sludge Waste	4.083	0.937	3.147	160
	Wood/Wood Waste Liquids	2.510	0.383	2.127	73
	Wood/Wood Waste Solids	311.180	55.395	255.785	8,050
Chemicals and Allied Products	**Total**	**4.319**	**0.152**	**4.167**	**28**
	Other Biomass Liquids	0.061	0.005	0.056	1
	Sludge Waste	0.305	0.043	0.261	9
	Wood/Wood Waste Solids	3.953	0.104	3.849	18
Biorefineries	**Total**	**532.042**	**-**	**532.042**	**-**
	Biofuels Losses and Coproducts[c]	532.042	-	532.042	-
	Biodiesel Feedstock	1.195	-	1.195	-
	Ethanol Feedstock	530.847	-	530.847	-
Other[a]	**Total**	**8.810**	**0.349**	**8.461**	**37**
Nonspecified[b]	**Total**	**106.502**	**-**	**106.502**	**-**
	Ethanol[d]	11.652	-	11.652	-
	Landfill Gas	92.233	-	92.233	-
	Municipal Solid Waste Biogenic[e]	2.617	-	2.617	-

Source:
U.S. Department of Energy, Energy Information Administration, *Renewable Energy Annual* , 2008, Washington, D.C., Table 1.8, http://www.eia.doe.gov/cneaf/solar.renewables/page/rea_data/table1_8.html

Note: Totals may not equal sum of components due to independent rounding.
= Not Applicable.

[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.

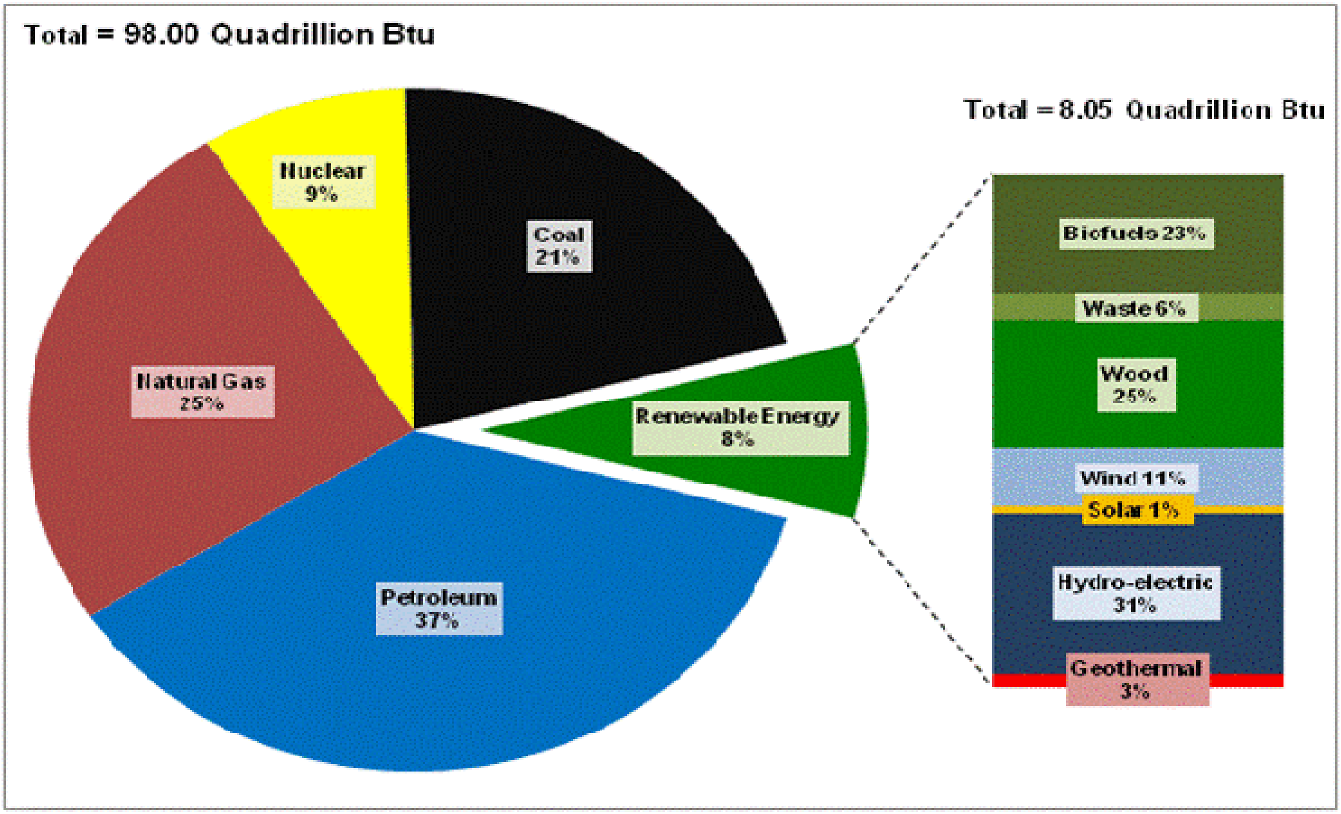
[c]Losses and coproducts from production of biodiesel and ethanol.

[d]Ethanol primarily derived from corn minus denaturant.

[e]Includes paper and paper board, wood, food, leather, textiles and yard trimmings.

Biomass is the single largest source of renewable energy in the United States. Biomass, which includes biofuels, waste and woody materials, surpassed hydroelectric power in 2005 and by 2010 accounted for over half of all renewable energy consumption. In 2010, biomass contributed about 4.4% of the total U.S. energy consumption of 98 quadrillion Btu. Wood, wood waste, and black liquor from pulp mills is the single largest source, accounting for almost one-half of total biomass energy consumption. Wastes (which include municipal solid waste, landfill gas, sludge waste, straw, agricultural by-products, and other secondary and tertiary sources of biomass) accounts for 11% of total biomass consumption. The remaining share is alcohol fuel derived principally from corn grain.

Section: INTRODUCTION
Summary of Biomass Energy Consumption, 2010



Source:
U.S. Department of Energy, Energy Information Administration, *Monthly Energy Review*, July 2011,
Table 1.3, *Primary Energy Consumption by Source,* and Table 10.1, *Renewable Energy Production and* Consumption *by Source*.
http://www.eia.doe.gov/emeu/mer/contents.html

Sustainability

Sustainability can be defined as the ability of an activity to meet the needs of the present without compromising the ability of future generations to meet their own needs (Bruntland, 1987). The potential for bioenergy to be a more sustainable source of liquid fuel, electric power, and heat than current dominant sources is the major driver behind policies that support bioenergy research and development. Sustainability comprises overlapping environmental, economic, and social aspects. Tools to assess sustainability include indicators and life-cycle analyses. Sustainability of bioenergy can be assessed at scales ranging from individual operations (e.g., a farm or biorefinery) to industries (e.g., soybean biodiesel or mixed-feedstock cellulosic ethanol) of regional, national, or global extent. Assessments of sustainability must consider effects throughout the supply chain, even when focusing on a single operation within that chain. (For example, the concept of spatial footprints can be used to incorporate aspects of land-use efficiency in feedstock production when assessing the sustainability of biorefineries.)

Although usage of the term varies, the ability of a particular system to persist over time can be called “viability” and is one aspect of sustainability. Long-term profitability is the most obvious aspect of viability. However, viability has environmental and social as well as economic components. For example, viability of plant-based feedstock production requires the maintenance of soil quality, and bioenergy systems in general require acceptance from the public.

In addition to viability, sustainability encompasses the extent to which a particular system contributes to the ability of a broader system – a region, a country, or the globe – to meet its present and future needs. Environmental considerations for the sustainability of a bioenergy system include effects on soil quality, water quality and quantity, greenhouse gas (GHG) balance, air quality, biodiversity, and productivity. Social and economic considerations overlap and include employment, welfare, international trade, energy security, and natural resource accounts, in addition to profitability and social acceptability.

Indicators can be used to assess the sustainability of bioenergy systems. Sustainability indicators can be defined as any measurable quantity that provides information about potential or realized effects of human activities on environmental, social, or economic phenomena of concern. Indicators can relate to management practices (e.g., amount of fertilizer applied) or to their effects (e.g., nutrients in soil or in waterways). Indicators based on management practices can be useful in certification systems, such as those under development by the Roundtable for Sustainable Biofuels and the Council on Sustainable *Biomass* Production. Indicators that measure effects can be used to provide an empirical grounding for the interpretation of management-based indicators or to assess the overall sustainability of a bioenergy industry or pathway. To the extent possible, indicators should reflect the entire supply chain. Such indicators can provide guidance for decisions such as choosing a specific conversion technology or choosing locations that are both suitable for low-cost feedstock production as well as close to markets.

Life-cycle analyses (LCAs) are another tool used to assess bioenergy sustainability. An LCA typically considers one or more quantities of environmental significance (e.g., energy consumption, C_{eq} emissions, consumptive water use) and sums the contribution to that quantity (negative as well as positive) from each step of the entire supply chain ("cradle to grave"). LCAs can seem straightforward on the surface, but LCAs measuring similar quantities can give disparate results depending on how system boundaries, baseline conditions, and co-products are defined and dealt with.

More generally, different approaches to system boundaries, baseline conditions, and co-products pose challenges to any effort to assess the sustainability of bioenergy systems. The treatment of baseline conditions is particularly problematic. The term "baseline" can describe conditions that exist prior to the implementation of bioenergy production, or it can describe the most likely alternative uses of the land and resources. The former type of baselines can potentially be measured. In some cases, the latter type of baselines can be approximated by carefully selecting and monitoring land resources that are similar except lacking bioenergy systems. In other cases, especially when assessing effects that may be geographically dispersed (e.g., air pollution or energy security), suitable proxy sites may not exist for those latter baselines, and alternate scenarios must be projected through simulation modeling.

A full understanding of the relative sustainability of a bioenergy system requires comparing the effects of that system to the effects of displaced or alternative sources of energy. This comparison may or may not be considered an issue of baselines. Typically, bioenergy systems are compared against fossil fuel systems (such as production of electricity from coal or liquid fuels from petroleum). The sustainability of fossil fuel systems should be considered in sustainability assessments, including advantages such as pre-existing infrastructure and disadvantages such as non-renewability, high GHG emissions, adverse health impacts, and (in the case of oil) frequent location of resources in politically unstable regions. Comparisons between bioenergy and other renewable energy technologies are also appropriate in some situations, particularly when the desired end product is electricity.

A central controversy regarding the sustainability of bioenergy concerns the idea of indirect land-use change (iLUC). Given certain assumptions, economic models predict that bioenergy production could raise global agricultural commodity prices, inducing the conversion of forests and grasslands to bioenergy production. Researchers disagree about whether these models are sufficiently realistic, valid, and/or based on accurate input data for use in policymaking. This topic is explored more fully in "Indirect Land-Use Change – The Issues" found in the feedstock section.

Although researchers disagree about whether and to what extent current bioenergy systems are sustainable, there is relatively broad agreement that bioenergy has at least the potential to be more sustainable than currently dominant energy systems. For example, many researchers believe that the most pressing concerns about current bioenergy sustainability could be addressed by growing lignocellulosic biomass crops such as switchgrass, Miscanthus, or hybrid poplar on land that is degraded, abandoned, or ill-suited to growing traditional crops. Such a plan will require advances both in technology (e.g., to overcome the recalcitrance of lignocellulose) and in policy (e.g., the widespread adoption of sound standards for sustainability). Despite daunting challenges, research progresses on both fronts.

Works cited:

Bruntland, G.H. (ed.) 1987. Our Common Future: The World Commission on Environment and Development. Oxford University Press, Oxford. Online at: http://www.un-documents.net/wced-ocf.htm

Further reading:

Bringezu, S., Schütz, H., O´Brien, M., Kauppi, L., Howarth, R.W., McNeely, J., 2009. Towards sustainable production and use of resources: assessing biofuels. United Nations Envrionment Programme. Online at: http://www.unep.org/pdf/Assessing_Biofuels-full_report-Web.pdf

Dale, V., Fargione, J., Kline, K., Weins, J., 2010. Biofuels: implications for land use and biodiversity. Biofuels and Sustainability Reports, Ecological Society of America. Online at: http://www.esa.org/biofuelsreports/files/ESA Biofuels Report_VH Dale et al.pdf

Pickett, J., Anderson, D., Bowles, D., Bridgwater, T., Jarvis, P., Mortimer, N., Poliakoff, M., Woods, J., 2008. Sustainable biofuels: prospects and challenges. The Royal Society. Online at: http://royalsociety.org/Sustainable-biofuels-prospects-and-challenges/

Written by: Allen McBride, Oak Ridge Institute for Science and Education, September 2011.

Indirect Land-Use Change – The Issues

A central controversy regarding the sustainability of bioenergy concerns the idea of indirect land-use change (iLUC). With respect to bioenergy, we can define iLUC as any land-use change caused by bioenergy production, excluding the conversion of land used directly for that production. The central hypothesis behind iLUC concerns is that when land used for a given purpose is converted to bioenergy feedstock production, then land used for the original purpose will be more scarce, increasing the value of such land and inducing people to convert other land to that purpose. For example, if an acre of land used to grow corn for livestock feed is converted to growing corn for ethanol, then it would be assumed that the price of feed corn would increase by approximately the amount required to induce someone else to convert an acre of land from some other purpose to producing corn for feed. Furthermore, if this land to be converted to feed corn production has high carbon stocks (e.g., old-growth forest), then the conversion will release CO_2 to the atmosphere, creating a carbon debt that could take decades to pay off via offset fossil fuel combustion. Under certain simple assumptions, scenarios such as this must occur. For example, attempts to quantify GHG emissions from bioenergy iLUC are guaranteed to produce positive results if researchers use models that assume that:

- all agricultural land available for conversion is fully utilized,
- all non-agricultural land available for conversion is relatively undisturbed and has high carbon stores,
- all land available for conversion is privately held,
- all landowners seek to maximize profit, and
- increases in bioenergy production occur suddenly (i.e., act as economic "shocks").

However, these assumptions do not hold in many areas of the world. Because modeling requires generalizations, assumptions will inevitably be violated to some degree. These violations are acceptable only when correcting them would not greatly affect results. In the case of iLUC, conceptual models suggest that correcting some of these assumptions in simulation models could fundamentally change conclusions about iLUC. For example, at the margins of rainforests, land-use change may be driven by multi-year cycles of shifting cultivation, including low-profit and GHG-intensive slash-and-burn techniques. In addition, new deforestation may be driven in part by the desire to claim effectively ungoverned land. Increased commodity prices could plausibly provide incentives for farmers in these areas to more sustainably and intensively manage already-cleared land instead of abandoning it to clear secondary or primary forest.

Unfortunately, data may not currently exist to allow iLUC simulations that would take such potentially crucial mechanisms into account. More research is needed to collect such data, including better resolution land-use and land-cover data throughout the world, and surveys of land managers to better understand motivations for management decisions. In addition to better data, more work is needed to integrate existing but difficult-to-reconcile data sets, such as those with high spatial but low temporal resolution and vice-versa. Techniques of causal analysis pioneered in epidemiology hold promise for the challenge of determining whether bioenergy plays a significant market-mediated role in deforestation and other land-use change.

Researchers disagree about whether potential iLUC effects should be considered in policymaking. Because some models predict large GHG emissions from iLUC, some researchers argue that not considering iLUC effects would be an unacceptable risk. Other researchers argue that the uncertainty surrounding current estimates of iLUC, both in terms of differing estimates from current models as well as the lack of empirical validation of those models, is too large to consider their results in policymaking. In addition, some researchers argue that considering iLUC effects of bioenergy systems in policymaking is inappropriate because analogous indirect land-use change effects of fossil fuel exploration, extraction, and use are poorly understood and are not taken into account in estimates of environmental and socioeconomic effects of fossil fuels. Finally, there is philosophical debate about how to apportion “blame” (e.g., carbon penalties) among multiple causal factors leading to a given outcome. For example, if certain indirect deforestation would not have occurred in the absence of a biofuel system, then the same could also be said of the individuals or groups actually burning or cutting that forest.

Further reading:

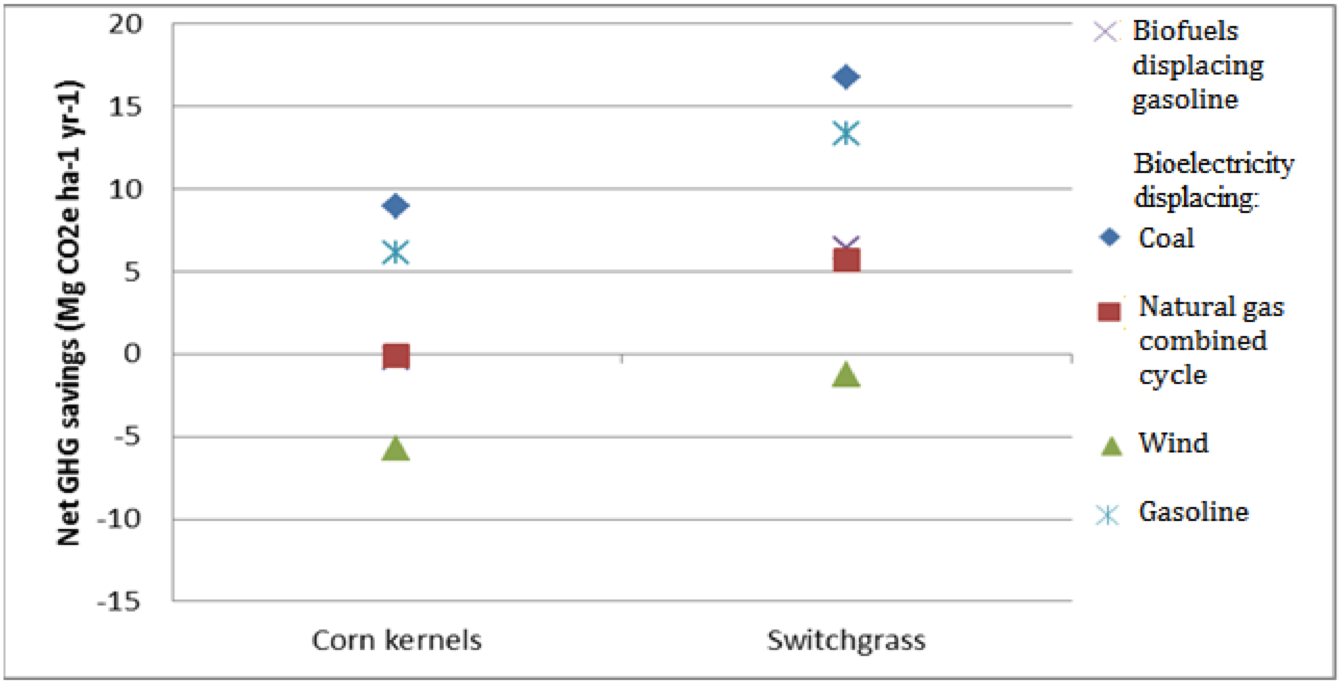
Fritsche, U. R., Sims, R. E. H. and Monti, A., 2010. Direct and indirect land-use competition issues for energy crops and their sustainable production – an overview. Biofuels, Bioproducts and Biorefining, 4: 692–704. Online at: http://onlinelibrary.wiley.com/doi/10.1002/bbb.258/full

Kline, K., Dale, V.H., Lee, R., Leiby, P., 2009. In defense of biofuels, done right. Issues Sci. Technol. 25, 75-84. Online at: http://www.issues.org/25.3/kline.html

Greenhouse gas emissions are one of the many factors used in comparing the sustainability level of various energy sources. Greenhouse emissions from fossil fuels are generally greater than emissions from biomass derived fuels. However biomass fuels can also vary greatly with respect to levels of greenhouse gas emissions depending on the biomass resource used, how those resources were produced or collected, and the biomass to energy conversion technology pathway. One way of obtaining a sense of the difference in emissions between fossil fuels and various biomass energy technology pathways is to evaluate net greenhouse gas savings based on which fossil fuel source is being displaced. Such an evaluation has been recently performed comparing corn grain and switchgrass as the biomass feedstock for production of liquid transportation fuels, electric transportation, and electricity for other uses.

Section: INTRODUCTION

A Comparison of Climate Impacts of Various Bioenergy Systems



This figure (from Lemoine et al 2010) shows that net GHG savings per area of cropland are sensitive to assumptions about which fossil fuel technology is being displaced. The X marker shows ethanol displacing gasoline. The blue asterik follows a study by Campbell et al (2009) in assuming that bioelectricity is used to power electrified vehicles and displaces gasoline. The diamond, square, and triangle (coal, natural gas combined cycle, and wind electricity) show the GHG benefit (or cost) when bioelectricity displaces each of these types of power. Corn grain production is assumed to have an indirect land use effect of 30g CO2e (MJ ethanol)-1 while switchgrass is assumed to be planted on Conservation Reserve Land with no indirect land use effect but also no soil carbon sequestration.

Sources:

Lemoine, D.M. et al. The Climate Impacts of Bioenergy Systems Depend on Market and Regulatory Policy Contexts. Environmental Science & Technology 44:7347-7350

Campbell, J.E.; Lobel, D.B.; Field, C.B. Greater transportation energy and GHG offsets from bioelectricity than ethanol. Science 2009, 324, 1055-1057.

Supplementary material including a complete description of the Energy Displacement Model is available free of charge at http://pubs.acs.org.

Biomass Resources Overview

Biomass Resources include all plant and plant-derived (organic) materials that are available on a renewable or recurring basis. Plant biomass is a complex mixture of organic materials, primarily carbohydrates (~75% dry weight) and lignin (~25% dry weight) with the proportions varying by plant type, but also containing fats, proteins and minerals. The carbohydrates consist mainly of cellulose or hemicellulose fibers which give strength to plant structures with a small portion of carbohydrates in the form of starches and simple sugars. Lignin is the glue that holds the fibers together. Thus the stems, stalks, branches, and leaves of plants are the lignocellulosic components of plants which are eaten by forage animals for food, processed mechanically for bioproducts (such as wood used in buildings or furniture), or processed thermally or biochemically in many different ways to produce heat, electricity, chemicals, and biofuels. Both the primary lignocellulosic resources (trees, grasses, and stalks of food crops) and all by-products of processing (from pulping black liquor to sawdust to food waste and manure) compose the biomass resource base that can be utilized for producing various types of bioenergy. For production of liquid biofuels, some processes involve separating the lignin from the cellulose and hemicellulose in order to gain access to the carbohydrates that can be broken down into sugars. Reduction of lignocellulosic materials to sugars and other compounds is anticipated to be the major source of liquid biofuels and chemicals in the future. Examples of biomass resources that are currently used for liquid biofuels include: starches from the grain of corn (maize), wheat and other grains; sugars squeezed from the stalks of sugarcane; and oils derived from soybeans and other oilseed crops.

All biomass resources available for producing bioenergy and biofuels are expected to be produced and harvested in a sustainable manner. A recent analysis of biomass resources (US Department of Energy, 2011), includes a more rigorous treatment and modeling of resource sustainability than was done in a previous evaluation (Perlack et al. 2005). The 2011 update evaluates two scenarios—baseline and high yield. Overall, results of this update are consistent with the 2005 study in terms of the magnitude of the resource potential previously estimated to be over one billion dry tons on an annual basis.

In the 2011 baseline scenario, forest resource quantities are estimated to vary from about 33 to 119 million dry tons currently to about 35 to 129 million dry tons in 2030 over a price range of ($20-$80 per dry ton). Primary forest biomass (derived from logging, thinnings, and land clearing) is the single largest source of forest resource. The agricultural resources show considerably more supply, with the quantity increasing significantly over time. This increase is due to yield growth (assumed to be about 1% per year) and assumptions of more land managed with no-till or reduced cultivation, all of which makes more crop residue available. The increase can also be attributed to the deployment of energy crops, which are assumed to be first planted in 2014 and have yield growth of 1% per year that is due to breeding and selection and experience gained). In 2012, biomass supplies are estimated to range from about 59 million dry tons at a *farmgate price of $40 per dry ton or less to 162 million dry tons at $60 per dry ton.

The composition of this biomass is about two-thirds crop residue and one-third various agricultural processing residues and wastes. By 2030, quantities increase to 160 million dry tons at the lowest simulated price to 664 million dry tons at the highest simulated price ($60 per dry ton). At prices above $50 per dry ton, energy crops become the dominant resource after 2022.

No high-yield scenario was evaluated for forest resources except for the woody crops. Forest residues come from existing timberlands, and there is no obvious way to increase volumes other than reducing the amounts of residues retained onsite for environmental sustainability or decreasing the merchantable utilization requirements—neither option was considered. Forest residues and wastes total to 100 million dry tons by 2022.

The high-yield agriculture scenario assumes a greater proportion of corn in reduced and no-till cultivation and increased corn yields (averaging 2% per year) to about double the current rate of annual increase, all factors which increase residue levels. Agricultural residues and wastes are about 244 million dry tons currently and increase to 404 million dry tons by 2030 at a farmgate price of $60 per dry ton. For energy crops, the high-yield scenario increased the annual rate of crop productivity growth from the 1% baseline to 2%, 3%, and 4% annually. Energy crops are the largest potential source of biomass feedstock, with potential energy crop supplies varying considerably depending on what is assumed about productivity. At a 2% annual growth rate, energy crop potential is 540 million dry tons by 2030 and 658 million dry tons if an annual increase in productivity of 3% is assumed. Both of these estimates assume a farmgate price of $60 per dry ton. Increasing yield growth to 4% pushes the energy crop potential to nearly 800 million dry tons. Energy crops become very significant in the high-yield scenario—providing over half of the potential biomass.

In total, potential supplies at a forest roadside or farmgate priceof $60 per dry ton range from 855 to 1009 million dry tons by 2022 and from about 1046 to 1305 million dry tons by 2030, depending on what is assumed about energy crop productivity (2% to 4% annual increase over current yields). This estimate does not include resources that are currently being used, such as corn grain and forest products industry residues. By including the currently used resources, the total biomass estimate jumps to well over one billion dry tons and to over 1.6 billion dry tons with more aggressive assumptions about energy crop productivity.

The above results, along with estimates of currently used resources are summarized in the Data Book table entitled “Summary of Currently Used and Potential Biomass.” One important year highlighted in this table is 2022—the year in which the revised Renewable Fuels Standard (RFS) mandates the use of 36 billion gallons per year (BGY) of renewable fuels (with 20 billion gallons coming from cellulosic biofuels). The feedstock shown in the baseline scenario accounts for conventional biofuels (corn grain, ethanol, and biodiesel) and shows 602 million dry tons of potential lignocellulosic biomass resource. This potential resource is more than sufficient to provide feedstock to produce the required 20 billion gallons of cellulosic biofuels. The high-yield scenario demonstrates a potential that far exceeds the RFS mandate.

* The farmgate price is a basic feedstock price that includes cultivation (or acquisition), harvest, and delivery of biomass to the field edge or roadside. It excludes on-road transport, storage, and delivery to an end user. For grasses and residues this price includes baling. For forest residues and woody crops this includes minimal comminution (e.g. chipping).

Sources:

Perlack RD, Wright LL, Turhollow AF, Graham RL, Stokes BJ, Erbach DC. 2005. Biomass as feedstock for a bioenergy and bioproducts industry: the technical feasibility of a billion-ton annual supply. DOE/GO-102995-2135 or ORNL/TM-2005/66. Oak Ridge National Laboratory, Oak Ridge, TN. 60 pp. www1.eere.energy.gov/biomass/publications.html

U.S. Department of Energy. 2011. U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry. R.D. Perlack and B.J. Stokes (Leads), ORNL/TM-2010/224. Oak Ridge National Laboratory, Oak Ridge, TN p.227. (accessed 8-15-2011 at https://bioenergykdf.net/content/billiontonupdate)

Biomass Definitions in Legislation

Biomass has been referenced in legislation for over 30 years. Definitions of biomass have evolved over time, mostly since 2004. A recent report by the Congressional Research Service provides a comprehensive review of fourteen biomass definitions found in recent enacted legislation. Seven definitions in pending legislation are also reviewed. Comments on similarities and differences among the definitions are provided and issues for biomass feedstock development related to differences in definitions are discussed. Definitions from the two most recent pieces of enacted legislation were extracted from the report. A key difference regards the inclusion or non-inclusion of biomass harvested from federal land. It is highly recommended that the full report be accessed to understand the implications of the various biomass definitions found in legislation.

In the Food, Conservation, and Energy Act of 2008 (2008 farm bill, P.L. 110-246) Title IX, Sec. 9001(12) the term "renewable biomass" means--

A) materials, pre-commercial thinnings, or invasive species from National Forest System land and public lands (as defined in section 103 of the Federal Land Policy and Management Act of 1976 (43 U.S.C. 1702)) that—(i) are byproducts of preventive treatments that are removed—(I) to reduce hazardous fuels; (II) to reduce or contain disease or insect infestation; or (III) to restore ecosystem health; (ii) would not otherwise be used for higher-value products; and (iii) are harvested in accordance with—(I) applicable law and land management plans; and (II) the requirements for—(aa) old-growth maintenance, restoration, and management direction of paragraphs (2), (3), and (4) of subsection (e) of section 102 of the Healthy Forests Restoration Act of 2003 (16 U.S.C. 6512); and (bb) large-tree retention of subsection (f) of that section; or

(B) any organic matter that is available on a renewable or recurring basis from non-Federal land or land belonging to an Indian or Indian tribe that is held in trust by the United States or subject to a restriction against alienation imposed by the United States, including—(i) renewable plant material, including—(I) feed grains; (II) other agricultural commodities; (III) other plants and trees; and (IV) algae; and (ii) waste material, including—(I) crop residue; (II) other vegetative waste material (including wood waste and wood residues); (III) animal waste and byproducts (including fats, oils, greases, and manure); and (IV) food waste and yard waste.

In the Energy Independence and Security Act of 2007 (EISA, P.L. 110-140) Title II, Sec. 201(1)(I) the term "renewable biomass" means each of the following:

(i) Planted crops and crop residue harvested from agricultural land cleared or cultivated at any time prior to the enactment of this sentence that is either actively managed or fallow, and nonforested.

(ii) Planted trees and tree residue from actively managed tree plantations on non-federal land cleared at any time prior to enactment of this sentence, including land belonging to an Indian tribe or an Indian individual, that is held in trust by the United States or subject to a restriction against alienation imposed by the United States.

(iii) Animal waste material and animal byproducts.

(iv) Slash and pre-commercial thinnings that are from non-federal forestlands, including forestlands belonging to an Indian tribe or an Indian individual, that are held in trust by the United States or subject to a restriction against alienation imposed by the United States, but not forests or forestlands that are ecological communities with a global or State ranking of critically imperiled, imperiled, or rare pursuant to a State Natural Heritage Program, old growth forest, or late successional forest.

(v) Biomass obtained from the immediate vicinity of buildings and other areas regularly occupied by people, or of public infrastructure, at risk from wildfire.

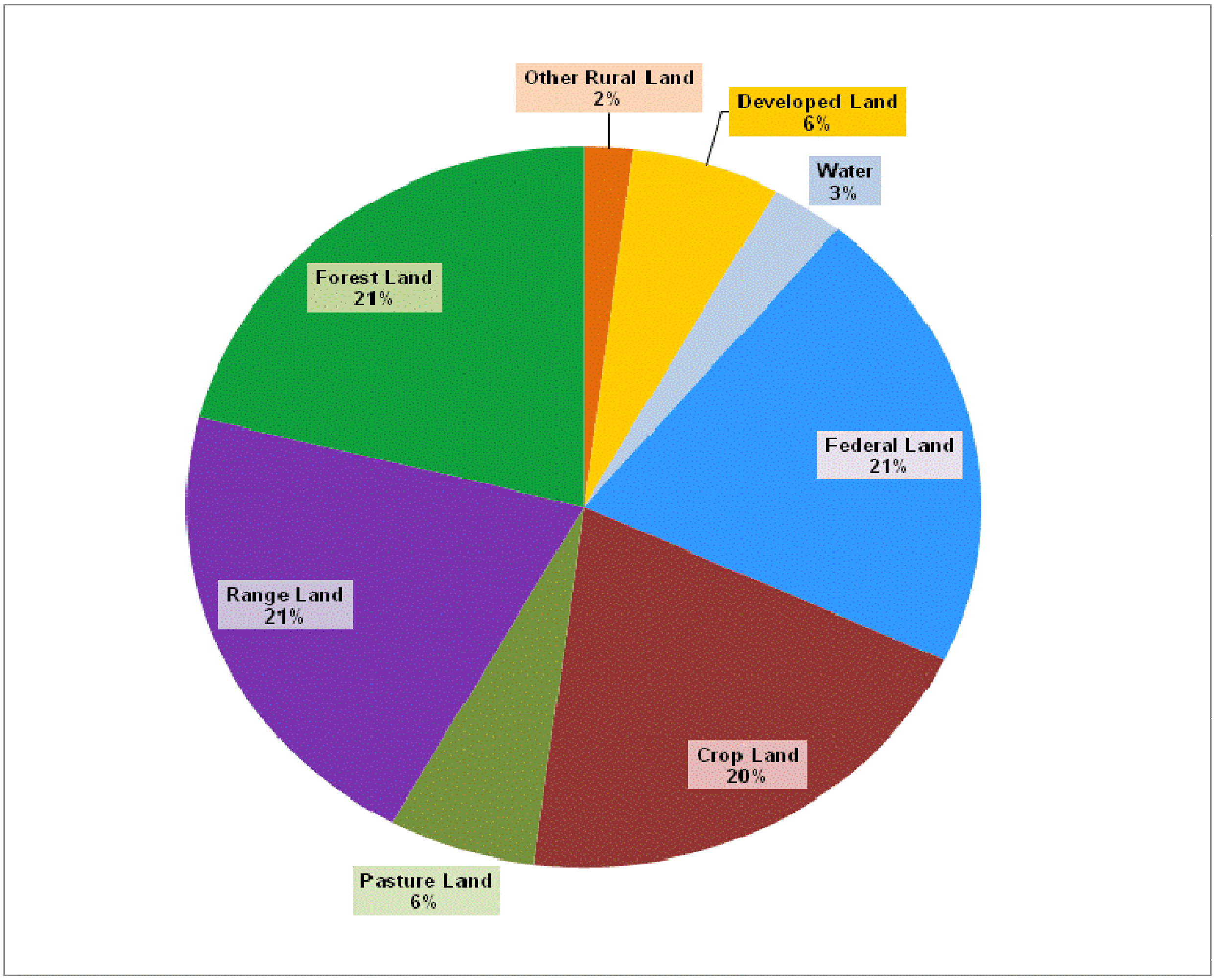
(vi) Algae.

(vii) Separated yard waste or food waste, including recycled cooking and trap grease.

Source: Bracmort K. and Gorte, Ross W. *Biomass: Comparison of Definitions in Legislation Through the 111th Congress.* Congressional Research Service. October 8, 2010. 21 p.

In 2007, the United States had a total surface area of 1,938 million acres. Based on the 2007 Natural Resources Inventory, 20% is classified as crop land and 21% was classified as forest land which shows that nearly half of the land area in the U.S. is well suited for either biomass crops or biomass residuals. Pasture land and Range land is for the most part, too dry to provide large quantities of biomass material. Developed land is a potential source for post-consumer biomass residuals like those found in municipal solid waste landfills.

Major Uses of Land in the United States, 2007

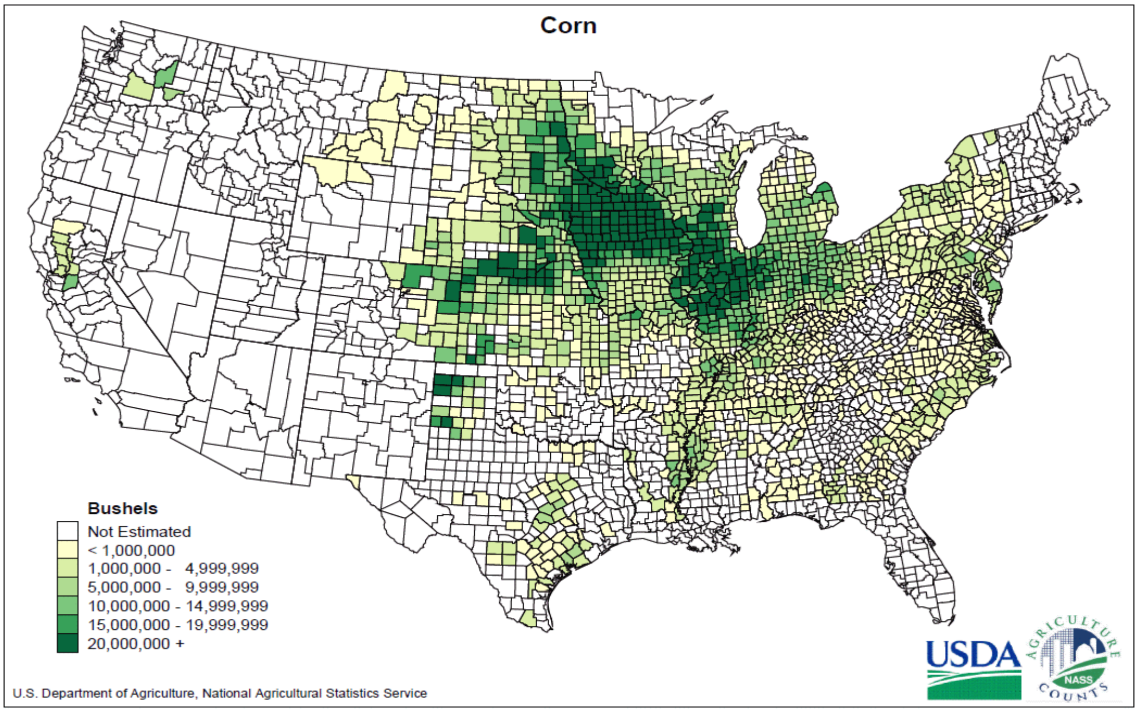


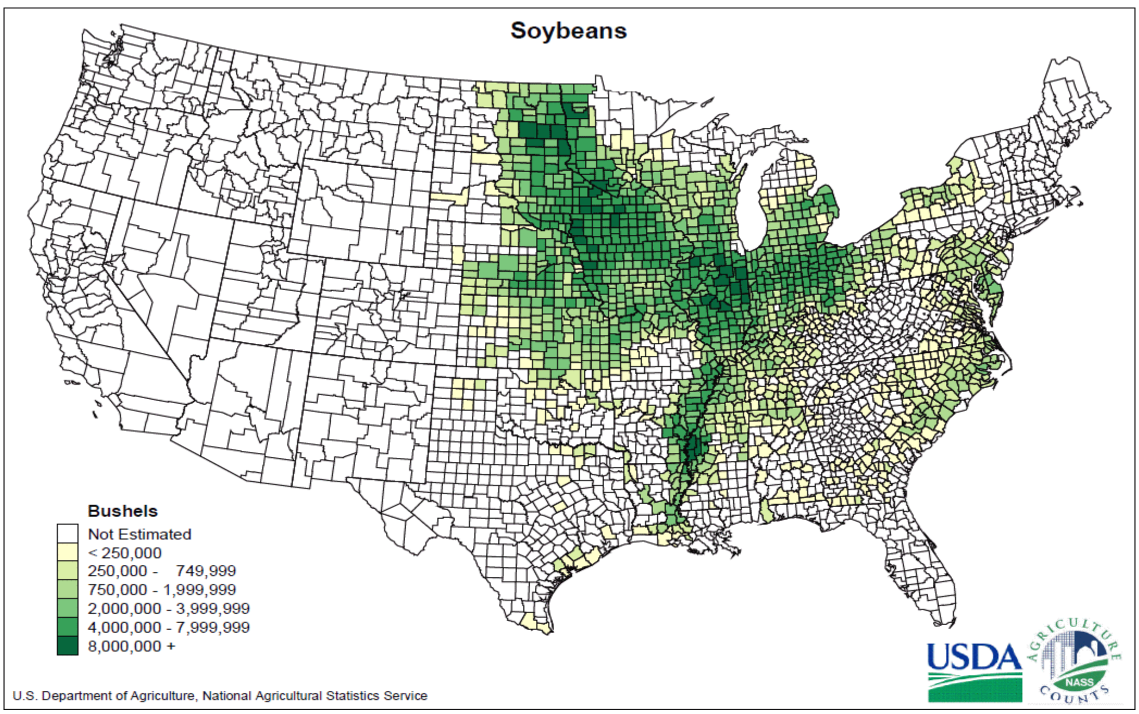
Source:
U.S. Department of Agriculture, 2009. *Summary Report: 2007 National Resources Inventory* , Natural Resources Conservation Service, Washington, DC, and Center for Survey Statistics and Methodology, Iowa State University, Ames, Iowa. 123 pages.
http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1041379.pdf

Note:
Cropland includes CRP Land, which is reported separately in the source document.
CRP = Conservation Reserve Program

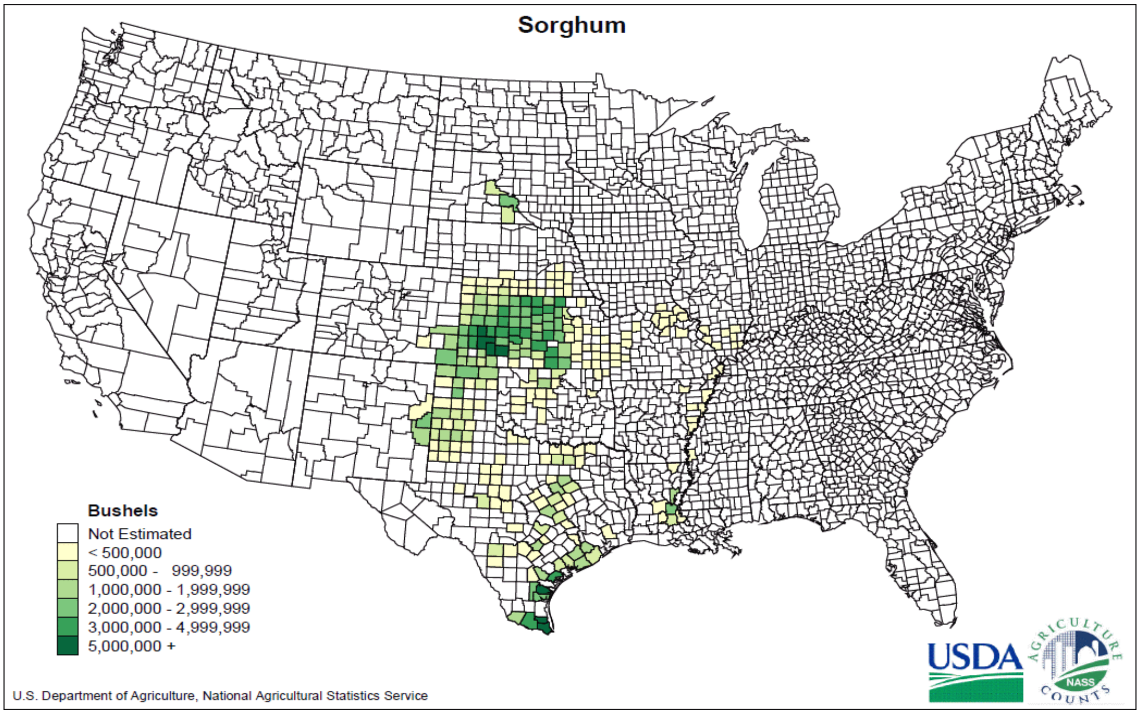
Location of commodity crop production shows where agricultural residues are potentially available for collection and energy crops potentially available for production.

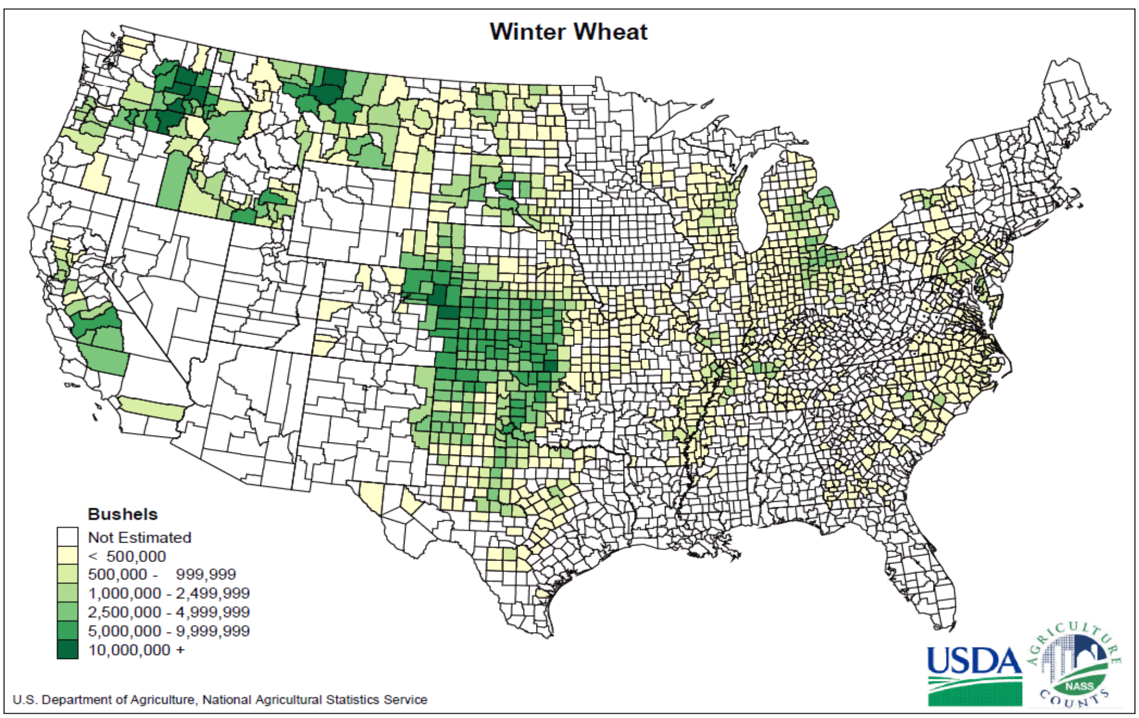
Section: INTRODUCTION
Geographic Locations of Major Crops, 2010
(production acreage by county)



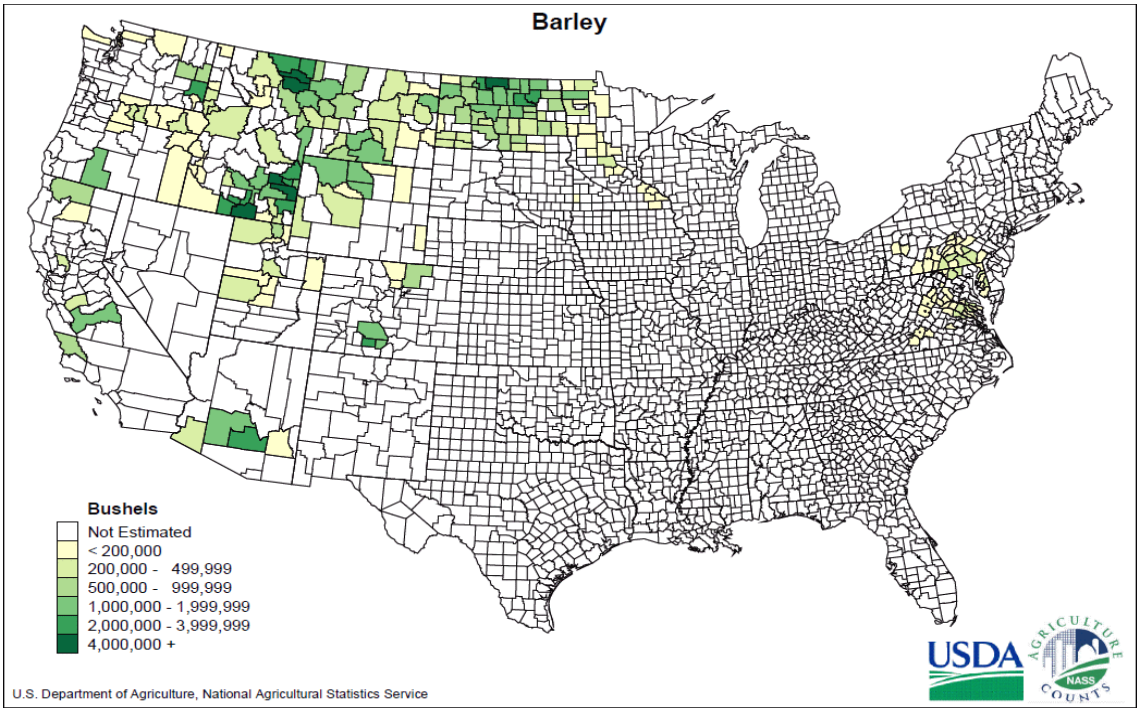


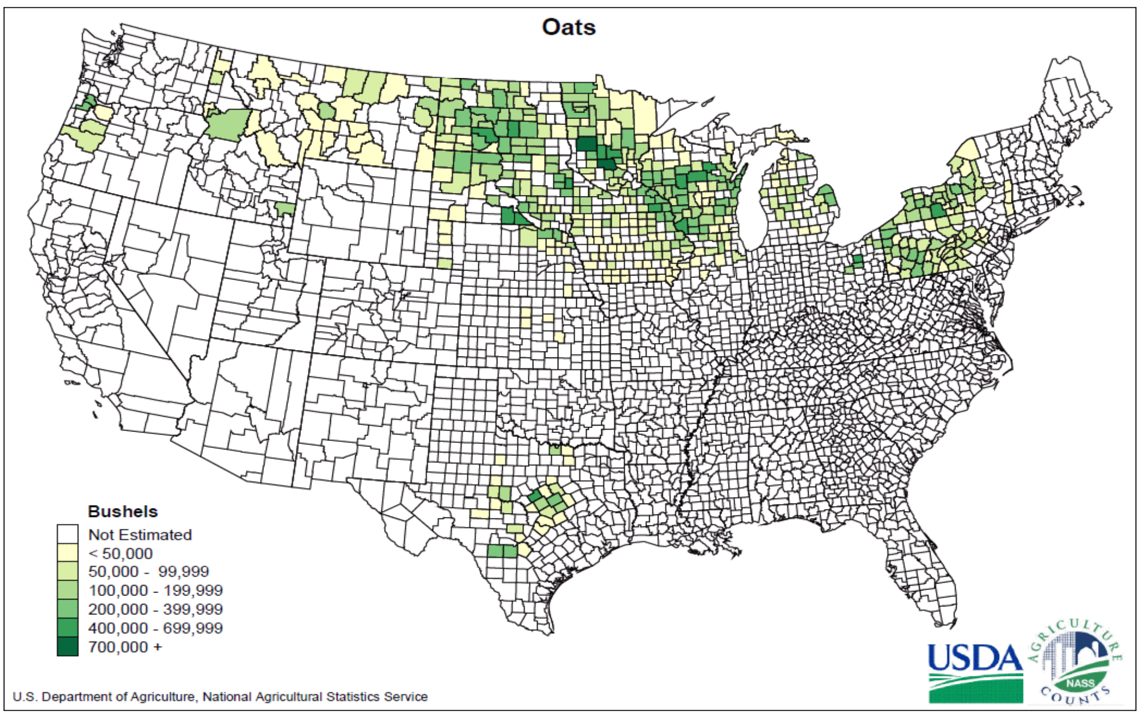
Geographic Locations of Major Crops, 2010
(production acreage by county)



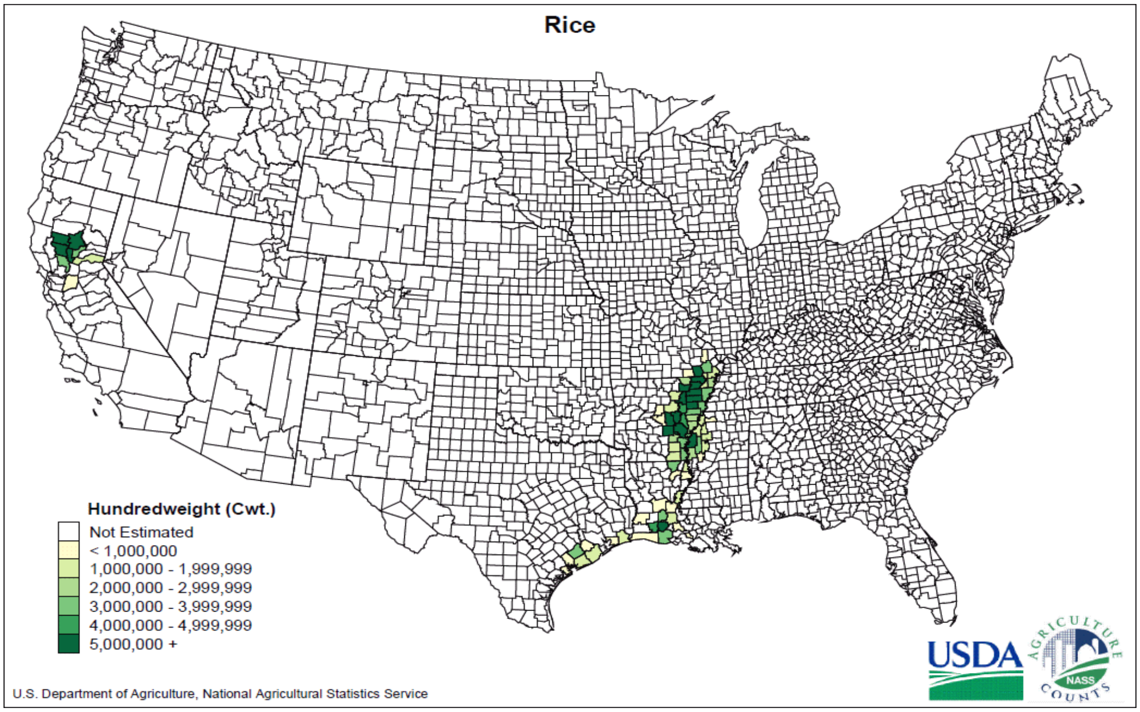


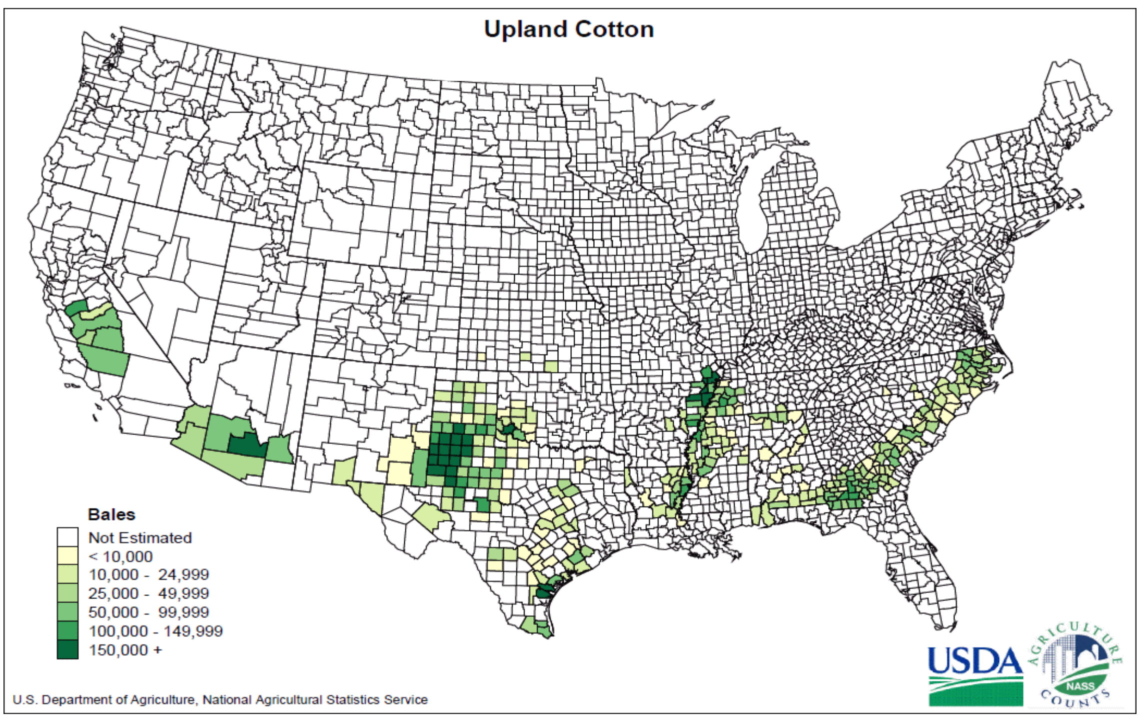
Section: INTRODUCTION
Geographic Locations of Major Crops, 2010
(production acreage by county)





Section: INTRODUCTION
Geographic Locations of Major Crops, 2010
(production acreage by county)



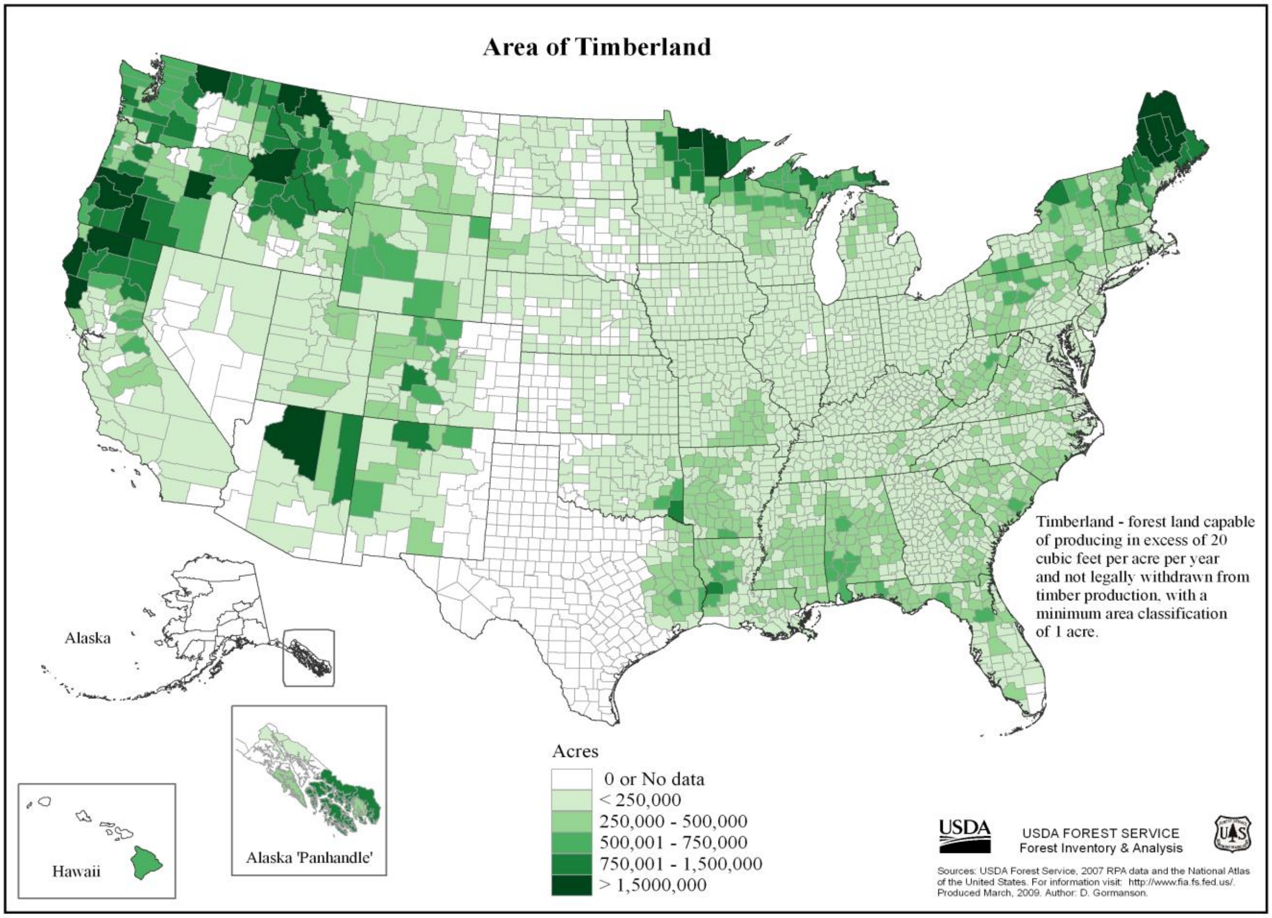


Source:
U.S. Department of Agriculture, National Agricultural Statistics Service
http://www.nass.usda.gov/Charts_and_Maps/A_to_Z/index.asp#h

This map shows the spatial distribution of the nation's timberland in 2007 by county. Nationwide, there are 514 million acres of forest land classified as timberland. This land is the source of a wide variety of forest products and forest residue feedstocks, such as logging residue and fuel treatment thinnings to reduce the risk of fire.

In this map, timberland is defined as forest land capable of producing in excess of 20 cubic feet per acre per year and not legally withdrawn from timber production, with a minimum area classification of 1 acre.

Section: INTRODUCTION
Geographic Distribution of Timberland by County, 2007



Source:
USDA Forest Service, 2007 RPA data, available at:
http://fia.fs.fed.us/tools-data/maps/2007/descr/ytim_land.asp
USDA Forest Service, Forest Inventory and Analysis. 2007 RPA data and the National Atlas of the United States.

Currently used biomass feedstocks are largely derived from agriculture and the forestry sector, with the majority of that being used by the forestry sector to generate energy for industrial processes. Fuelwood, another substantial category includes the residential and commercial sector as well as biomass consumed by the electric utility industry in dedicated biomass plants and co-firing applications. Municipal solid waste (MSW) sources are allocated to forestry (65%) and cropland (35%) sectors. Ethanol and biodiesel projections are based on federal mandates of 15 billion gallons per year of biofuels and 1 billion gallons per year of biodiesel. The ethanol numbers assume corn grain at 56 pounds per bushel, 15.5% moisture content, and 2.8 gallons per bushel.

Section: INTRODUCTION
Projected Consumption of Currently Used Biomass Feedstocks by Source
(Million Dry Tons per Year)

Source	Current	2017	2022	2030
Forest				
Fuelwood	38	72	96	106
Mill Residue	32	38	39	42
Pulping liquors	45	52	54	58
MSW sources	14	20	20	20
Total Forest	**129**	**182**	**210**	**226**
Agriculture				
Ethanol[a]	76(109)	88(127)	88(127)	88(127)
Biodiesel[b]	2	4	4	4
MSW sources	7	11	11	11
Total agricultural	**85(118)**	**103(142)**	**103(142)**	**103(143)**
Total Currently Used Resources	**214 (247)**	**284(342)**	**312(351)**	**328(368)**

Sources:
Perlack, R. D., and B. J. Stokes. *U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry*, ORNL/TM-2010/224, Oak Ridge National Laboratory, Oak Ridge, TN, 2011.
Bioenergy Knowledge Discovery Website, https://bioenergykdf.net

[a] The first number is the portion of corn consumed to make ethanol. The number in parenthesis is the amount of corn required. For example, it takes 127.5 million dry tons to make 15 billion gallon per year of ethanol. However, only 88.3 million dry tons are consumed in making the ethanol. The remainder (39.2 million dry tons) is distiller's grain and is excluded from the total.

[b] Included all sources of biodiesel. Current consumption is 43% from soybeans and 57% from other sources, including animal fats and waste oils. The proportion of sources of future feedstocks will vary and are assumed to have an average conversion rate of 7.5 pounds of oil/fats per gallon of diesel.

In 2022 the revised Renewable Fuels Standard (RFS) mandates the use of 36 billion gallons per year (BGY) of renewable fuels (with 20 billion gallons coming from cellulosic biofuels). The feedstock shown in the baseline scenario accounts for conventional biofuels (corn grain, ethanol, and biodiesel) and shows 602 million dry tons of potential lignocellulosic biomass resource. This potential resource is more than sufficient to provide feedstock to produce the required 20 billion gallons of cellulosic biofuels. The high-yield scenario demonstrates a potential that far exceeds the RFS mandate.

Section: INTRODUCTION
Summary of Currently Used and Potential Biomass
(Million Dry Tons)

Feedstock	2012	2017	2022	2030
	Baseline scenario			
Forest resources currently used	129	182	210	226
Forest biomass & waste resource potential	97	98	100	102
Agricultural resources currently used	85	103	103	103
Agricultural biomass & waste resource potential	162	192	221	265
Energy crops[1]	0	101	282	400
Total currently used	**214**	**284**	**312**	**328**
Total potential resources	**258**	**392**	**602**	**767**
Total baseline	**473**	**676**	**914**	**1094**
	High-yield scenario (2%-4%)			
Forest resources currently used	129	182	210	226
Forest biomass & waste resource potential	97	98	100	102
Agricultural resources currently used	85	103	103	103
Agricultural biomass & waste resource potential[2]	244	310	346	404
Energy crops	0	139-180	410-564	540-799
Total currently used	**214**	**284**	**312**	**328**
Total potential	**340**	**547-588**	**855-1009**	**1046-1305**
Total high-yield (2-4%)	**555**	**831-872**	**1168-1322**	**1374-1633**

Sources:

Perlack R. D., L. L. Wright, A. F. Turhollow, R. L. Graham, B. J. Stokes, and D. C. Erbach, *Biomass as Feedstock Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-ton Annual Supply,* ORNL/TM-2005/66. Oak Ridge National Laboratory, Oak Ridge, TN, 2005. http://www1.eere.energy.gov/biomass/publications.html

Perlack, R. D., and B. J. Stokes (Leads), *U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry* , ORNL/TM-2011/224. Oak Ridge National Laboratory, Oak Ridge, TN, 2011.

Note: Under the high-yield scenario, energy crops are shown for 2% to 4% annual increase in yield.
Numbers may not add due to rounding.

The summary assumes price paid is $60 per dry ton or less at the farm gate or forest edge and thus does not include additional costs to preprocess, handle or transport the feedstock. Scenario descriptions are discussed in the Biomass Resource Overview text and in the 2011 reference below.

BIOFUELS

Contents	Data Type	Updated
Biofuels Overview	**Text**	09/27/2011
Green Hydrocarbon Biofuels	Text	09/27/2011
Diagram of Routes to Make Biofuels	*Figure*	09/09/2011
Biological and Chemical Catalysts for Biofuels	Table	09/09/2011
Ethanol		
Ethanol Overview	**Text**	09/27/2011
Specifications Contained in ASTM D 4806 Standard Specification from Denatured Fuel Ethanol for Blending with Gasoline	Table	09/12/2011
Fuel Property Comparison for Ethanol, Gasoline and No.2 Diesel	Table	09/12/2011
Ethanol Production		
World Fuel Ethanol Production by Country or Region, 2010	Table	09/12/2011
Fuel Ethanol Production and Imports, 1981-2010	Table	09/27/2011
Ethanol Plant Statistics, 1999-2011	Table	09/12/2011
Ethanol Production Capacity by Feedstock, 2011	Table	09/27/2011
Ethanol Production Capacity by Plant Energy Source, 2009	Table	09/27/2011
Active and Under Construction Ethanol Biorefineries and Capacity, by State, 2011	Table	06/21/2011
The Ethanol Production Process - Wet Milling	*Figure*	09/12/2011
The Ethanol Production Process - Dry Milling	*Figure*	09/12/2011
The Production of Ethanol from Cellulosic Biomass	*Figure*	09/12/2011
Water Consumption for Ethanol and Petroleum Gasoline Production	Table	09/30/2011
Ethanol Consumption		
Ethanol Consumption in E85 and Gasohol, 1995-2009	Table	09/23/2011
Economics		
Economic Contribution of the Ethanol Industry, 2009	Table	09/12/2011
Sustainability		
Ethanol Net Energy Balances and Greenhouse Gas Emissions	*Figure*	09/12/2011
Comparisons of Energy Inputs for Three Ethanol Scenarios and Gasoline	*Figure*	09/12/2011
Comparative Results Between Ethanol and Gasoline Based on an Evaluation by the GREET Model	*Figure*	09/09/2011
Comparison of Ethanol Energy Balance With and Without Inclusion of Coproduct Energy Credits	Table	09/09/2011

Biofuels Overview

A variety of fuels can be produced from biomass resources including liquid fuels, such as, ethanol, methanol, biodiesel, Fischer-Tropsch diesel and gasoline, 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 most commonly made by converting the starch from corn 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 2010 production and consumption at over 13 billion gallons based primarily on 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.

Bio-oil

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 bio-oil. 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 2009. The bio-oils currently produced are suitable for use in boilers for electricity generation. There is currently ongoing research and development to produce bioOil of sufficient quality for transportation applications.

Other Hydrocarbon Biofuels

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 or ethanol. 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.

A wide range of single molecule biofuels or fuel additives can be made from lignocellulosic biomass. Such production has the advantage of being chemically essentially the same as petroleum-based fuels. Thus modifications to existing engines and fuel distribution infrastructure are not required. Additional information on green hydrocarbon fuels can be found on the Green Hydrocarbon Biofuels page.

Sources: U.S. Department of Energy, Energy Efficiency and Renewable Energy, Alternative Fuels & Advanced Vehicles Data Center
http://www.afdc.energy.gov/afdc/fuels/
http://www1.eere.energy.gov/biomass/

Green Hydrocarbon Biofuels

A biofuel is a liquid transportation fuel made from biomass. A wide range of single molecule biofuels or fuel additives can be made from lignocellulosic biomass including:

• Ethanol or ethyl alcohol
• Butanol or butyl alcohol
• Hydroxymethylfurfural (HMF) or furfural
• Gamma valerolactone (GVL)
• Ethyl levulinate (ELV)

The production of hydrocarbon biofuels from biomass has many advantages:

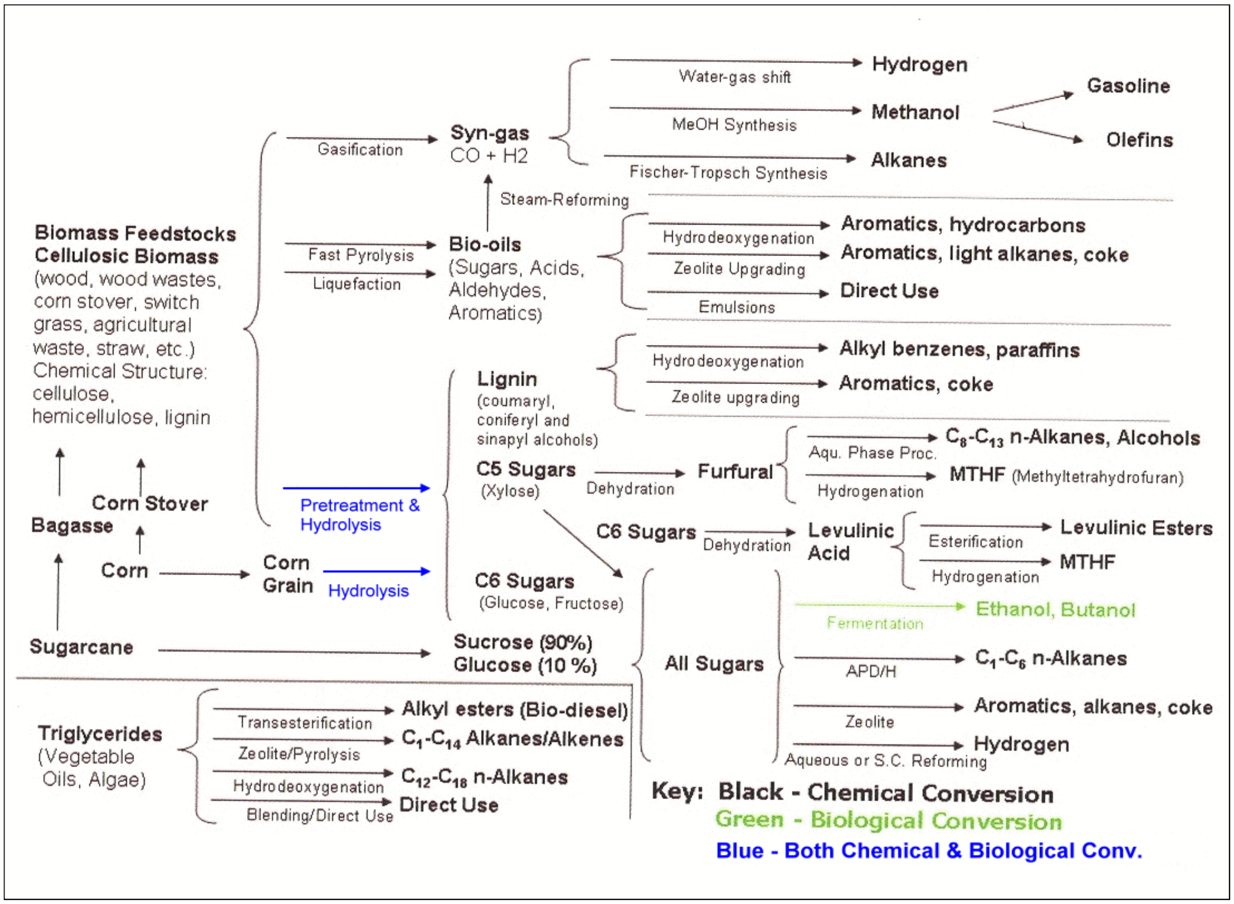
- "Green" hydrocarbon fuels are chemically essentially the same as petroleum-based fuels. Thus modifications to existing engines and fuel distribution infrastructure are not required.
- "Green" hydrocarbon fuels are energy equivalent to petroleum-based fuels, thus no mileage penalty is encountered from their use.
- "Green" hydrocarbon fuels are immiscible in water. This allows the biofuels to self-separate from water which eliminates the high cost associated with water separation by distillation.
- "Green" hydrocarbon fuels are produced at high temperatures, which translates into faster reactions and smaller reactors. This allows for the fabrication and use of portable processing units that allow the conversion of biomass closer to the biomass source.
- The amount of water required for processing "Green" hydrocarbon fuels from biomass, if any, is minimal.
- The heterogeneous catalysts used for the production of "Green" hydrocarbon biofuels are inherently recyclable, allowing them to be used for months or years.

Additionally, "Green" gasoline or diesel biofuels, which are a mixture of compounds, can be synthesized from lignocellulosic biomass by catalytic deoxygenation. Green diesel can also be made via the catalytic deoxygenation of fatty acids derived from virgin or waste vegetable oils or animal fats.

Biofuels can be produced using either biological (e.g., yeast) or chemical catalysts with each having advantages and disadvantages. Chemical catalysts range from solid heterogeneous catalysts to homogeneous acids. Most biofuel production pathways use chemical catalysts.

Source: National Science Foundation. 2008. *Breaking the Chemical and Engineering Barriers to Lignocellulosic Biofuels: Next Generation Hydrocarbon Biorefineries*, Ed. George Huber. University of Massachusetts Amherst. National Science Foundation. Bioengineering, Environmental, and Transport Systems Division. Washington D.C.

Section: BIOFUELS
Diagram of Routes to Make Biofuels



Source:

NSF. 2008. *Breaking the Chemical and Engineering Barriers to Lignocellulosic Biofuels: Next Generation Hydrocarbon Biorefineries*, Ed. George Huber. University of Massachusetts Amherst. National Science Foundation. Bioengineering, Environmental, and Transport Systems Division. Washington D.C.

Section: BIOFUELS
Catalyst Types and Conditions for Use in Producing Biofuels

	Biological Catalysts	Chemical Catalysts
Products	Alcohols	A Wide Range of Hydrocarbon Fuels
Reaction Conditions	Less than 70ºC, 1 atm	10-1200ºC, 1-250 atm
Residence Time	2-5 days	0.01 second to 1 hour
Selectivity	Can be tuned to be very selective (greater than 95%)	Depends on reaction. New catalysts need to be developed that are greater than 95% selective.
Catalyst Cost	$0.50/gallon ethanol *(cost for cellulase enzymes, and they require sugars to grow) $0.04/gallon of corn ethanol*	$0.01/gallon gasoline *(cost in mature petroleum industry)*
Sterilization	Sterilize all Feeds *(enzymes are being developed that do not require sterilization of feed)*	No sterilizaton needed
Recyclability	*Not possible*	Yes with Solid Catalysts
Size of Cellulosic Plant	2,000-5,000 tons/day	100-2,000 tons/day

Source:

NSF. 2008. *Breaking the Chemical and Engineering Barriers to Lignocellulosic Biofuels: Next Generation* Hydrocarbon Biorefineries, Ed. George Huber. University of Massachusetts Amherst. National Science Foundation. Bioengineering, Environmental, and Transport Systems Division. Washington D.C.

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 2009, more than 7.3 billion gasoline-equivalent gallons were added to gasoline in the United States to meet biofuel requirements 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. October 2010, the Environmental Protection Agency granted a partial waiver to allow E15 to be sold in the U.S., subject to several conditions. 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

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.

Section: BIOFUELS

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

Property	Specification	ASTM Test Method
Ethanol volume %, min	92.100	D 5501
Methanol, volume %. max	0.500	
Solvent-washed gum, mg/100 ml max	5.000	D 381
Water content, volume %, max	1.000	E 203
Denaturant content, volume %, min	1.960	
volume %, max	4.760	
Inorganic Chloride content, mass ppm (mg/L) max	40.000	D 512
Copper content, mg/kg, max	0.100	D1688
Acidity (as acetic acid CH3COOH), mass percent (mg/L), max	0.007	D1613
pHe	6.5-9.0	D 6423
Appearance	precipitated contaminants (clear & bright)	

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

Note: ASTM = American Society for Testing and Materials

Section: BIOFUELS
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[a]
Centipoise @ 60° F	1.19	0.37–0.44[b]	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[b]	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[b]	14.7
Volume % fuel in vaporized stoichiometric mixture	6.5	2	–

Source: U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Alternative Fuels Data Center http://www.afdc.energy.gov/afdc/fuels/properties.html

[a]Pour Point, ASTM D 97.
[b]Calculated.
[c]Based on Cetane.

The U.S. produces more fuel ethanol than any other country; Brazil produces the second most. Together, the U.S. and Brazil produced a little over 86% of the world's fuel ethanol in 2010.

Section: BIOFUELS

World Fuel Ethanol Production by Country or Region, 2010

(Millions of gallons, all grades)

Region	2010
North & Central America	13,720.99
Europe	1,208.58
South America	7,121.76
Asia	785.91
Oceania	66.04
Africa	43.59
Total	**22,946.87**

Individual Countries	2010
United States	13,230.00
Brazil	6,577.89
European Union	1,039.52
China	541.55
Canada	290.59

Source:

Renewable Fuels Association, Industry Statistics, Ethanol Industry Overview: World Fuel Ethanol Production.
http://www.ethanolrfa.org/pages/statistics#F

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.

Fuel ethanol production has been on the rise in the U.S. since 1980, though production has increased dramatically in recent years. Fuel ethanol production increased by 22% between 2009 and 2010.

Section: BIOFUELS
Fuel Ethanol Production and Imports, 1981-2010
(million gallons)

Year	Production	Net Imports
1981	83	N/A
1982	225	N/A
1983	415	N/A
1984	510	N/A
1985	617	N/A
1986	712	N/A
1987	819	N/A
1988	831	N/A
1989	843	N/A
1990	748	N/A
1991	866	N/A
1992	985	N/A
1993	1,154	10,248
1994	1,289	11,718
1995	1,358	16,254
1996	973	13,146
1997	1,288	3,570
1998	1,405	2,772
1999	1,465	3,654
2000	1,622	4,872
2001	1,765	13,230
2002	2,140	12,852
2003	2,804	12,264
2004	3,404	148,764
2005	3,904	135,828
2006	4,884	731,136
2007	6,521	439,194
2008	9,309	529,620
2009	10,938	198,240
2010	13,298	(382,843) [a]

Source:
U.S. Department of Energy, Energy Information Administration, *Monthly Energy Review*, August 2011, Washington, D.C., Table 10.3.
Additional resources: www.eia.doe.gov

[a] Data for 1981-2009 are only imports. Beginning in 2010, data are for fuel ethanol imports minus exports.

Between 1999 and 2011, the number of ethanol plants in the U.S. quadrupled, 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, http://www.ethanolrfa.org/pages/statistics.

Section: BIOFUELS
Ethanol Plant Statistics, 1999-2011

Year	Total Ethanol Plants	Ethanol Production Capacity (million gallons per year)	Plants Under Construction/ Expanding	Capacity Under Construction/ Expanding (million gallons per year)	States with Ethanol Plants
1999	50	1,701.7	5	77.0	17
2000	54	1,748.7	6	91.5	17
2001	56	1,921.9	6	64.7	18
2002	61	2,347.3	13	390.7	19
2003	68	2,706.8	11	483.0	20
2004	72	3,100.8	15	598.0	19
2005	81	3,643.7	16	754.0	18
2006	95	4,336.4	31	1,778.0	20
2007	110	5,493.4	76	5,635.5	21
2008	139	7,888.4	61	5,536.0	21
2009	170[a]	10,569.4[a]	24	2,066.0	26
2010	189	11,877.4	15	1,432.0	26
2011	204	13,507.9	10	522.0	29

Source:

Renewable Fuels Association, Ethanol Industry Statistics: *Ethanol Industry Overview*.
http://www.ethanolrfa.org/pages/statistics

Note:

As of January each year. May not match other sources.

[a] Operating plants

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.

Section: BIOFUELS
Ethanol Production Capacity by Feedstock, 2011

Plant Feedstock	Capacity (million gallons/year)	% of Capacity	No. of Plants	% of Plants
Corn	14,226.0	96.2%	193	90.2%
Corn/Milo	422.0	2.9%	6	2.8%
Corn/Barley	65.0	0.4%	2	0.9%
Milo/Wheat Starch	48.0	0.3%	1	0.5%
Cheese Whey	7.6	0.1%	3	1.4%
Beverage Waste	5.4	0.0%	1	0.5%
Potato Waste	4.0	0.0%	1	0.5%
Waste Beer	3.0	0.0%	1	0.5%
Seed Corn	1.5	0.0%	1	0.5%
Sugar Cane Bagasse	1.5	0.0%	1	0.5%
Wood Waste	1.5	0.0%	1	0.5%
Waste Sugars/Starches	1.0	0.0%	1	0.5%
Brewery Waste	0.4	0.0%	1	0.5%
Woody Biomass	0.0	0.0%	1	0.5%
Total	**14,786.9**	**100.0%**	**214**	**100.0%**

Source:
Renewable Fuels Association, August 8, 2011.
http://www.ethanolrfa.org/bio-refinery-locations/

Note:
Totals were estimated when individual plant data were not available.

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

Section: BIOFUELS
Ethanol Production Capacity by Plant Energy Source, 2009

Energy Source	Capacity (Million Gallons per Year)	% of Capacity	No. of Plants	% of Plants	Combined Heat and Power Technology (CHP)
Coal[a]	1,758	14.6%	17	9.4%	8
Coal, Biomass	50	0.4%	1	0.6%	0
Natural Gas[b]	9,627	80.1%	151	83.9%	13
Natural Gas, Biomass[c]	115	1.0%	3	1.7%	1
Natural Gas, Coal	35	0.3%	1	0.6%	1
Natural Gas, Landfill Biogas, Wood	110	0.9%	1	0.6%	0
Natural Gas, Syrup	101	0.8%	2	1.1%	0
Waste Heat[d]	50	0.4%	1	0.6%	1
Waste Heat[d,] Natural Gas	175	1.5%	3	1.7%	3
Total	**12,020**	**100.0%**	**180**	**100.0%**	**27**

Source:
Environmental Protection Agency, Assesment and Standards Division, Office of Transportation and Air Quality, *Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis* , EPA-420-R-10-006, February 2010.
http://www.epa.gov/otaq/renewablefuels/420r10006.pdf

[a]Includes four plants that are permitted to burn biomass, tires, petroleum coke, and wood waste in addition to coal and one facility that intends to transition to biomass in the future.
[b] Includes two facilities that might switch to biomass, one facility that intends to burn thin stillage biogas, and two facilities that were once considering switching to coal in the future.
[c]Includes one facility processing bran in addition to natural gas.
[d]Waste heat from utility partnerships.

With increased blending of ethanol in gasoline, demand for ethanol has continued to rise, requiring greater production capacity. As of August 8, 2011, there were 214 biorefineries producing 14,786.9 million gallons of ethanol per year and another seven biorefineries under construction. The Renewable Fuels Association tracks the statistics found in the table below and provides plant names, locations and feedstocks used. To see the most current information and greater detail, click on the link in the source listed below.

Section: BIOFUELS
Active and Under Construction Ethanol Biorefineries and Capacity, by State, 2011

State	Number of Biorefineries	Capacity (mgy)	Production (mgy)	Biorefineries Under Construction	Under Construction Expansion - Capacity (mgy)
Arizona	1.0	55.0	55.0	-	-
California	6.0	271.5	266.5	-	-
Colorado	4.0	125.0	125.0	-	-
Georgia	3.0	100.4	100.4	1.0	10.0
Idaho	2.0	54.0	54.0	-	-
Illinois	14.0	1,417.0	1,417.0	1.0	5.0
Indiana	14.0	1,039.0	1,039.0	1.0	110.0
Iowa	40.0	3,775.0	3,775.0	1.0	115.0
Kansas	13.0	492.5	492.5	1.0	20.0
Kentucky	2.0	38.4	38.4	-	-
Louisiana	1.0	1.5	1.5	-	-
Michigan	5.0	268.0	268.0	-	-
Minnesota	22.0	1,150.1	1,150.1	-	-
Mississippi	1.0	54.0	54.0	-	-
Missouri	5.0	251.0	251.0	-	-
Nebraska	26.0	2,135.0	2,135.0	-	-
New Mexico	1.0	25.0	25.0	-	-
New York	2.0	164.0	164.0	-	-
North Carolina	1.0	-	-	1.0	60.0
North Dakota	6.0	391.0	389.5	-	-
Ohio	7.0	538.0	538.0	-	-
Oregon	3.0	149.0	149.0	-	-
Pennsylvania	1.0	110.0	110.0	-	-
South Dakota	15.0	1,022.0	1,022.0	-	-
Tennessee	2.0	225.0	225.0	-	-
Texas	4.0	355.0	355.0	-	-
Virginia	1.0	65.0	65.0	-	-
Wisconsin	10.0	504.0	504.0	1.0	3.0
Wyoming	2.0	11.5	11.5	-	-
TOTAL	**214.0**	**14,786.9**	**14,780.4**	**7.0**	**323.0**

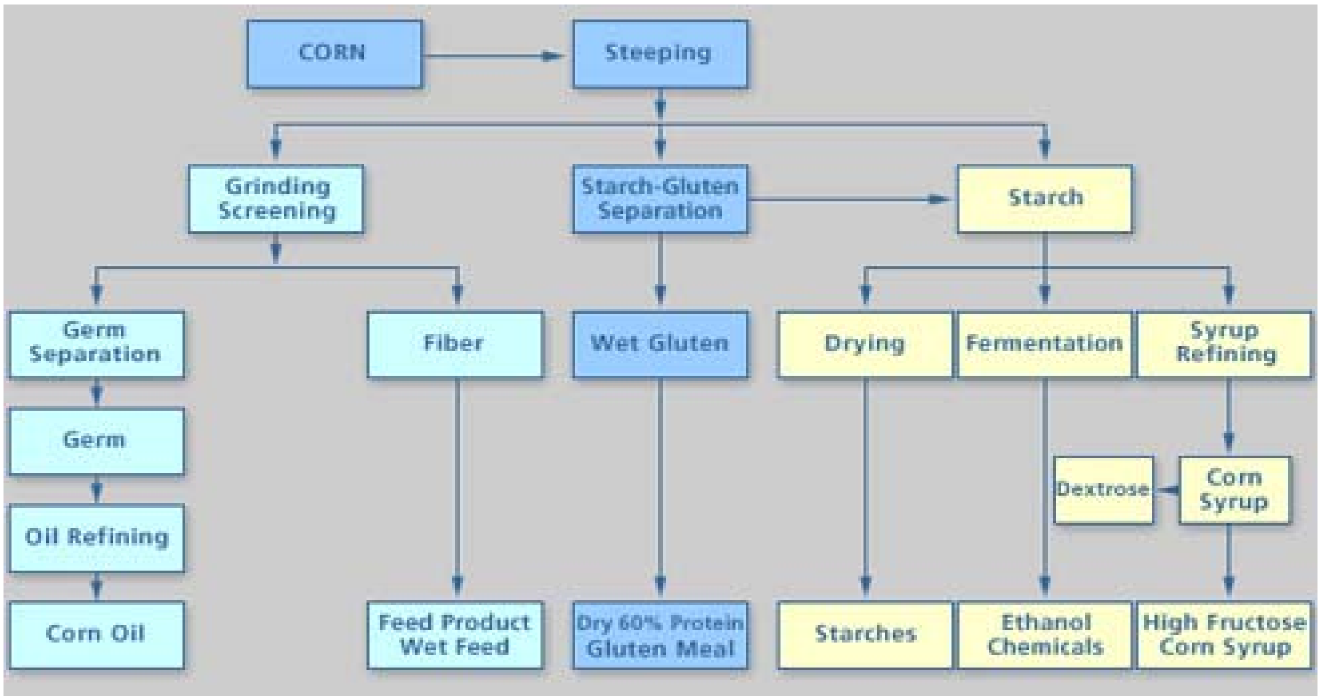
Source:
Renewable Fuels Association:
http://www.ethanolrfa.org/bio-refinery-locations/

Note:
mgy = million gallons per year

Totals were estimated when individual plant data were not available.

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.

Section: BIOFUELS
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.

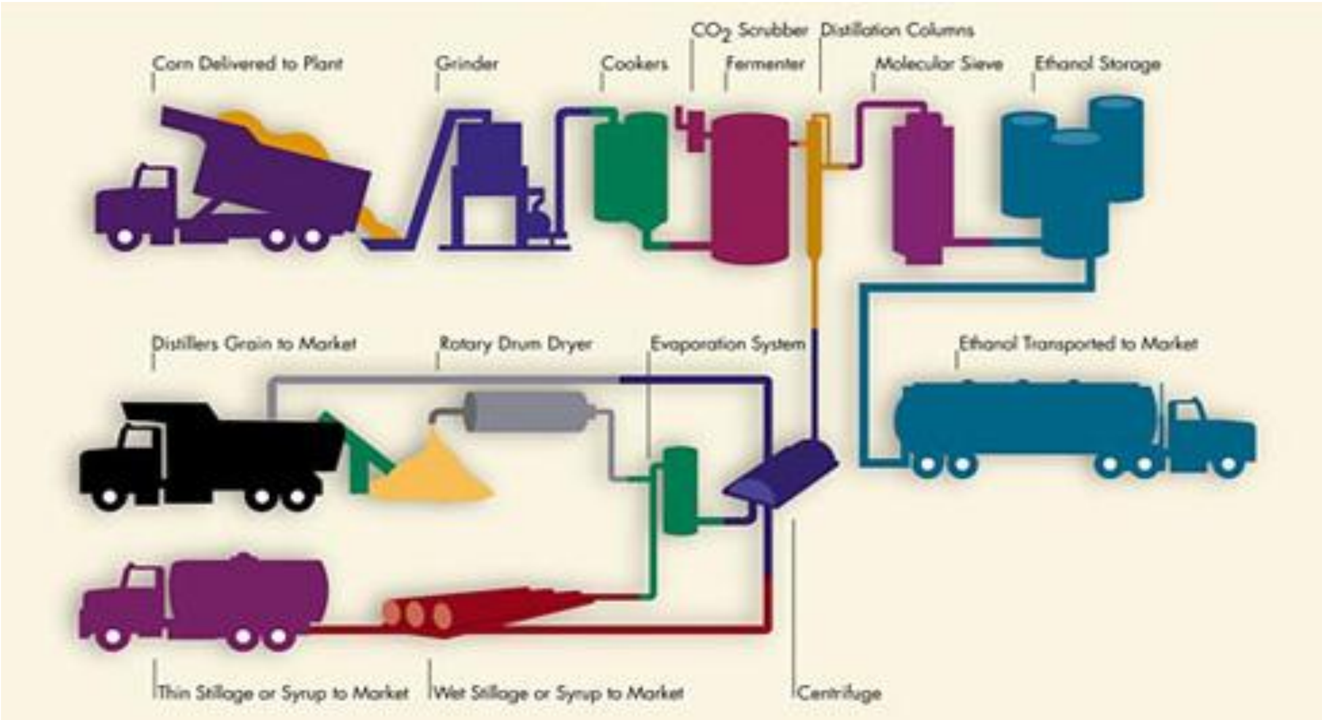
The steeping liquor is concentrated in an evaporator. This concentrated product, heavy steep water, is co-dried with the fiber component and is then sold as corn gluten feed to the livestock industry. Heavy steep water is also sold by itself as a feed ingredient and is used as a component in Ice Ban, 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/pages/how-ethanol-is-made

Section: BIOFUELS
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.

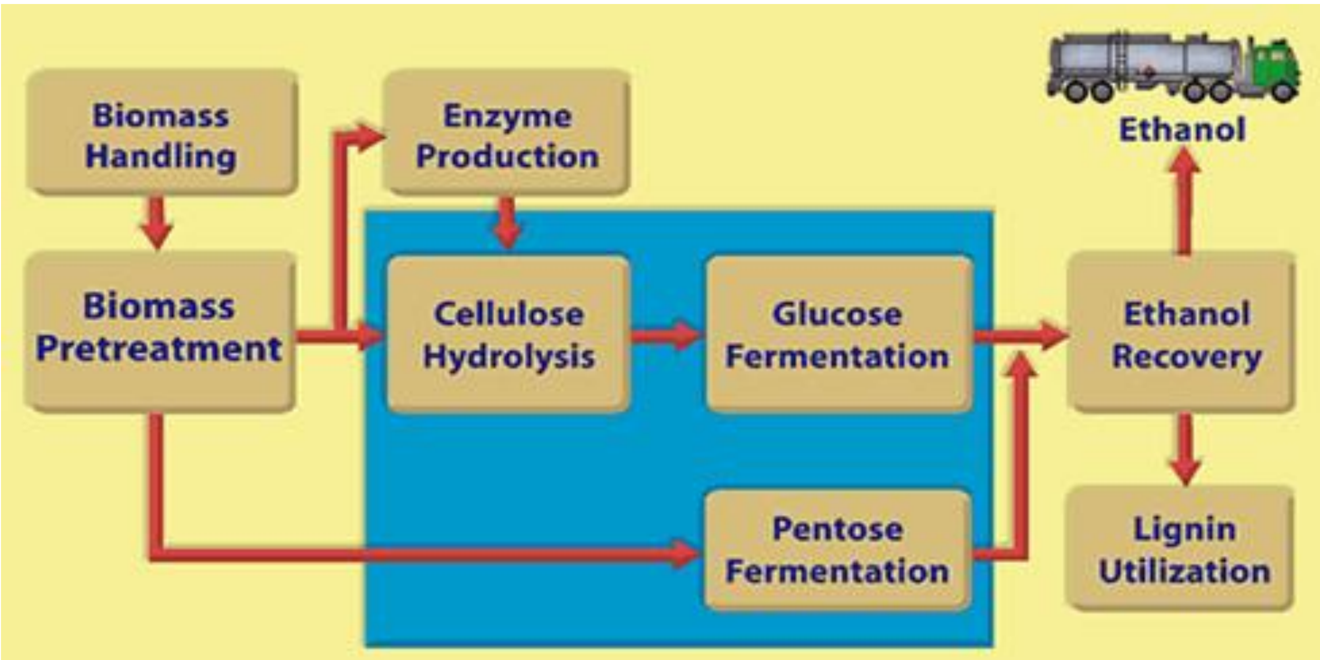
The anhydrous ethanol is blended with about 5% denaturant (such as natural gasoline) to render it undrinkable and thus not subject to beverage alcohol tax. It is then ready for shipment to gasoline terminals or retailers.

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/pages/how-ethanol-is-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.

Section: BIOFUELS
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.

1. 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.

2. 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.

3. 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.

4. 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.
5. 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.
6. 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.
7. 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.
8. 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/pages/how-ethanol-is-made
and the Department of Energy, Energy Efficiency and Renewable Energy,
http://www1.eere.energy.gov/biomass/abcs_biofuels.html

Note: See Appendix B, "Characteristics of Selected Feedstocks and Fuels."

A recent study on the consumption of water in the production of ethanol and gasoline shows that there is variability by region, feedstock, soil and climate condition, and production technology for ethanol. There is also much variability in water use in the production of gasoline due to the age of oil well, recovery technology, and extent of produced-water re-injection and steam recycling. This table shows ranges for the amount of water consumed (net) for five different fuels/feedstocks.

Section: BIOFUELS
Water Consumption for Ethanol and Petroleum Gasoline Production
(Quadrillion Btu)

Fuel (feedstock)	Net Water Consumed[a]	Major Factors Affecting Water Use
Corn ethanol	17-239 gal/gal ethanol[b]	Regional variation caused by irrigation requirements due to climate and soil types
Switchgrass ethanol	1.9-9.8 gal/gal ethanol[b]	Production technology
Gasoline (U.S. conventional crude)	3.4-6.6 gal/gal gasoline	Age of oil well, production technology, and degree of produced water recycle
Gasoline (Saudi conventional crude)	2.8-5.8 gal/gal gasoline	Age of oil well, production technology, and degree of produced water recycle
Gasoline (Canadian oli sands)[c]	2.6-6.2 gal/gal gasoline	Geologic formation, production technology

Source:

Argonne National Laboratory, *Consumptive Water Use in the Production of Ethanol and Petroleum Gasoline - 2011 Update*, ANL/ESD/09-1-Update, July 2011.

[a]In gallons of water per gallon of fuel specified.

[b]All water used in ethanol conversion is allocated to the ethanol product. Wather consumption for corn and switchgrass farming includes irrigation.

[c]Including thremal recovery, upgrading and refining.

Ethanol is used as an oxygenate, blended with gasoline to be used as gasohol in conventional vehicles. The amount of ethanol used in gasohol dwarfs the amount used in E85.

Section: BIOFUELS
Ethanol Consumption in E85 and Gasohol, 1995-2009
(Thousands of gasoline-equivalent gallons)

	E85	Percent of Total	Ethanol in Gasohol	Percent of Total	Total
1995	166	0.02%	934,615	99.98%	934,781
2000	10,530	0.94%	1,114,313	99.06%	1,124,843
2001	12,756	1.08%	1,173,323	98.92%	1,186,079
2002	15,513	1.06%	1,450,721	98.94%	1,466,234
2003	22,420	1.15%	1,919,572	98.85%	1,941,992
2004	26,844	1.10%	2,414,167	98.90%	2,441,011
2005	38,074	1.36%	2,756,663	98.64%	2,794,737
2006	44,041	1.17%	3,729,168	98.83%	3,773,209
2007	54,091	1.14%	4,694,304	98.86%	4,748,395
2008	62,464	0.96%	6,442,781	99.04%	6,505,245
2009	71,213	0.96%	7,343,133	99.04%	7,414,346

Source:
U.S. Department of Energy, Energy Information Administration, *Alternatives to Traditional Transportation Fuels*, 2009, Table C1. Washington DC, April 2011, Website: http://www.eia.gov/fuelrenewable.html

Note: Gallons of E85 and gasohol do not include the gasoline portion of the blended fuel.

The ethanol industry spent $16 billion in 2009 on raw materials, other inputs, goods and services to produce more than nine billion gallons of ethanol. Most of this spending was for corn and other grains used as raw material to make ethanol. An additional $1.7 billion was spent on tranportation of grain and other inputs to production facilities; ethanol from the plant to terminals where it is blended with gasoline; and co-products to end-users. All expenditures for operations, transportation and spending for new plants under construction added an estimated $53.3 billion in additional gross output in the U.S. economy, increased household earnings by nearly $16 billion, and created over 399,283 jobs.

Section: BIOFUELS
Economic Contribution of the Ethanol Industry, 2009

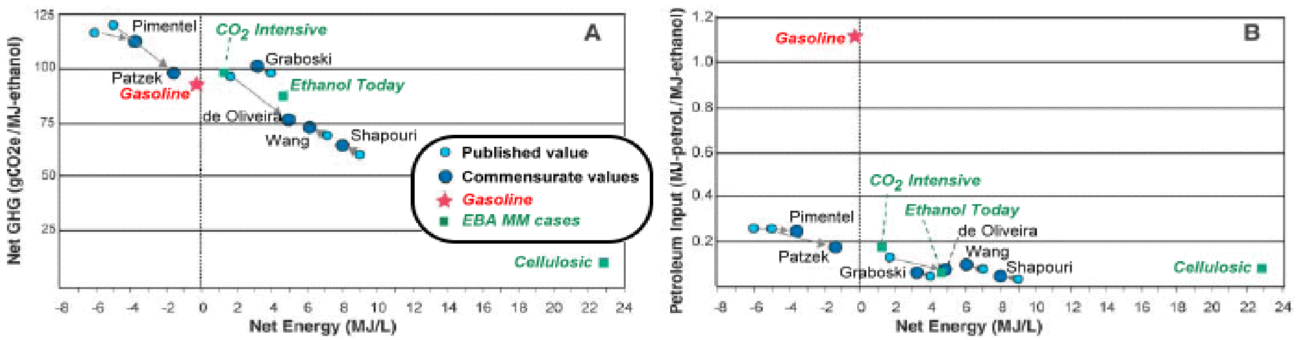
	Expenditures (Mil 2009$)	Impact		
		GDP (Mil 2009$)	Earnings (Mil 2009$)	Employment (Jobs)
Annual Operations				
Feedstock (Corn)	$10,041.0	$13,507.0	$5,353.0	180,111
Enzymes and chemicals	$1,052.0	$1,477.0	$755.0	14,564
Denaturants	$443.0	$450.0	$241.0	4,220
Electricity	$398.0	$571.0	$239.0	4,358
Natural gas	$1,144.0	$1,623.0	$751.0	13,413
Water	$130.0	$200.0	$93.0	1,959
Maintenance	$276.0	$482.0	$262.0	6,809
Wholesale Trade	$2,127.0	$3,440.0	$1,736.0	36,677
Management and Administration	$212.0	$380.0	$214.0	4,573
Earnings to households	$218.0	$291.0	$145.0	3,786
Transportation	$1,654.0	$2,650.0	$1,389.0	31,247
Value of Ethanol Production	$0.0	$17,490.0	$218.0	0
Value of co-products	$0.0	$2,761.0	$0.0	0
Total Annual Operations	**$17,695.0**	**$45,323.0**	**$11,397.0**	**301,718**
New Capacity				
Construction (labor and other)	$1,215.5	$2,169.0	$1,287.0	31,828
Equipment and machinery	$1,423.4	$2,176.0	$1,133.0	24,895
Total	**$2,639.0**	**$4,345.0**	**$2,420.0**	**56,724**
R&D Spending on new technology	**$2,000.0**	**$3,651.0**	**$2,162.0**	**40,842**
Grand Total	**$22,334.0**	**$53,319.0**	**$15,978.0**	**399,283**

Source:
Urbanchuk, John M., *Contribution of the Ethanol Industry to the Economy of the United States* , Prepared for The Renewable Fuels Association, February 12, 2010, http://www.ethanol.org/pdf/contentmgmt/2009_ethanol_economic_contribution.pdf

The net energy balance and greenhouse gas emissions associated with ethanol production have been analyzed by multiple groups. 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 the Biofuel Analysis MetaModel (EBAMM) to investigate these issues. 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. Equalizing system boundaries among studies 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.

Section: BIOFUELS
Ethanol Net Energy Balances and Greenhouse Gas Emissions



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:

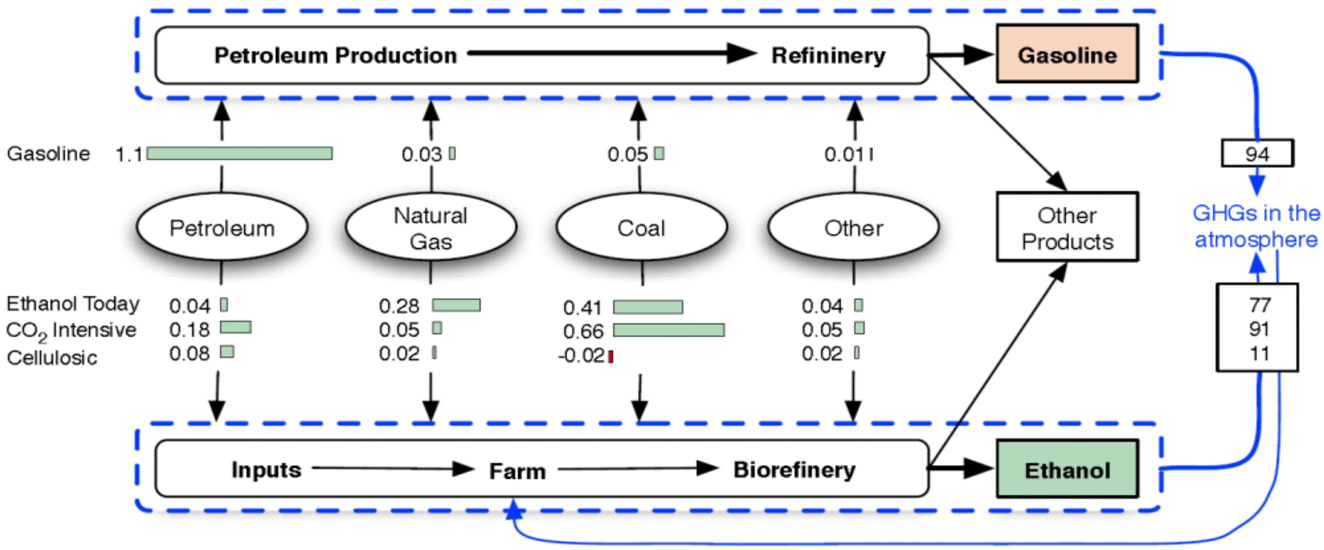
T. Patzek. *Crit. Rev. Plant Sci*. **23**, 519 (2004).
D. Pimentel, T. Patzek, *Nat. Resourc. Res.* **14**, 65(2005).
M.E.D. de Oliveira, B.E. Vaughn, E.J. Rykiel, *Bioscience*, **55**, 593(2005).
H. Shapouri, A. McAloon, "The 2001 net energy balance of corn ethanol" (U.S. Department of Agriculture, Washington, D.C. 2004).
M. Graboski, "Fossil energy use in the manufacture of corn ethanol" (National Corn Growers Association, Washington, DC. 2002). http://www.ncga.com/
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

Note: gCO2e (as shown in figure A above) is grams of CO2 equivalent.

This graphic 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 switchgrass grown 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.

Section: BIOFUELS

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

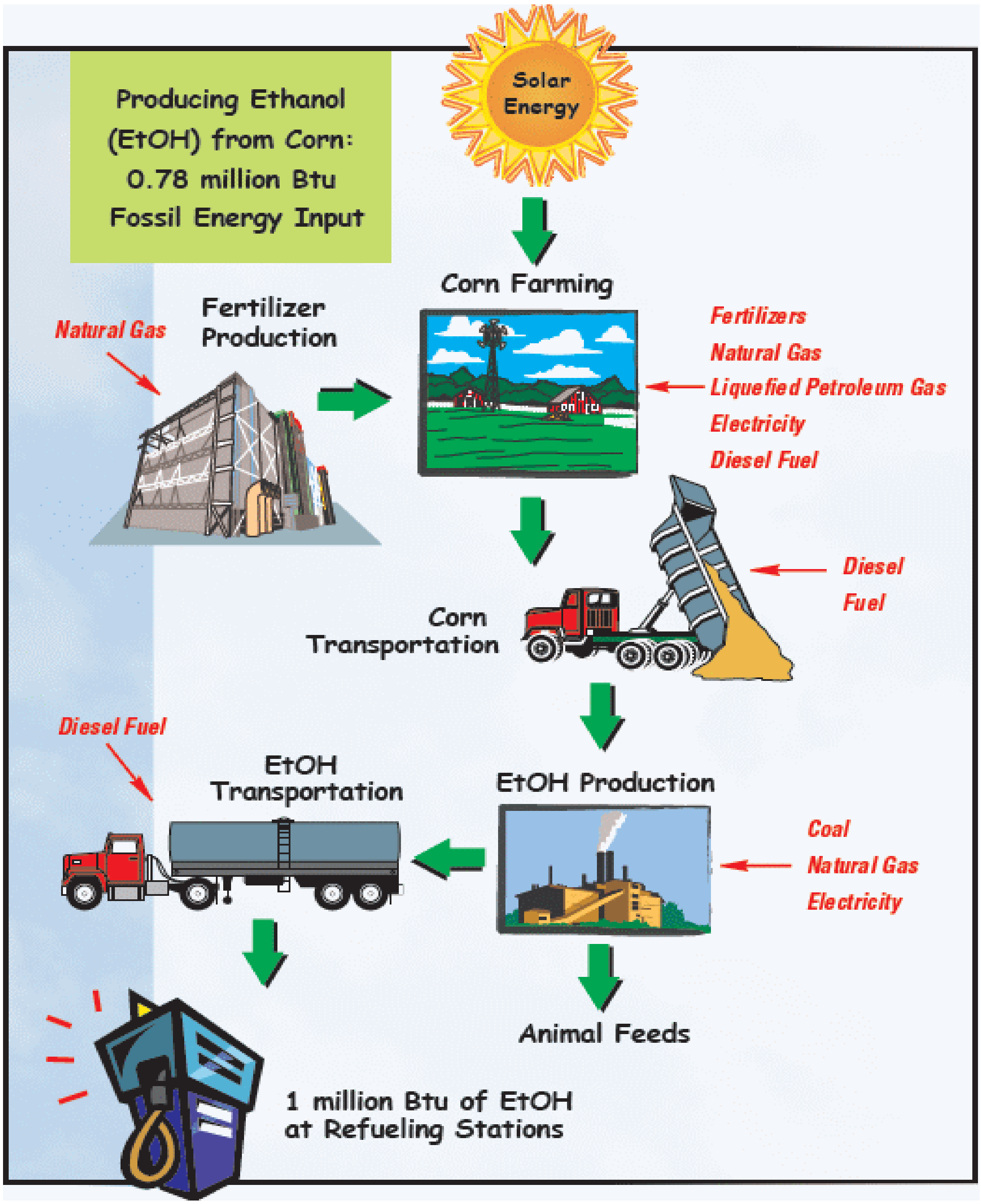


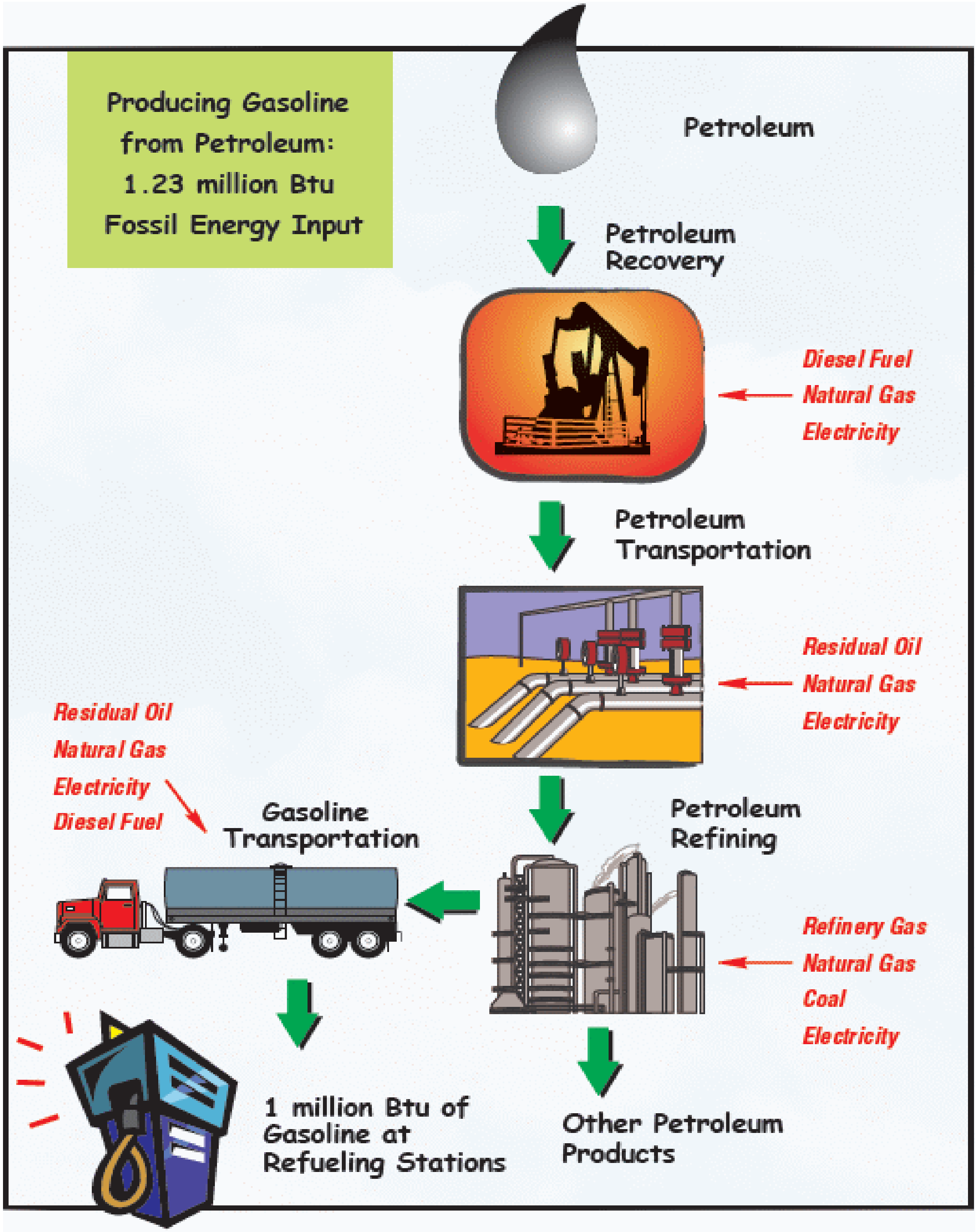
Source:

A.E. Farrell, R.J. Plevin, B.T. Turner, A.D. Jones, M. O'Hare, and D.M. Kammen. Ethanol Can Contribute To Energy and Environmental Goals. Science, Vol 311, January 27, 2006.
http://www.sciencemag.org/content/311/5760/506.full

This figure shows the fossil energy inputs used to produce and deliver a million Btu of ethanol and gasoline to a refueling station. This figure is based on GREET (Greenhouse gases, Regulated Emissions, and Energy Use in Transportation) model. The GREET model is in the public domain and is available at: http://greet.es.anl.gov/

Section: BIOFUELS
Comparative Results between Ethanol and Gasoline Based on an Evaluation by the GREET Model




Producing Gasoline from Petroleum: 1.23 million Btu Fossil Energy Input
Petroleum
Petroleum Recovery
Diesel Fuel
Natural Gas
Electricity
Petroleum Transportation
Residual Oil
Natural Gas
Electricity
Petroleum Refining
Refinery Gas
Natural Gas
Coal
Electricity
Residual Oil
Natural Gas
Electricity
Diesel Fuel
Gasoline Transportation
1 million Btu of Gasoline at Refueling Stations
Other Petroleum Products

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 1.8d.1 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 six criteria pollutants: volatile organic compounds, carbon monoxide, nitrogen oxide, particulate matter with size smaller than 10 micron (PM10), particulate matter with size smaller than 2.5 micron, and sulfur oxides.

GREET includes more than 100 fuel pathways including petroleum fuels, natural gas fuels, biofuels, hydrogen, and electricity produced from various feedstocks.

GREET includes more than 80 vehicle/fuel systems:

- Conventional spark-ignition engine vehicles
- Spark-Ignition, Direct-Injection Engine Vehicles
- Compresson-Ignition, Direct-Injection Engine Vehicles
- Hybrid electric vehicles
  - Spark-ignition engines
  - Compression-ignition engines
- Plug-in hybrid electric vehicles
  - Spark-ignition engines
  - Compression-ignition engines
- Battery-powered electric vehicles
- Fuel-cell vehicles

Source:

Figures: Ethanol: The Complete Energy Life-Cycle Picture. Second revised edition, March 2007
http://www.transportation.anl.gov/pdfs/TA/345.pdf

Text: Argonne National Laboratory, Transportation Technology R&D Center,
http://greet.es.anl.gov/

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 an 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		Weighted
	Dry	Wet	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		Weighted
	Dry	Wet	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, D.C. 2004.
http://www.usda.gov/oce/reports/energy/net_energy_balance.pdf

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.

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

National Biodiesel Board, www.biodiesel.org/resources/biodiesel_basics/default.shtm

Biomass Energy Data Book – 2011 – http://cta.ornl.gov/bedb

Europe has been the dominant region for biodiesel production with increased production each year since 2005. North America has been a distant second led by the United States until 2009. In 2009, U.S. biodiesel production fell by over 10 thousand barrels per day while continued growth in Central & South America and Asia & Oceania surpassed North America in production of biodiesel for the first time. The economic downturn, changes in Federal Incentives for biodiesel and foreign trade policies have contributed to the decrease in U.S. biodiesel production in 2009.

Section: BIOFUELS
World Biodiesel Production by Region and Selected Countries, 2005-2009
(Thousand barrels per day)

Region/Country	2005	2006	2007	2008	2009
North America	**6.1**	**17.1**	**33.7**	**45.9**	**35.2**
United States	5.9	16.3	32.0	44.1	32.9
Central & South America	**0.5**	**2.2**	**15.2**	**38.6**	**57.9**
Brazil	0.0	1.2	7.0	20.1	27.7
Europe	**68.1**	**113.2**	**137.5**	**155.0**	**172.6**
France	8.4	11.6	18.7	34.4	41.1
Germany	39.0	70.4	78.3	61.7	51.2
Italy	7.7	11.6	9.2	13.1	13.1
Eurasia	**0.3**	**0.3**	**0.7**	**2.5**	**3.8**
Lithuania	0.1	0.2	0.5	1.3	1.9
Asia & Oceania	**2.2**	**9.1**	**15.8**	**28.8**	**38.5**
China	0.8	4.0	6.0	8.0	8.0
Korea, South	0.2	0.9	1.7	3.2	5.0
Malaysia	0.0	1.1	2.5	4.5	5.7
Thailand	0.4	0.4	1.2	7.7	10.5
World	**77.2**	**142.0**	**202.9**	**270.9**	**308.2**

Source:

U.S. Energy Information Administration, International Energy Statistics, Biofuels Production.
The above table was derived from an interactive table generated on December 9, 2010.
http://tonto.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=79&pid=79&aid=1

SECTION: BIOFUELS
Biodiesel Production Capacity by State

State	Number of Plants	Total Production Capacity
Alabama	3	45,000,000
Arizona	3	34,000,000
Arkansas	2	50,000,000
California	16	74,500,000
Colorado	1	15,000,000
Connecticut	3	5,000,000
Delaware	1	11,000,000
Florida	6	23,900,000
Georgia	5	45,000,000
Idaho	1	1,500,000
Illinois	4	158,000,000
Indiana	5	101,300,000
Iowa	8	173,530,000
Kansas	3	63,800,000
Kentucky	3	60,750,000
Louisiana	2	72,000,000
Maine	1	500,000
Maryland	1	4,000,000
Massachusetts	4	16,000,000
Michigan	3	37,000,000
Minnesota	3	36,000,000
Mississippi	1	20,000,000
Missouri	10	225,400,000
Montana	1	250,000
Nevada	2	2,000,000
New Hampshire	1	5,500,000
New Mexico	1	1,000,000
New York	3	20,250,000
North Carolina	6	44,500,000
North Dakota	1	85,000,000
Ohio	7	106,000,000
Oklahoma	2	35,000,000
Pennsylvania	8	144,500,000
Rhode Island	2	1,000,000
South Carolina	3	101,000,000
South Dakota	1	7,000,000
Tennessee	3	5,880,000
Texas	14	374,500,000
Utah	1	10,000,000
Virginia	5	22,800,000
Washington	6	130,000,000
West Virginia	1	3,000,000
Wisconsin	4	30,600,000
Total	**161**	**2,402,960,000**

Source:
National Biodiesel Board.

http://www.biodiesel.org/buyingbiodiesel/(X(1)S(gzbharfm1xdya3bh4eqv2aeo))/plants/showall.aspx?AspxAutoDetectCookieSupport=1

Note:
Includes 14 plants for which no capacity was listed.

Production of biodiesel in the U.S. peaked in 2008 with 678 million gallons. Likely due to the economic recession, biodiesel production fell in 2009 and 2010, but is expected to rise again in 2011.

SECTION: BIOFUELS
Biodiesel Production, Imports and Exports, 2001-2010
(million gallons)

Year	Production	Imports	Exports
2001	9	3	2
2002	10	8	2
2003	14	4	5
2004	28	4	5
2005	91	9	9
2006	250	45	35
2007	490	140	272
2008	678	315	677
2009	506	77	266
2010	309	23	105

Source:
U.S. Department of Energy, Energy Information Administration, *Monthly Energy Review*, August 2011, Washington, DC, Table 10.4. (Additional resources: www.eia.doe.gov)

Biomass Energy Data Book – 2011 – http://cta.ornl.gov/bedb

Biodiesel Production Capacity by Feedstock

Feedstock	Annual Production Capacity
Canola	93,000,000
Canola, Camelina, Safflower, Sunflower	250,000
Crude or Refined Vegetable Oils	36,000,000
Full Spectrum, including but not limited to Yellow Grease, Jatropha & Algae	3,000,000
Multi Feedstock	1,664,700,000
Palm	15,000,000
Recycled Cooking Oil	6,430,000
Recycled Cooking Oil, Tallow	1,500,000
Soy	496,900,000
Sunflower, Canola	3,000,000
Tallow	1,250,000
Used Cooking Oil	1,500,000
Waste Oil	11,030,000
Waste Vegetable Oil	2,500,000
Yellow Grease	3,000,000
Unknown	63,900,000
Total	**2,402,960,000**

Source:
National Biodiesel Board.

http://www.biodiesel.org/buyingbiodiesel/plants/showall.aspx?Aspx

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 (Commercial Biodiesel Production Methods) for a description of several types of tryglycerides that are found in vegetable oils.

Section: BIOFUELS
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	14:0	16:0	18:0	18:1	18:2	18:3	20:0	22:1
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=3.97						

Source:
J. Van Gerpen, B. Shanks, 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.

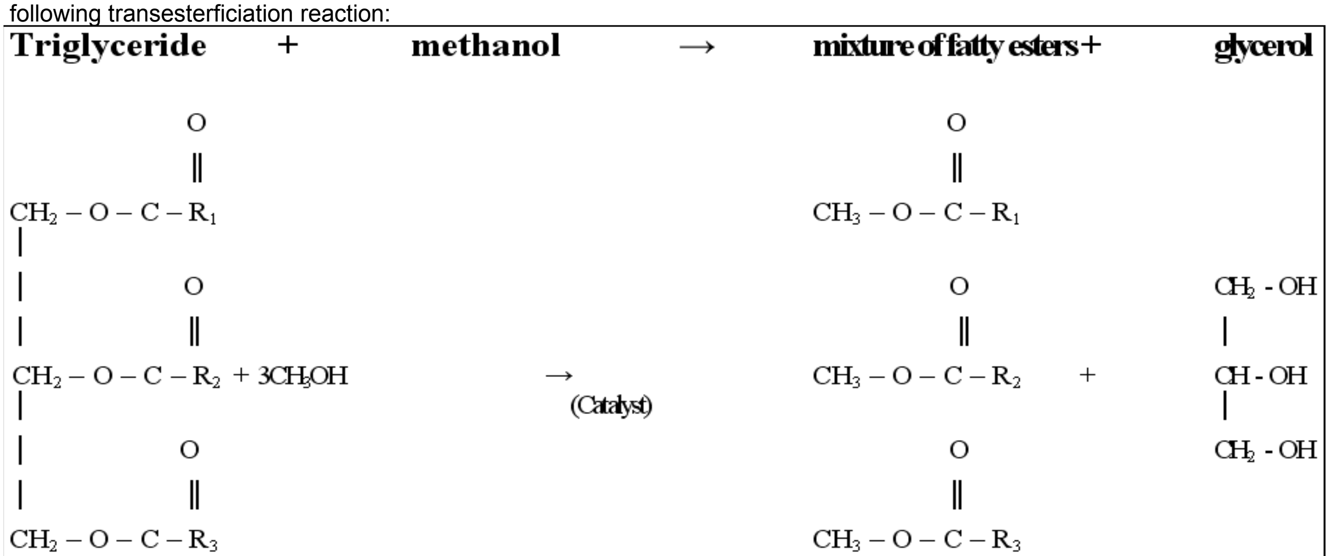
Available on-line at:
www.nrel.gov/docs/fy04osti/36244.pdf

Section: BIOFUELS

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 transesterficiation reaction:



R_1, R_2, and R_3 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:

J. Van Gerpen, B. Shanks, R. Pruszko, D. Clements, and G. Knothe, *Biodiesel Production Technology* , National Renewable Energy Laboratory subcontractor report NREL/SR-510-36244, chapter 1, page 1, 2004. http://www.nrel.gov/docs/fy04osti/36244.pdf

The parameters for B100 fuel are specified through the biodiesel standard, ASTM D6751. This standard identifies the parameters that pure biodiesel (B100) must meet before being used as a pure fuel or being blended with petrodiesel.

Section: BIOFUELS
Specification for Biodiesel (B100)

Property	ASTM Method	Limits	Units
Calcium and Magnesium, combined	EN 14538	5 max.	ppm
Flash Point	D93	93.0	Degrees C
Alcohol Control (one of the following must be met)			
1. Methanol Content	EN 14110	0.2 max	% mass
2. Flash Point	D93	130 min	Degrees C
Water & Sediment	D2709	0.050 max	% vol
Kinematic Viscosity, 40°C	D445	1.9 - 6.0	mm^2/sec
Sulfated Ash	D874	0.020 max	% mass
Sulfur S15 Grade	D5453	0.0015 max	% mass (ppm)
Sulfur S500 Grade	D5453	0.05 max	% mass (ppm)
Copper Strip Corrosion	D130	No. 3 max	
Cetane Number	D613	47 min	
Cloud Point	D2500	Report to customer	Degrees C
Carbon Residue 100% sample[a]	D4530	0.050 max	% mass
Acid Number	D664	0.50 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, T90 AET	D 1160	360 max	Degrees C
Sodium/Potassium, combined	EN 14538	5 max	ppm
Oxidation Stability	EN 14112	3 min	hours
Cold Soak Filterability	Annex to D6751	360 max	seconds
For use in temperatures below -12 C	Annex to D6751	200 max	seconds

Source:
National Renewable Energy Laboratory, Biodiesel Handling and Use Guide, Fourth Edition, NREL/TP-540-43672, January 2009.
http://www.nrel.gov/vehiclesandfuels/pdfs/43672.pdf

Note:
T90=Temperature 90% recovered; AET=Atmospheric equivalent temperature.

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

SECTION: BIOFUELS
Specification for Biodiesel Blends B6 to B20

Property	Test Method	Grade			Units
		B6 to B20 S15	B6 to B20 S500[a]	B6 to B20 S5000[b]	
Acid Number	D664	0.3	0.3	0.3	mg KOH/g, max
Viscosity	D445	1.9-4.1[c]	1.9-4.1[c]	1.9-4.1[c]	mm2/s at 40°C
Flash Point	D93	52[d]	52[d]	52[d]	°C, min
Sulfur Content[e]	D5453	15	--	--	μg/g
	D2622	--	0.05	--	mass %, max
	D129	--	--	0.5	mass %, max
Distillation Temperature	D86	343	343	343	°C, 90% evaporated, max
Ramsbottom carbon residue on 10% bottoms	D524	0.35	0.35	0.35	mass %, max
Cetane Number	D613	40[f]	40[f]	40[f]	min
One of the following must be met:					
(1) Cetane index	D976-80	40	40	40	min
(2) Aromaticity	D1319-88	35	35	--	vol %, max
Ash Content	D482	0.01	0.01	0.01	mass %, max
Water and Sediment	D709	0.05	0.05	0.05	vol %, max
Copper Corrosion	D130	No. 3	No. 3	No. 3	3h @ 50°C
Biodiesel Content	DXXXX[g]	6-20	6-20	6-20	% (V/V)
Oxidation Stability	EN14112	6	6	6	hours, min
Lubricity, HFRR @ 60°C	D6079	520[h]	520[h]	520[h]	micron, max

Source:
National Renewable Energy Laboratory, Biodiesel Handling and Use Guide,
http://www.nrel.gov/vehiclesandfuels/pdfs/43672.pdf

[a]Under U.S. regulations, if Grades B20 S500 are sold for tax-exempt purposes, then, at or beyond terminal storage tanks, it is required to contain the dye Solvent Red 164.

[b]Under U.S. regulations, Grades B20 S5000 are required to contain a sufficient amount of the dye solvent Red 164 so its presence is visually apparent.

[c]If Grade No.1-D or blends of Grade No.1-D and Grade No.2-D diesel fuel are used, the minimum viscosity shall be 1.3 mm2/s.

[d]If Grade No.1-D or blends of Grade No. 1-D and Grade No. 2-D diesel fuel are used, or a cloud point of less than -12°C is specified, the minimum flash point shall be 38°C.

[e]Other sulfur limits can apply in selected areas in the United States and in other countries.

[f]Low ambient temperatures as well as engine operation at high altitudes may require the use of fuels with higher cetane ratings.

[g]Where specified, the blend level shall be +/- 2% volume unless a different tolerance is agreed to by the purchaser and supplier.

[h]If the diesel fuel is qualified under Table 1 of D 975 for lubricity, it is not necessary to measure the lubricity of the blend.

Section: BIOFUELS
Commercial Biodiesel Production Methods

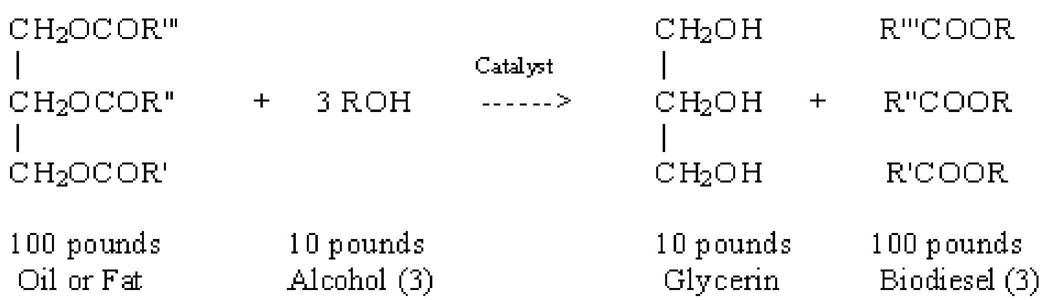
The production processes for biodiesel are well known. There are three basic routes to biodiesel production from oils and fats:

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.



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

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.

Section: BIOFUELS
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% to -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
http://www.biodiesel.org/resources/fuelfactsheets/
http://www.biodiesel.org/pdf_files/fuelfactsheets/emissions.pdf

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
http://www.epa.gov/otaq/models/analysis/biodsl/p02001.pdf

B100 is 100% Biodiesel while B20 is a blend of 20% Biodiesel and 80% conventional petroleum based diesel

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

Bio-oil Overview

A totally different process than that used to produce biodiesel can be used to convert biomass into a renewable diesel fuel known as bio-oil. The process, called fast or flash pyrolysis, occurs by heating compact solid fuels in the absence of air at temperatures between 450 and 500 degrees Celsius for a very short period of time (less than 2 seconds) and then condensing the resulting vapors within 2 seconds. The bio-oils currently produced are suitable for use in boilers or in turbines designed to burn heavy oils for electricity generation. There is currently ongoing research and development to upgrade bio-oil into transportation fuels. There are many companies in the bio-oil business, including DynaMotive Energy Systems; Esyn Group; BTG Technology Group; ABRI TECH, Inc.; Renewable Oil International; and Renewable Fuel Technologies. Additional information about DynaMotive and Ensyn Group, both with commercial fast pyrolysis bio-oil facilities, follows.

DynaMotive Energy Systems is commercializing a proprietary fast pyrolysis process that converts forest and agricultural residue (non-food crops) into liquid bio-oil and char. The company opened their first bio-oil cogeneration facility in West Lorne, 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 company's mills and lumber kilns. A 200 ton-per-day plant in Guelph, Ontario was completed in 2007, along with a new pilot plant and test plant nearby.

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 bio-oil. Ensyn has RTP[tm] facilities in commercial operation. Four of the commercial facilities are in Wisconsin and one is near Ottawa, Canada. The largest of these facilities processes about 75 green tons per day of mixed hardwood wastes. Commercial demonstration facilities in Belridge, California, and a Feedstock Test Facility in San Antonio, Texas, help the company continue research for future renewable fuels. Ensyn has several international projects as well – using pine residues in Italy and palm residues in Malaysia. A recent alliance with UOP (a Honeywell Company) is also expected to further the technologies to produce renewable liquid fuels for heat, power, and transport fuels.

Sources: DynaMotive Energy Systems Corporation, http://www.dynamotive.com/

Ensyn Group Inc., http://www.ensyn.com/

BTG Group, http://www.btgworld.com/

Renewable Oil Technologies, http://www.renewableoil.com/

Renewable Fuel Technologies, http://www.renewablefueltech.com/

Pyrolysis is thermal decomposition occurring in the absence of oxygen. Slow pyrolysis, or carbonization, is a proven technology using low temperatures and long residence times. Charcoal is the main ouput from carbonization. Fast pyrolysis is an emerging technology that uses moderate temperatures and short residence times. This type of pyrolysis produces much more liquid than the other types of pyrolysis; thus, fast pyrolysis is currently being used to produce liquid bio-oils that replace petroleum-based liquid fuels.

Section: BIOFUELS

Output Products by Method of Pyrolysis

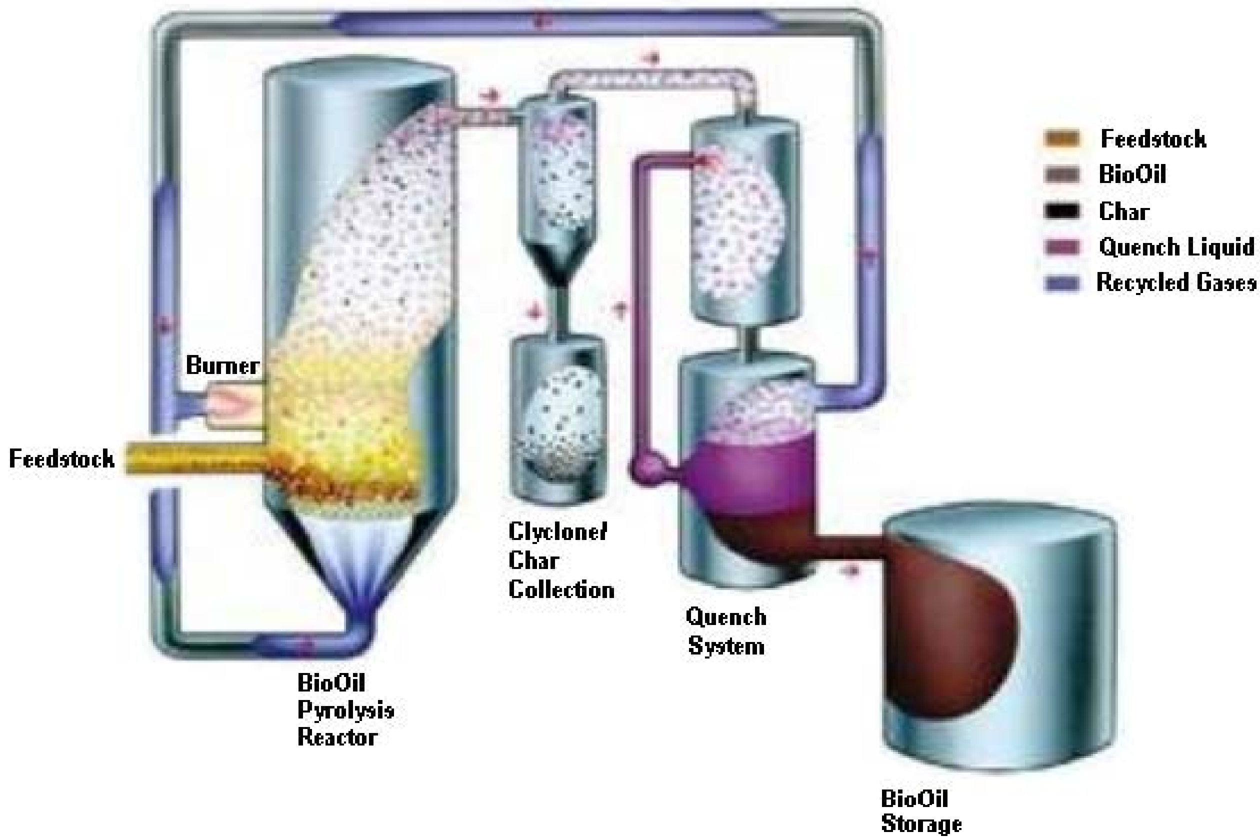
Process	Liquid	Char	Gas
Fast Pyrolysis	75%	12%	13%
Carbonization	30%	35%	35%
Gasification	5%	10%	85%

Source:

Czernik, Stefan. *Review of Fast Pyrolysis of Biomass*. National Renewable Energy Laboratory, 2002.

Bio-oil 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.

Section: BIOFUELS
A Fast Pyrolysis Process for Making Bio-oil



Source:
http://www.dynamotive.com/technology/fast-pyrolysis/

Notes:
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 bio-oil already made in the process. The bio-oil condenses and falls into the product tank, while the noncondensable gases are recycled back to the reactor and burned to provide process heat. The entire reaction from injection to quenching takes only two seconds.

One hundred percent of the feedstock is utilized in the process to produce bio-oil and char. The characteristics of the bio-oil are described in tables found under bio-oil 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 by the briquette industry, among other things including blending back into the bio-oil to make a fuel slurry. The non-condensed gases are re-circulated to fuel approximately 75% of the energy needed by the pyrolysis process. The relative yields of bio-oil, char, and non-condensable gases vary depending on feedstock composition.

Bio-oil is a liquid fuel made from biomass, such as sawdust and bagasse. It is environmentally friendly and sustainable.

Section: BIOFUELS
Bio-oil Characteristics

Tests	Methods	Results	Units
Water Content	Karl Fisher	2.0	%wt
pH	Phmeter	2.2	
Density @ 15^oC	ASTM D4052	1.207	Kg/L
High Heating Value	DIN51900	17.57 (7,554 BTU/lb)	MJ/Kg
Low Heating Value	DIN51900	15.83 (6,806 BTU/lb)	MJ/Kg
Solids Content	Insolubles in Ethanol	0.06	%wt
Ash Content	ASTM D482	0.0034	%wt
Pour Point	ASTM D97	-30	
Flash Point	STM D93	48.0	
Conradson Carbon	ASTM D189	16.6	%wt
Kinematic Viscosity			
@ 20^oC	ASTM D445	47.18	mm^2/s
@ 50^oC	ASTM D445	9.726	mm^2/s
Carbon	ASTM D5291	42.64	%wt
Hydrogen	ASTM D5291	5.83	%wt
Nitrogen	ASTM D5291	0.10	%wt
Sulphur	ASTM	0.01	%wt
Chlorine	ASTM	0.012	%wt
Alkali Metals	ICP	<0.003	%wt

Source:
http://www.dynamotive.com/assets/resources/PDF/PIB-BioOil.pdf

Note:
%wt = percent by weight; Kg = kilogram; L = liter; MJ = megajoule
mm^2/s = square milimeter per second; BTU/lb = British thermal unit per pound.

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

Section: BIOFUELS
Bio-oil Fuel Comparisons

	Units	BioTherm® Bio-oil	Light Fuel Oil	Heavy Fuel Oil
High Heating Value	MJ/kg	16-19	46	43
Flash Point	°C	48-55	38	60
Pour Point	°C	-15	-6	N/A
Density (15°C)	Kg/L	1.2	0.865	0.986
Acidity	pH	2-3	N/A	N/A
Solids (Char)	%wt	0.01-0.2	N/A	N/A
Moisture	%wt	20-25	N/A	<0.5
Ash	%wt	<0.02	Trace	0.08
Kinematic Viscosity				
@ 20°C	cSt	70	3-6	2,000-9,000
@ 40°C	cSt	19	1.8-3.5	500-1,000
@ 60°C	cSt	8	1.4-2.5	100-200
@ 80°C	cSt	4	1.1-1.8	40-70

Source:

DynaMotive,

http://www.dynamotive.com/assets/resources/PDF/PIB-BioOil.pdf

Notes:

N/A = not applicable; MJ/kg = megajoule per kilogram; C = Celsius; Kg/L = kilogram per liter; %wt = percent by weight; cSt = centistokes.

Annotated Summary of Biofuel and Biomass Electric Incentives: Online Information Resources

Yacobucci B D. Biofuels Incentives: A Summary of Federal Programs - Updated September 15, 2010

http://environmental-legislation.blogspot.com/2010/09/biofuels-incentives-summary-of-federal.html

This 18 page document is easily readable and well-organized. It first describes Federal programs supporting research, development and deployment of biofuels and biomass electric, then has tables showing the legislative incentives that were updated by the Energy Independence and Security Act of 2007 (EISA 2007) and added by the 2008 Farm Bill - The Food, Conservation, and Energy Act of 2008.

U.S. Department of Agriculture. 2008 Farm Bill Side-By-Side. Title IX: Energy

http://www.ers.usda.gov/FarmBill/2008/Titles/TitleIXEnergy.htm

This is an extremely useful document providing brief descriptions of 2008 Farm Bill provisions and authorizations relevant to energy with comparisons to similar provisions in the previous farm bill where they existed. The document also links to energy provisions in other sections of the 2008 Farm Bill.

Energy Efficiency and Renewable Energy State Activities and Partnerships

http://apps1.eere.energy.gov/states/maps/renewable_portfolio_states.cfm

A Department of Energy site that contains a map linking to descriptions of state Renewable Portfolio Standards (RPS) as of May 2009 (created by DSIRE - Database of State Incentives for Renewables & Efficiency). The site also contains a list summarizing state RPS levels with links to the administrative offices.

DSIRE - Database for State Incentives for Renewables & Efficiency

http://www.dsireusa.org/

The DSIRE website, which is kept up-to date claims to be a comprehensive source of information on state, local, utility, and federal incentives that promote renewable energy and energy efficiency. The site contains many summary maps and tables that can be downloaded as PowerPoint files.

American Wind Energy Association

http://www.awea.org/learnabout/publications/factsheets/factsheets_federal.cfm

This website contains fact sheets that address the National Renewable Electricity Standard (RES) and U.S. Energy Incentives.

Renewable Fuels Association. Renewable Fuels Standard

http://www.ethanolrfa.org/pages/RFS-2-EMTS-Information

The Renewable Fuels Standard webpage on the Renewable Fuels Association site describes the 2010 Renewable Fuels Standard, and summarizes pertainent sections of EISA.

Cantwell M. Comprehensive Guide to Federal Biofuel Incentives. 2006

http://cantwell.senate.gov/services/Biofuels/index.cfm

This 25 page document is a very comprehensive and easily readable guide to federal legislation resulting from EPACT 2005 (of which several incentives are still in effect). It also contains information on Federal agency program authorizations for supporting the research, development and deployment of biofuels, and biomass electric technologies. It is valuable for comparison with them more recent EISA 2007 bill and the 2008 Farm Bill.

These states have laws and incentives for alternative fuels production and/or use.

Federal and State Alternative Fuel Incentives, 2011

Jurisdiction	Biodiesel	Ethanol	Natural Gas	Propane (LPG)	Hydrogen Fuel Cells	EVs	HEVs or PHEVs	NEVs	Aftermarket Conversions	Fuel Economy or Efficiency	Idle Reduction	Other
Federal	34	30	27	27	27	22	8	2	6	13	6	9
Alabama	7	5	4	4	3	3	1	0	0	1	2	0
Alaska	2	3	4	2	2	2	0	1	2	2	0	0
Arizona	7	6	13	13	11	13	1	1	0	0	2	2
Arkansas	4	3	6	3	2	2	0	0	1	1	2	0
California	13	10	25	16	22	30	23	3	5	5	4	8
Colorado	8	9	11	8	7	6	2	1	3	1	3	0
Connecticut	5	4	8	5	7	7	6	0	3	2	3	3
Delaware	3	3	3	5	2	3	2	1	0	2	3	0
Dist. of Columbia	1	2	4	3	3	5	3	0	0	2	1	1
Florida	12	13	3	3	7	7	3	1	0	1	2	1
Georgia	6	6	7	3	3	5	0	0	2	1	3	1
Hawaii	8	10	5	5	6	9	1	1	0	1	1	0
Idaho	4	2	3	3	2	0	1	1	0	1	0	0
Illinois	20	18	10	9	9	10	6	2	4	3	3	0
Indiana	10	15	9	6	5	5	4	1	3	1	1	0
Iowa	13	18	6	5	5	7	0	1	1	1	0	0
Kansas	9	14	5	4	1	1	0	1	1	1	1	0
Kentucky	7	7	6	4	1	1	1	1	0	1	0	0
Louisiana	6	10	12	5	1	4	2	1	2	1	0	0
Maine	7	7	4	4	3	4	1	1	0	1	2	1
Maryland	2	3	1	1	0	4	3	2	0	0	1	2
Massachusetts	5	4	4	2	2	3	2	0	0	0	1	1
Michigan	9	9	4	4	5	6	7	0	0	2	1	0
Minnesota	9	11	3	2	4	5	2	2	0	1	2	1
Mississippi	4	4	8	5	2	2	1	0	1	1	0	0
Missouri	8	6	7	6	5	4	0	1	0	0	1	0
Montana	8	7	4	4	2	2	0	1	1	1	0	0
Nebraska	5	6	4	3	2	2	0	0	1	0	1	0
Nevada	6	5	7	7	6	6	5	1	0	0	1	0
New Hampshire	7	3	3	3	3	3	2	1	0	1	3	0
New Jersey	2	2	4	4	2	4	3	1	0	1	1	1
New Mexico	12	9	7	6	8	7	2	1	1	1	1	1
New York	9	10	13	8	9	9	4	1	0	1	3	2
North Carolina	13	11	6	6	5	6	3	0	1	1	3	0
North Dakota	12	9	3	2	3	0	0	1	0	0	0	0
Ohio	8	9	4	4	4	3	0	0	1	0	2	0
Oklahoma	11	12	13	9	8	9	3	1	5	0	1	0
Oregon	11	11	6	5	5	9	3	1	2	3	4	5
Pennsylvania	6	5	5	3	3	3	1	0	1	1	5	1
Rhode Island	2	1	2	1	2	2	1	1	0	1	1	3
South Carolina	11	9	3	4	7	2	3	1	0	0	2	0
South Dakota	10	11	1	2	0	0	0	0	0	0	0	0
Tennessee	11	10	5	4	2	4	4	1	0	2	0	0
Texas	9	9	14	10	6	8	6	1	3	0	4	1
Utah	1	1	12	7	4	7	2	0	2	1	2	0
Vermont	5	5	6	4	4	4	3	1	1	3	2	1
Virginia	15	10	13	9	10	12	4	1	3	3	2	1
Washington	18	14	9	8	6	19	6	1	4	2	3	2
West Virginia	5	5	7	7	7	7	4	1	2	0	2	1
Wisconsin	15	12	9	9	8	7	5	1	0	0	2	0
Wyoming	0	1	1	0	0	0	0	0	0	0	0	0
Totals	**435**	**419**	**363**	**286**	**263**	**305**	**144**	**43**	**62**	**68**	**90**	**49**

Source:
U.S. Department of Energy, Energy Efficiency and Renewable Energy, Alternative Fuels Data Center. April 14, 2011.
http://www.afdc.energy.gov/afdc/laws/matrix/tech

Notes: Because an incentive may apply to more than one alternative fuel, adding the totals for each row will result in counting one incentive multiple times.
EV - Electric Vehicle, HEV - Hybrid Electric Vehicle, PHEV - Plug-in Hybrid Electric Vehicle, NEV - Neighborhood Electric Vehicle (maximum speed of 25 mph)

BIOPOWER

Contents	Data Type	Updated
Biomass Power Overview	**Text**	04/05/2011
Biomass Power Technology in Commercial/Demonstration Phase During 2000-2006	Table	09/20/2011
Alkali Content and Slagging Potential of Various Biofuels	Table	09/20/2011
Reburning with Wood Fuels for NOx Mitigation	Text	09/30/2011
Carbon Dioxide Uncontrolled Emission Factors	Table	09/30/2011
Nitrogen Oxides Uncontrolled Emission Factors	Table	09/30/2011
Sulfur Dioxide Uncontrolled Emission Factors	Table	09/30/2011
Range in Elemental Composition of Industrial Wood Ash Samples and Ground Limestone	Table	09/30/2011
Biomass Power Technology Fuel Specifications and Capacity Range	Table	09/30/2011
Renewable Energy Generation and Capacity Supplying Green Pricing Programs, 2009	Table	09/30/2011
Renewable Energy Sources Supplying Competitive and REC Markets, 2009	Table	09/30/2011
Utility Green Pricing Programs Using Biomass and Biomass Based Resources	Table	09/30/2011
Competitive Electricity Markets Retail Green Power Product Offerings, August 2010	Table	09/30/2011
National Retail Renewable Energy Certificate Product Offerings, August 2010	Table	09/30/2011
New Biomass Power Plants by Year	*Figure*	09/30/2011
Biomass Power Plant Capacity by Year	*Figure*	09/30/2011
Current Biomass Power Plants	Table	09/30/2011
New Landfill Gas Power Plants by Year	*Figure*	09/30/2011
Landfill Gas Power Plant Capacity by Year	*Figure*	09/30/2011
Current Landfill Gas Power Plants	Table	09/30/2011
New Municipal Solid Waste Power Plants by Year	*Figure*	09/30/2011
Municipal Solid Waste Power Plant Capacity by year	*Figure*	09/30/2011
Current Municipal Solid Waste Power Plants	Table	09/30/2011
Green Pricing and Net Metering Customers, 2002 - 2009	Table	09/30/2011
Capacity Additions and Retirements by Energy Source, 2009	Table	09/30/2011
Fossil Fuel Displacement by Biopower		
Coal Displacement Calculation, 2010	Table	09/30/2011
Renewable Energy Impacts Calculation, 2010	Table	09/30/2011
Number of Home Electricity Needs Met Calculation, 2010	Table	09/30/2011

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, 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, cofiring 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 oxygen-limited environment where the solid biomass breaks down to form a flammable gas. The producer gas can be cleaned and filtered to remove problem chemical compounds. The producer 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 percent. Additionally, gasifiers are sometimes located next to existing coal or natural gas boilers and used to fire or supplement the fuels to these boilers.

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
http://www1.eere.energy.gov/biomass/abcs_biopower.html

Section: BIOPOWER
Biomass Power Technology in Commercial/Demonstration Phase during 2000-2006

Technology Category	Biomass Conversion Technology	Primary Energy Form Produced	Primary Energy Conversion and RecoveryTechnology	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-fueling in CFB gasifiers	Low or medium Btu producer gas	Combustion turbine or boiler and steam turbine	Electricity
Slow pyrolysis	Kilns or retorts	Charcoal	Stoves and furnaces	Heat
Fast (flash) pyrolysis	Reactors	Pyrolysis oil (bio-oil), charcoal	Combustion turbines, boilers, diesel engines, furnaces, catalytic reactors	Heat, electricity, synthetic liquid fuels, (BTL)
Anerobic digestion	Digesters, landfills	Biogas (medium Btu gas)	Spark ignition engines, combustion turbines,	Heat, electricity

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://nws.chem.uu.nl/publica/Publicaties%201995/95029.htm

Many biomass fuels cause slagging and other forms of deposit formation during combustion. These deposits can reduce heat transfer, reduce combustion efficiency, and damage combustion chambers when large particles break off. Research has focused on two alkali metals, potassium and sodium, and silica, all elements commonly found in living plants. In general, it appears that faster growing plants (or faster growing plant components such as seeds) tend to have higher concentrations of alkali metal and silica. Thus materials such as straw, nut hulls, fruit pits, weeds, and grasses tend to create more problems when burned than wood from a slow growing tree.

Potassium and sodium metals, whether in the form of oxides, hydroxides, or metallo-organic compounds tend to lower the melting point of ash mixtures containing various other minerals such as silica (SiO2). The high alkali content (up to 35%) in the ash from burning annual crop residues lowers the fusion or 'sticky temperature' of these ashes from 2200' F for wood ash to as low as 1300' F. This results in serious slagging on the boiler grate or in the bed and fouling of convection heat transfer surfaces. Even small percentages (10%) of some of these high alkali residues burned with wood in conventional boilers will cause serious slagging and fouling in a day or two, necessitating combustion system shutdown.

A method to predict slagging and fouling from combustion of biomass fuels has been adapted from the coal industry. The method involves calculating the weight in pounds of alkali (K20 + Na20) per million Btu in the fuel as follows:

$$\frac{1 \times 10^{6}}{\text{Btu/lb}} \times \text{ \% Ash} \times \text{ \% Alkali of the Ash} = \frac{\text{lb Alkali}}{\text{MM Btu}}$$

This method combines all the pertinent data into one Index Number. A value below 0.4lb/MM Btu is considered a fairly low slagging risk. Values between 0.4 and 0.8 lb/MM Btu will probably slag with increasing certainty of slagging as 0.8 lb/MM Btu is approached. Above 0.8 lb/MM Btu, the fuel is virtually certain to slag and foul.

Section: BIOPOWER
Alkali Content and Slagging Potential of Various Biofuels

Fuel	Btu/lb (dry)	Ash %	Total Alkali % in Ash	Total Alkali lb/ton	Total Alkali lb/MMBtu	
WOOD						**Minimal Slagging**
Pine Chips	8,550	0.70%	3.00%	0.4	0.07	**.4 lb/MMBtu**
White Oak	8,165	0.40%	31.80%	2.3	0.14	
Hybrid Poplar	8,178	1.90%	19.80%	7.5	0.46	
Urban Wood Waste "Clean"	8,174	6.00%	6.20%	7.4	0.46	**Probable Slagging**
Tree Trimmings	8,144	3.60%	16.50%	11.9	0.73	
PITS, NUTS, SHELLS						
Almond Shells	7,580	3.50%	21.10%	14.8	0.97	**Certain Slagging**
Refuse Derived Fuel	5,473	9.50%	9.20%	17.5	1.60	
GRASSES						
Switch Grass	7,741	10.10%	15.10%	30.5	1.97	
Wheat Straw-average	7,978	5.10%	31.50%	32.1	2.00	
Wheat Straw-hi alkali	7,167	11.00%	36.40%	80.0	5.59	
Rice Straw	6,486	18.70%	13.30%	49.7	3.80	
Bagasse - washed	8,229	1.70%	12.30%	4.2	0.25	

Source:
Thomas R. Miles, Thomas R. Miles Jr., Larry L. Baxter, Bryan M. Jenkins, Laurance L. Oden. Alkali Slagging Problems with Biomass Fuels, First Biomass Conference of the Americas: Energy, Environment, Agriculture, and Industry, Volume 1, 1993.

Reburning with Wood Fuels for NOx Mitigation

Reburning is a combustion modification technology based on the principle that hydrocarbon fragments (CH) can react with Nitrogen Oxides (NOx). Reburning is accomplished by secondary fuel injection downstream of the fuel-lean primary combustion zone or a furnace. The second stage or reburning zone is usually operated at an overall fuel-rich condition, allowing a significant fraction of the primary NOx to be reduced to N2 and other nitrogenous species. In the third zone, additional air is introduced to establish overall fuel-lean conditions and allow for the burnout of remaining fuel fragments.

Reburning studies with coal and natural gas have shown NOx emission reductions of 50-60% with about 15% of the heat input coming from the reburn fuel. In contrast, experimental results have shown NOx reductions as high as 70% using approximately 10-15% wood heat input.

The stoichiometric ratio in the reburn zone was the single most important variable affecting NOx reduction. The highest reductions were found at a reburn stoichiometric ratio of 0.85.

One additional benefit of using wood instead of natural gas for reburning—it is difficult to mix natural gas into the products of the primary combustion zone since the gas must be injected from the wall, at relatively low flows. Wood particles, which must be transported to the furnace by a carrier medium (likely candidates are air or flue gas), would have a ballistic effect upon entering the furnace that would enhance cross-stream mixing compared to natural gas.

Source: Brouwer, J., N.S. Harding, M.P. Heap, J.S. Lighty, and D.W. Pershing, 1997, *An Evaluation of Wood Reburning for NOx Reduction from Stationary Sources*, final report to the DOE/TVA Southeastern Regional Biomass Energy Program, Muscle Shoals, AL, Contract No. TV-92271 (available at www.bioenergyupdate.com).

Section: BIOPOWER

Carbon Dioxide Uncontrolled Emission Factors

(Pounds of CO_2 per Million Btu)

Fuel And EIA Fuel Code	Factor[a]
Bituminous Coal	205.573
Distillate Fuel Oil	161.386
Geothermal	16.600
Jet Fuel	156.258
Kerosene	159.535
Lignite Coal	215.070
Municipal Solid Waste	91.900
Natural Gas	117.080
Petroleum Coke	225.130
Propane Gas	139.178
Residual Fuel Oil	173.906
Synthetic Coal	205.573
Subbituminous Coal	214.212
Tire-Derived Fuel	189.538
Waste Coal	205.573
Waste Oil	210.000

Source:

U.S. Department of Energy, Energy Information Administration, *Electric Power Annual 2009*, Washington, D.C., Revised January, 2011. Web site: http://www.eia.gov/cneaf/electricity/epa/epata3.html

[a] CO_2 factors do not vary by combustion system type or boiler firing configuration.

Nitrogen Oxides Uncontrolled Emission Factors

Fuel And EIA Fuel Code	Emissions Units	Combustion System Type/Firing Configuration							
		Cyclone Boiler	Fluidized Bed Boiler	Opposed Firing Boiler	Spreader Stoker Boiler	Tangential Boiler	All Other Boiler Types	Combustion Turbine	Internal Combustion Engine
Agricultural Byproducts	Lbs per ton	1.2	1.2	1.2	1.2	1.2	1.2	NA	NA
Blast Furnace Gas	Lbs per MMCF	15.4	15.4	15.4	15.4	15.4	15.4	30.4	256.55
Bituminous Coal	Lbs per ton	33	5	12 [31]	11	10.0 [14.0]	12.0 [31.0]	NA	NA
Black Liquor	Lbs per ton[a]	1.5	1.5	1.5	1.5	1.5	1.5	NA	NA
Distillate Fuel Oil	Lbs per MG	24	24	24	24	24	24	122	443.8
Jet Fuel	Lbs per MG	24	24	24	24	24	24	118	432
Kerosene	Lbs per MG	24	24	24	24	24	24	118	432
Landfill Gas	Lbs per MMCF	72.44	72.44	72.44	72.44	72.44	72.44	144	1215.22
Lignite Coal	Lbs per ton	15	3.6	6.3	5.8	7.1	6.3	NA	NA
Municipal Solid Waste	Lbs per ton	5	5	5	5	5	5	NA	NA
Natural Gas	Lbs per MMCF	280	280	280	280	170	280	328	2768
Other Biomass Gas	Lbs per MMCF	112.83	112.83	112.83	112.83	112.83	112.83	313.6	2646.48
Other Biomass Liquids	Lbs per MG	19	19	19	19	19	19	NA	NA
Other Biomass Solids	Lbs per ton	2	2	2	2	2	2	NA	NA
Other Gases	Lbs per MMCF	152.82	152.82	152.82	152.82	152.82	152.82	263.82	2226.41
Other	Lbs per MMCF	280	280	280	280	170	280	328	2768
Petroleum Coke	Lbs per ton	21	5	21	21	21	21	NA	NA
Propane Gas	Lbs per MMCF	215	215	215	215	215	215	330.75	2791.22
Residual Fuel Oil	Lbs per MG	47	47	47	47	32	47	NA	NA
Synthetic Coal	Lbs per ton	33	5	12 [31]	11	10.0 [14.0]	12.0 [31.0]	NA	NA
Sludge Waste	Lbs per ton[a]	5	5	5	5	5	5	NA	NA
Subbituminous Coal	Lbs per ton	17	5	7.4 [24]	8.8	7.2	7.4 [24.0]	NA	NA
Tire-Derived Fuel	Lbs per ton	33	5	12 [31]	11	10.0 [14.0]	12.0 [31.0]	NA	NA
Waste Coal	Lbs per ton	15	3.6	6.3	5.8	7.1	6.3	NA	NA
Wood Waste Liquids	Lbs per MG	5.43	5.43	5.43	5.43	5.43	5.43	NA	NA
Wood Waste Solids	Lbs per ton	2.51	2	2.51	1.5	2.51	2.51	NA	NA
Waste Oil	Lbs per MG	19	19	19	19	19	19	NA	NA

Source:
U.S. Department of Energy, Energy Information Administration, Electric Power Annual 2009, Washington, D.C., November 2010. Web site: http://www.eia.gov/cneaf/electricity/epa/epata2.html

Note:
Factors for Wet-Bottom Boilers are in Brackets; All Other Boiler Factors are for Dry-Bottom
Units: Lbs = pounds; MMCF = million cubic feet; MG = thousand gallons
[a]Although Sludge Waste and Black Liquor consist substantially of liquids, these fuels are measured and reported to EIA in tons.

Section: BIOPOWER
Sulfur Dioxide Uncontrolled Emission Factors

Fuel And EIA Fuel Code	Emissions Units	Combustion System Type/Firing Configuration							
		Cyclone Boiler	Fluidized Bed Boiler	Opposed Firing Boiler	Spreader Stoker Boiler	Tangential Boiler	All Other Boiler Types	Combustion Turbine	Internal Combustion Engine
Agricultural Byproducts	Lbs per ton	0.08	0.01	0.08	0.08	0.08	0.08	NA	NA
Blast Furnace Gas	Lbs per MMCF	0.60	0.06	0.60	0.60	0.60	0.60	0.60	0.60
Bituminous Coal[a]	Lbs per ton	38.00	3.80	38.00	38.00	38.00	38.00	NA	NA
Black Liquor	Lbs per ton[b]	7.00	0.70	7.00	7.00	7.00	7.00	NA	NA
Distillate Fuel Oil[a]	Lbs per MG	157.00	15.70	157.00	157.00	157.00	157.00	140.00	140.00
Jet Fuel[a]	Lbs per MG	157.00	15.70	157.00	157.00	157.00	157.00	140.00	140.00
Kerosene[a]	Lbs per MG	157.00	15.70	157.00	157.00	157.00	157.00	140.00	140.00
Landfill Gas	Lbs per MMCF	0.60	0.06	0.60	0.60	0.60	0.60	0.60	0.60
Lignite Coal[a]	Lbs per ton	30.00	3.00	30.00	30.00	30.00	30.00	NA	NA
Municipal Solid Waste	Lbs per ton	1.70	0.17	1.70	1.70	1.70	1.70	NA	NA
Natural Gas	Lbs per MMCF	0.60	0.06	0.60	0.60	0.60	0.60	0.60	0.60
Other Biomass Gas	Lbs per MMCF	0.60	0.06	0.60	0.60	0.60	0.60	0.60	0.60
Other Biomass Liquids[a]	Lbs per MG	157.00	15.70	157.00	157.00	157.00	157.00	140.00	140.00
Other Biomass Solids	Lbs per ton	0.23	0.02	0.23	0.23	0.23	0.23	NA	NA
Other Gases	Lbs per MMCF	0.60	0.06	0.60	0.60	0.60	0.60	0.60	0.60
Other	Lbs per MMCF	0.60	0.06	0.60	0.60	0.60	0.60	0.60	0.60
Petroleum Coke[a]	Lbs per ton	39.00	3.90	39.00	39.00	39.00	39.00	NA	NA
Propane Gas	Lbs per MMCF	0.60	0.06	0.60	0.60	0.60	0.60	0.60	0.60
Residual Fuel Oil[a]	Lbs per MG	157.00	15.70	157.00	157.00	157.00	157.00	NA	NA
Synthetic Coal[a]	Lbs per ton	38.00	3.80	38.00	38.00	38.00	38.00	NA	NA
Sludge Waste	Lbs per ton[b]	2.80	0.28	2.80	2.80	2.80	2.80	NA	NA
Subbituminous Coal[a]	Lbs per ton	35.00	3.50	35.00	38.00	35.00	35.00	NA	NA
Tire-Derived Fuel[a]	Lbs per ton	38.00	3.80	38.00	38.00	38.00	38.00	NA	NA
Waste Coal[a]	Lbs per ton	30.00	3.00	30.00	30.00	30.00	30.00	NA	NA
Wood Waste Liquids[a]	Lbs per MG	157.00	15.70	157.00	157.00	157.00	157.00	140.00	140.00
Wood Waste Solids	Lbs per ton	0.29	0.08	0.29	0.08	0.29	0.29	NA	NA
Waste Oil[a]	Lbs per MG	147.00	14.70	147.00	147.00	147.00	147.00	NA	NA

Source:
U.S. Department of Energy, Energy Information Administration, Electric Power Annual 2009, Washington, D.C., Revised: January 2011. Web site: http://www.eia.gov/cneaf/electricity/epa/epata1.html

Note:
Units: Lbs = pounds; MMCF = million cubic feet; MG = thousand gallons.

[a]For these fuels, emissions are estimated by multiplying the emissions factor by the physical volume of fuel and the sulfur percentage of the fuel (other fuels do not require the sulfur percentage in the calculation).

[b]Although Sludge Waste and Black Liquor consist substantially of liquids, these fuels are measured and reported to EIA in tons.

For the purpose of agricultural soil amendment, wood ash application is similar to lime application. Both materials can benefit crop productivity but wood ash has an added advantage of supplying additional nutrients. Both materials are also alkaline and could cause crop damage if over applied or misused.

Section: BIOPOWER

Range in Elemental Composition of Industrial Wood Ash Samples and Ground Limestone

Element	Wood Ash[a]	Limestone
Macroelements	**Concentration in %**	
Calcium	15 (2.5-33)	31.00
Potassium	2.6 (0.1-13)	0.13
Aluminum	1.6 (0.5-3.2)	0.25
Magnesium	1.0 (0.1-2.5)	5.10
Iron	0.84 (0.2-2.1)	0.29
Phosphorus	0.53 (0.1-1.4)	0.06
Manganese	0.41 (0-1.3)	0.05
Sodium	0.19 (0-0.54)	0.07
Nitrogen	0.15 (0.02-0.77)	0.01
Microelements	**Concentration in mg/kg**	
Arsenic	6 (3-10)	.
Boron	123 (14-290)	.
Cadmium	3 (0.2-26)	0.7
Chromium	57 (7-368)	6.0
Copper	70 (37-207)	10.0
Lead	65 (16-137)	55.0
Mercury	1.9 (0-5)	.
Molybdenum	19 (0-123)	.
Nickel	20 (0-63)	20.0
Selenium	0.9 (0-11)	.
Zinc	233 (35-1250)	113.0
Other Chemical Properties		
$CaCO_3$ Equivalent	43% (22-92%)	100%
pH	10.4 (9-13.5)	9.9
% Total solids	75 (31-100)	100.0

Source:

Risse, Mark, and Glen Harris. Soil Acidity and Liming Internet Inservice Training Website: "Best Management Practices for Wood Ash Used as an Agricultural Soil Amendment." Website accessed 09/20/11.
http://hubcap.clemson.edu/~blpprt/bestwoodash.html

[a] Mean and (Range) taken from analysis of 37 ash samples.

Section: BIOPOWER
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
Co-firing: pulverized coal boiler	Sawdust, non-stringy bark, shavings, flour, sander dust	<0.25 in (<6 mm)	< 25%	Up to 1500 MWee Example
Co-firing: cyclones	Sawdust, non-stringy bark, shavings, flour, sander dust	<0.5 in (<12 mm)	10 – 50%	40 to 1150 MWee Example
Co-firing: stokers, fluidized bed	Sawdust, non-stringy bark, shavings, flour, hog fuel	< 3 in (<72 mm)	10 – 50%	MWee 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
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
Fast pyrolysis	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

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

[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.

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 a majority of customer respondents is 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.

Section: BIOPOWER

Renewable Energy Generation and Capacity Supplying Green Pricing Programs, 2009

Source	Sales MWh	Percentage of Total Sales	Total MW	MW New Renewable
Wind	4,434,400	85.9%	1,534	1,472
Landfill gas	**353,400**	**6.8%**	**45**	**42**
Other biomass	**248,600**	**4.8%**	**35**	**35**
Solar	18,875	0.4%	14	13
Geothermal	45,000	0.9%	5	5
Hydro	63,100	1.2%	18	17
Unknown	1,700	0.0%	1	-
Total	**5,165,075**	**100.0%**	**1,652**	**1,584**

Source:

Green Power Marketing in the United States: A Status Report (2009 Data) Table 11
http://www.nrel.gov/docs/fy11osti/49403.pdf

Notes:

MW=megawatt
MWh=megawatt-hour

An estimated 24.8 billion kWh of renewable energy was sold to retail customers by competitive green power and REC marketers in 2009. This figure includes renewable energy from both pre-existing and new sources. In 2009, about 83% of the REC and green power competitive-market retail kilowatt-hour sales were supplied from new renewable energy sources.

Section: BIOPOWER

Renewable Energy Sources Supplying Competitive and REC Markets, 2009

Source	MWh Sales	Percentage of Total Sales	Total MW	MW New Renewable
Wind	17,683,000	71.2%	6,120	5,680
Biomass/Landfill gas	**2,391,000**	**9.6%**	**320**	**260**
Solar	28,000	0.1%	20	20
Geothermal	48,000	0.2%	10	10
Hydro	2,912,000	11.7%	830	420
Unknown	1,783,000	7.2%	410	-
Total	**24,845,000**	**100.0%**	**7,710**	**6,390**

Source:

Green Power Marketing in the United States: A Status Report (2009 Data) Table 16.
http://www.nrel.gov/docs/fy11osti/49403.pdf

Notes:

REC=Renewable Energy Certificate
MW=megawatt
MWh=megawatt-hour

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

Section: BIOPOWER

Utility Green Pricing Programs Using Biomass and Biomass Based Resources

(Updated August 2011)

State	Program Name	Type	Start Date	Premium
AL	Renewable Energy Rate	biomass co-firing (wood)	2003/2000	4.5¢/kWh
AL	Green Power Choice	landfill gas	2006	2.0¢/kWh
AL	Green Power Switch	landfill gas, PV, wind	2000	2.67¢/kWh
AK	Sustainable Natural Alternative Power (SNAP)	various local projects	2005	Contribution
AZ	Green Choice	wind and geothermal	2007	0.4¢/kWh
AZ	EarthWise Energy	central PV, wind, landfill gas, small hydro, geothermal	1998/2001	3.0¢/kWh
AZ	Renewable Resource Power Service	wind, hydro	2001	0.8¢/kWh
AZ	GreenWatts	landfill gas, PV	2000	10¢/kWh
AZ	GreenWatts	PV	2004	10¢/kWh
AR	ECA Green Power	hydro	2008	5.0¢/kWh
CA	Sun Power for the Schools	PV	2002	Contribution
CA	Green Power for the Grid	wind, landfill gas	2002	1.5¢/kWh
CA	Green Energy Champion	various	2007	2.0¢/kWh
CA	Green Power for a Green LA	wind, landfill gas	1999	3.0¢/kWh
CA	Light Green	25% renewable	2008	0.0¢/kWh
CA	Deep Green	100% renewable	2010	1.0¢/kWh
CA	Blue Sky Block	wind	2000	1.95¢/kWh
CA	Palo Alto Green	wind, PV	2003 / 2000	1.5¢/kWh
CA	Green Power	wind	2003	2.5¢/kWh
CA	Green Roseville	wind, PV	2005	1.5¢/kWh
CA	Greenergy	wind, landfill gas, hydro, PV	1997	1.0¢/kWh or $6/month
CA	SolarShares	PV	2007	5.0¢kWh or $30/month
CA	Santa Clara Green Power	wind, PV	2004	1.5¢/kWh
CA	Voluntary Renewable Energy Certificates Program	wind	2008	2.0¢/kWh
CO	Green Power	wind	1999	3.0¢/kWh
CO	Renewable Energy Certificates Program	wind and geothermal	2008	0.34¢/kWh
CO	Wind Power Pioneers	wind	1998	1.5¢/kWh
CO	Local Renewable Energy Pool	small hydro, PV	2002	2.33¢/kWh
CO	National Wind	wind	2006	1.0¢/kWh
CO	National Solar	solar	2006	5.5¢/kWh
CO	Wind Energy Premium	wind	1999	1.0¢/kWh-2.5¢/kWh
CO	Renewable Resource Power Service	wind, hydro	1998	0.8¢/kWh
CO	Renewable Energy Trust	PV	1993	Contribution
CO	WindSource	wind	1997	-0.67¢/kWh
CO	Wind Energy Program	wind	1999	0.6¢/kWh
DE	Renewable Energy Rider	landfill gas	2006	0.2¢/kWh
FL	Green for You	biomass, PV	2002	1.6¢/kWh
FL	Green for You	PV only	2002	11.6¢/kWh
FL	GRUgreen Energy	landfill gas, wind, PV	2003	2.0¢/kWh
FL	GO GREEN: USA Green	wind, biomass,PV	2004	1.60¢/kWh
FL	GO GREEN: Florida Ever Green	solar hot water, PV, biomass	2004	2.75¢/kWh
FL	Green Power Choice	landfill gas	2006	2.0¢/kWh
FL	Renewable Energy	PV, landfill, biomass co-firing (wood)	2001	2.5¢/kWh

Continued on next page

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

State	Program Name	Type	Start Date	Premium
FL	Green Fund	local PV projects	1999	Contribution
GA	Green Power EMC	landfill gas, PV in schools	2001	2.0¢/kWh-3.3¢/kWh
GA	Green Energy	landfill gas, solar	2006	3.5¢/kWh
GA	Green Power Switch	landfill gas, PV, wind	2000	2.67¢/kWh
HI	Sun Power for Schools	PV in schools	1997	Contribution
HI	Green Rate	distributed renewable energy systems	TBD	TBD
ID	Buck-A-Block	wind	2002	0.33¢/kWh
ID	Green Power Program	various	2001	0.98¢/kWh
ID	Blue Sky	wind	2003	0.71¢/kWh-1.94¢/kWh
ID	Alternative Renewable Energy Program	wind	2003	1.1¢/kWh
IL	Renewable Energy Option	wind, small hydro, PV	2005	2.5¢/kWh
IL	Green Power Program	wind, landfill gas	2003	1.2¢/kWh
IL	Evergreen Renewable Energy Program	landfill gas, biogas, hydro, wind	1997	1.5¢/kWh
IL	EnviroWatts	wind, landfill gas	2000	0.9¢/kWh-1.0¢/kWh
IN	GoGreen Power	wind, PV, landfill gas, digester gas	2001	2.5¢/kWh
IN	EnviroWatts	landfill gas	2001	2.0¢/kWh-4.0¢/kWh
IN	Green Power Option	wind	1998	0.35¢/kWh
IN	EnviroWatts	wind, landfill gas	2000	0.9¢/kWh-1.0¢/kWh
IA	Second Nature	landfill gas, wind	2001	2.0¢/kWh
IA	varies by utility	biomass, wind	2003	2.0¢/kWh-3.5¢/kWh
IA	Prairie Winds	wind	2000	0.5¢/kWh
IA	Harvest the Wind	wind	2000	2.5¢/kWh
IA	Wind Power	wind	2006	1.5¢/kWh-2.5¢/kWh
IA	Energy Wise Renewables	wind	2003	1.5¢/kWh
IA	Evergreen Renewable Energy Program	hydro, wind, landfill gas, biogas	1998	3.0¢/kWh
IA	Green Power Project	biodiesel, wind	2004	Contribution
IA	Green City Energy	wind, biomass, PV	2003	Varies by utility
IA	Renewable Advantage	wind	2004	Contribution
IA	RiverWinds	wind	2003	2.0¢/kWh-2.5¢/kWh
IA	Solar Muscatine	PV	2004	Contribution
IA	Green Power Choice	wind	2003	Contribution
IA	Iowa Energy Tags	wind	2001	2.0¢/kWh
KY	Renewable Resources Energy (EnviroWatts)	100% biomass	2007	3.65¢/kWh
KY	Green Energy	100% KY Low Impact Hydro Institute-Certified hydro	2007	1.3¢/kWh-1.67¢/kWh
KY	EnviroWatts	landfill gas	2002	2.75¢/kWh
KY	Green Power Switch	landfill gas, PV, wind	2000	2.67¢/kWh
LA	Green Pricing Program	biomass	2007	2.5¢/kWh
MA	BGreen	solar and wind	2009	2.0¢/kWh
MA	Green Power	hydro	2004	3.0¢/kWh
MA	NSTAR Green	wind	2008	0.8¢/kWh-1.45¢/kWh
MA	SELCO GreenLight	wind	2007	6.67¢/kWh
MI	Green Generation	68% wind, 32% landfill gas	2005	1.67¢/kWh
MI	GreenCurrents	wind, biomass	2007	2.0¢/kWh-2.5¢/kWh
MI	GreenWise Electric Power	landfill gas, small hydro	2001	3.0¢/kWh
MI	NatureWise	wind, landfill gas and animal waste methane	2004	1.4¢/kWh
MI	EnviroWatts	wind, landfill gas	2000	0.9¢/kWh-1.0¢/kWh

Continued on next page

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

State	Program Name	Type	Start Date	Premium
MI	Energy for Tomorrow	wind, landfill gas, hydro	2000	2.04¢/kWh
MN	Second Nature	landfill gas, wind	2002	2.0¢/kWh
MN	Prairie Winds	wind	2002	0.5¢/kWh
MN	Green Energy Program	wind, landfill gas	2000	1.5¢/kWh-2.5¢/kWh
MN	Evergreen Renewable Energy Program	hydro, wind, landfill gas, biogas	1998	1.5¢/kWh
MN	Wellspring Renewable Wind Energy Program	wind	1998	1.55¢/kWh-2.0¢/kWh
MN	WindSense	wind	2002	2.5¢/kWh
MN	Infinity Wind Energy	wind	1999	0.5¢/kWh
MN	RiverWinds	wind	2002	2.0¢/kWh-2.5¢/kWh
MN	Capture the Wind	wind	1998	1.5¢/kWh
MN	TailWinds	wind	2002	1.6¢/kWh
MN	WindSource	wind	2003	2.0¢/kWh
MS	Green Power Switch	landfill gas, PV, wind	2000	2.67¢/kWh
MO	Pure Power	75% wind, 25% other renewables	2007	1.5¢/kWh
MO	varies by utility	biomass, wind	2003	2.0¢/kWh-3.5¢/kWh
MO	WindCurrent	wind	2000	5.0¢/kWh
MO	EnviroWatts	wind, landfill gas	2000	0.9¢/kWh-1.0¢/kWh
MT	Prairie Winds	wind	2000	0.5¢/kWh
MT	E+ Green	wind, PV	2003	2.0¢/kWh
MT	Green Power Program	various renewables	2002	1.02¢/kWh
MT	Environmentally Preferred Power	wind, hydro	2002	1.05¢/kWh
MT	Renewable Resource Power Service	wind, hydro	2001	0.8¢/kWh
MT	Alternative Renewable Energy Program	wind	2003	1.1¢/kWh
NC	NC GreenPower	biomass, hydro, landfill gas, PV, wind	2003	2.5¢/kWh-4.0¢/kWh
NC	Green Power Switch	landfill gas, PV, wind	2000	2.67¢/kWh
ND	PrairieWinds	wind	2000	0.5¢/kWh
ND	Infinity Wind Energy	wind	1999	0.5¢/kWh
ND	RiverWinds	wind	2002	2.0¢/kWh-2.5¢/kWh
NE	Green Power Program	landfill gas, wind	2002	3.0¢/kWh
NE	Renewable Resource Power Service	wind, hydro	2001	0.8¢/kWh
NV	GreenWay	various	2005	1.95¢/kWh
NV	Desert Research Institute's GreenPower Program	PV on schools	Unknown	Contribution
NM	Renewable Energy Tariff	wind	2003	2.28¢/kWh
NM	Green Power	wind	2005	1.8¢/kWh
NM	Voluntary Renewable Energy Program	TBD	2008	4.0¢/kWh
NM	PNM Sky Blue	wind	2003	1.1¢/kWh
NM	Renewable Resource Power Service	wind, hydro	2001	0.4¢/kWh-2.5¢/kWh
NM	WindSource	wind	1999	3.0¢/kWh
OH	Nature's Energy	small hydro, landfill gas, wind	2003	1.3¢/kWh-1.5¢/kWh
OH	EnviroWatts	landfill gas	2006	2.0¢/kWh
OH	Green Connect	various	2008	1.0¢/kWh
OH	GoGreen Power	wind, PV, landfill gas, digester gas	2001	2.5¢/kWh

Continued on next page

Utility Green Pricing Programs Using Biomass and Biomass Based Resources

(Continued)

State	Program Name	Type	Start Date	Premium
OH	Green Resource Program	various	2007	0.5¢/kWh
OH	EnviroWatts	wind, landfill gas	2000	0.9¢/kWh-1.0¢/kWh
OK	varies by utility	biomass, wind	2003	2.0¢/kWh-3.5¢/kWh
OK	OG&E Wind Power	wind	2003	-0.246¢/kWh
OK	Pure & Simple	wind	2004	1.8¢/kWh (-0.45¢/kWh Edmond)
OK	WindChoice	100% wind	2011	1.72¢/kWh
OK	WindWorks	wind	2004	0.5¢/kWh
OR	Renewable Pioneers	PV, wind	2003	2.0¢/kWh
OR	Choice Energy	wind	2005	1.5¢/kWh
OR	Choose Renewable Electricity	wind, geothermal	2003	1.2¢/kWh
OR	EWEB Greenpower	various renewables	2007	1.0¢/kWh-1.5¢/kWh
OR	EWEB Wind Power	wind	1999	0.91¢/kWh
OR	Green Power Program	various	2001	0.98¢/kWh
OR	Environmentally-Preferred Power	wind	1999	2.5¢/kWh
OR	Green Power	wind	2002	1.5¢/kWh
OR	Blue Sky QS (Commercial Only)	wind	2004	Sliding scale depending on size
OR	Blue Sky Block	wind	2000	1.95¢/kWh
OR	Blue Sky Habitat	wind, biomass, PV	2002	0.78¢/kWh + $2.50/mo. donation
OR	Blue Sky Usage	wind, biomass, PV	2002	0.78¢/kWh
OR	Green Power	landfill gas	1998	1.8¢/kWh-2.0¢/kWh
OR	Clean Wind for Medium to Large Commercial & Industrial Accounts	wind	2003	1.7¢/kWh
OR	Clean Wind Power	wind	2002	1.75¢/kWh
OR	Green Source	existing geothermal, hydro, new wind	2002	0.8¢/kWh
OR	Renewable Future	wind	2007	1.5¢/kWh
OR	ECOchoice	various	2007	1.0¢/kWh
SC	Palmetto Clean Energy (PaCE)	wind, solar, landfill gas	2008	4.0¢s;/kWh
SC	Green Power Program	landfill gas	2001	3.0¢/kWh
SD	Prairie Winds	wind	2000	0.5¢/kWh
SD	RiverWinds	wind	2002	2.0¢/kWh-2.5¢/kWh
SD	Renewable Resource Power Service	wind, hydro	2001	0.8¢/kWh
TN	Green Power Switch	landfill gas, PV, wind	2000	2.67¢/kWh
TX	GreenChoice	wind, landfill gas	2000/1997	1.85¢/kWh
TX	Choose-To-Renew	wind, hydro	2005	-0.114¢/kWh
TX	Windtricity	wind	2000	3.0¢/kWh
TX	Wind Watts (10%/50%/100%)	new wind	2009	TBD
TX	Renewable Energy Tariff	wind	2001	1.92¢/kWh
TX	Renewable Power	wind, hydro	2006	0.5¢/kWh
UT	Clean Green Power	wind, small hydro	2005	2.95¢/kWh
UT	GreenWay	various	2004	1.95¢/kWh
UT	Blue Sky	wind	2003	0.71¢/kWh-1.94¢/kWh
UT	Blue Sky	wind	2000	1.95¢/kWh
UT	Renewable Resource Power Service	wind, hydro	2001	0.8¢/kWh

Continued on next page

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

State	Program Name	Type	Start Date	Premium
VT	CVPS Cow Power	biogas	2004	4.0¢/kWh
VT	CoolHome / CoolBusiness	wind, biomass	2002	Contribution
VT	Greener GMP	various renewables	2006	3.0¢/kWh
VA	Green Pricing Option	low impact hydro	2009	1.5¢/kWh
VA	Dominion Green Power	biomass, low-impact hydro, solar, wind	2009	1.5¢/kWh
WA	Buck-A-Block	wind	2002	0.33¢/kWh
WA	Green Power Program	landfill gas, wind, hydro	1999	Contribution
WA	Sustainable Natural Alternative Power (SNAP)	PV, wind, micro hydro	2001	Contribution
WA	Clallam County PUD Green Power Program	landfill gas	2001	0.69¢/kWh
WA	Green Lights	PV, wind	2002	1.5¢/kWh
WA	Renewable Resource Energy	wind, PV	2002	2.0¢/kWh
WA	Alternative Energy Resources Program	wind	2002	2.0¢/kWh
WA	Green Power	wind	2002	3.0¢/kWh
WA	Green Power Energy Rate	wind	2003	2.0¢/kWh
WA	Mason Evergreen Power	wind	2003	1.0¢/kWh
WA	Pure Power	wind	2007	2.5¢/kWh
WA	Go Green	wind, hydro	1999	3.5¢/kWh
WA	Green Power	landfill gas	2002	1.05¢/kWh
WA	Blue Sky Block	wind	2000	1.95¢/kWh
WA	Green by Choice	wind, hydro, biogas	2002	2.0¢/kWh
WA	Green Power Program	wind, PV, biogas	2002	1.25¢/kWh
WA	Seattle Green Power	PV, biogas	2002	Contribution
WA	Green Up	wind	2005	1.5¢/kWh
WA	Planet Power	wind	2002	2.0¢/kWh
WA	EverGreen Options	wind	2000	1.2¢/kWh
WV	Green Pricing Option	wind and hydro	2008	1.5¢/kWh
WI	Second Nature	wind, landfill gas	2000	2.0¢/kWh
WI	Evergreen Renewable Energy Program	hydro, wind, landfill gas, biogas	1998	1.5¢/kWh
WI	Wellspring Renewable Wind Energy Program	wind	1997	1.45¢/kWh-2.0¢/kWh
WI	Green Power Tomorrow	wind	1999	1.0¢/kWh
WI	Renewable Energy Program	small hydro, wind, biogas	2001	1.0¢/kWh
WI	Energy for Tomorrow	landfill gas, PV, hydro, wind	1996	1.37¢/kWh
WI	Solar Wise for Schools	PV in schools	1996	Contribution
WI	NatureWise	wind, landfill gas, biogas	2002	1.25¢/kWh
WY	Prairie Winds	wind	2000	0.5¢/kWh
WY	Renewable Premium Program	99% new wind, 1% new solar	2006	3.5¢/kWh
WY	Green Power	wind	2003	1.167¢/kWh
WY	Blue Sky	wind	2000	1.95¢/kWh
WY	Renewable Resource Power Service	wind, hydro	2001	0.8¢/kWh
WY	Wind Energy Program	wind	1999	0.6¢/kWh

Source: National Renewable Energy Laboratory, Golden, Colorado.
http://apps3.eere.energy.gov/greenpower/markets/pricing.shtml?page=1

Note: Utility green pricing programs may only be available to customers located in the utility's service territory.

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.

Section: BIOPOWER

Competitive Electricity Markets Retail Green Power Product Offerings[a], August 2010

State	Company	Product Name	Resource Mix[b]	Certification
Connecticut	CL&P/United Illuminating/Community Energy (CT Clean Energy Options Program)	New Wind Energy/Landfill Gas 50% or 100% of usage	50% new wind, 50% landfill gas	—
	CL&P/United Illuminating/Sterling Planet (CT Clean Energy Options Program)	Sterling Select 50% or 100% of usage	33% new wind, 33% small hydro, 34% landfill gas	—
Maine	Kennebunk Light and Power District	Village Green	hydro, landfill gas	—
Maryland	PEPCO Energy Services	Green Electricity 100% of usage	landfill gas	—
Massachusetts	Cape Light Compact	Cape Light Compact Green 50% or 100%*	75% small hydro, 24% new wind or landfill gas, 1% new solar	—
	Massachusetts Electric/Nantucket Electric/Clear Sky Power[d]	Clear Sky Home*	100% biomass	—
	Massachusetts Electric/Nantucket Electric/Mass Energy Consumers Alliance	New England GreenStart 50% or 100% of usage*	75% small hydro, 25% new biomass, wind and solar	—
	Massachusetts Electric/Nantucket Electric/Sterling Planet[d]	MA Clean Choice*	33% new wind, 33% new landfill gas, 33% small hydro	Environmental Resources Trust
New Jersey	PSE&G/JCP&L/Atlantic City Electric/Rockland Electric/Sterling Planet	NJ Clean Power Choice - Sterling Select	33% wind, 33% small hydro, 34% landfill gas	Environmental Resources Trust
New York	BlueRock Energy	Green Power (10%/50%/100%)	biomass, small and low-impact hydro	—
	Energy Cooperative of New York[e]	Renewable Electricity	25% new wind, 75% landfill gas	—
	Long Island Power Authority / EnviroGen	Green Power Program	75% landfill gas, 25% small hydro	—
	Long Island Power Authority / Sterling Planet	New York Clean	55% small hydro, 35% bioenergy, 10% wind	Environmental Resources Trust
	Long Island Power Authority / Sterling Planet	Sterling Green	40% new wind, 30% small hydro, 30% bioenergy	Environmental Resources Trust
	National Grid / EnviroGen	Think Green!	75% landfill gas, 25% low impact hydro	—
	Sterling Planet	NY Clean Choice	40% new wind, 30% small hydro, 30% bioenergy	Environmental Resources Trust
	Suburban Energy Services /Sterling Planet	Sterling Green Renewable Electricity	40% new wind, 30% small hydro, 30% bioenergy	Environmental Resources Trust

Continued on next page

Competitive Electricity Markets Retail Green Power Product Offerings as of August 2010
(continued)

Pennsylvania	Energy Cooperative of Pennsylvania	EcoChoice 100	89% landfill gas, 10% wind, 1% solar	—
	UGI Utilities	Renewable Residential Service - Alternative Energy (50% or 100% of usage)	100% MSW, waste coal, wood pulp	—
Rhode Island	Narragansett Electric / Clear Sky Power	Clear Sky Home	100% new bioenergy	—
	Narragansett Electric / People's Power and Light	New England GreenStart RI 50% or 100% of usage	70% small hydro, 17% bioenergy, 13% wind and solar	—
	Narragansett Electric / Sterling Planet	Sterling Supreme 100%	40% small hydro, 25% biomass, 25% new solar, 10% new wind	Environmental Resources Trust

Source:
National Renewable Energy Laboratory, *The Green Power Network*
http://apps3.eere.energy.gov/greenpower/markets/marketing.shtml?page=1

[a] As product prices fluctuate, please contact the listed marketers to get accurate price quote for products.
[b] New is defined as operating or repowered after January 1, 1997 based on the Green-e standard.
[c] Offered in PEPCO service territory.
[d] Products are only available in the National Grid service territory.
[e] Offered in Niagra Mohawk and NYSEG service territories.
[*] The Massachusetts Technology Collaborative's Clean Energy Choice (CEC) program provides local matching grants for clean energy projects for residents who make a voluntary offering.

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.

Section: BIOPOWER
National Retail Renewable Energy Certificate Product Offerings, August 2010

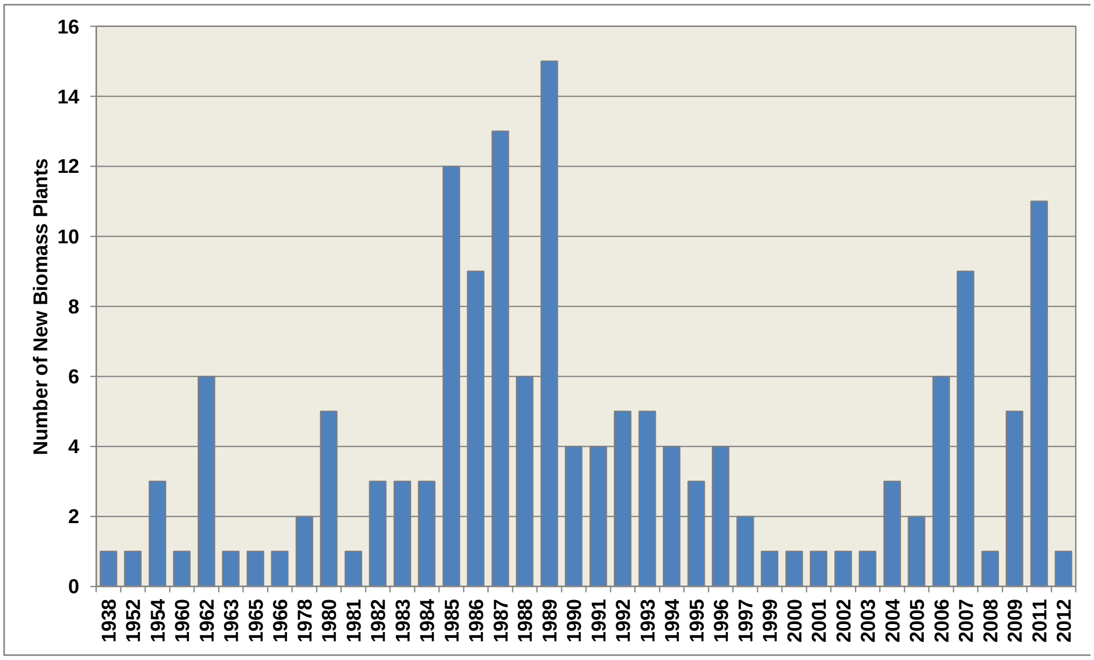
Certificate Marketer	Product Name	Renewable Resources	Location of Renewable Resources	Residential Price Premium*	Certification
3 Phases Renewables	Green Certificates	100% biomass, geothermal, hydro, solar, wind	Nationwide	1.2¢/kWh	Green-e
3Degrees	National Renewable Energy Certificates	100% wind, solar, geothermal, low-impact hydro, biogas, biomass	Nationwide	0.5¢/kWh-1.5¢/kWh	Green-e
NativeEnergy	Remooable Energy	100% new biogas	Pennsylvania	0.8¢/kWh-1.0¢/kWh	**
Carbon Solutions Group	CSG CleanBuild	biomass, biogas, wind, solar, hydro	Nationwide	0.9¢/kWh	Green-e
GP Renewables & Trading LLC	GP-REC Structured Product	solar, hydro, biomass, landfill gas, energy efficiency	Localized by state and region	0.2¢/kWh	—
Green Mountain Energy	BeGreen RECs	wind, solar, biomass	Nationwide	1.4¢/kWh	—
Santee Cooper	SC Green Power	landfill gas, solar	South Carolina	3.0¢/kWh	Green-e
Village Green Energy	Village Green Power	solar, wind, biogas	California, Nationwide	2.0¢/kWh-2.5¢/kWh	Green-e

Source:
National Renewable Energy Laboratory, *The Green Power Network*
http://apps3.eere.energy.gov/greenpower/markets/certificates.shtml?page=1

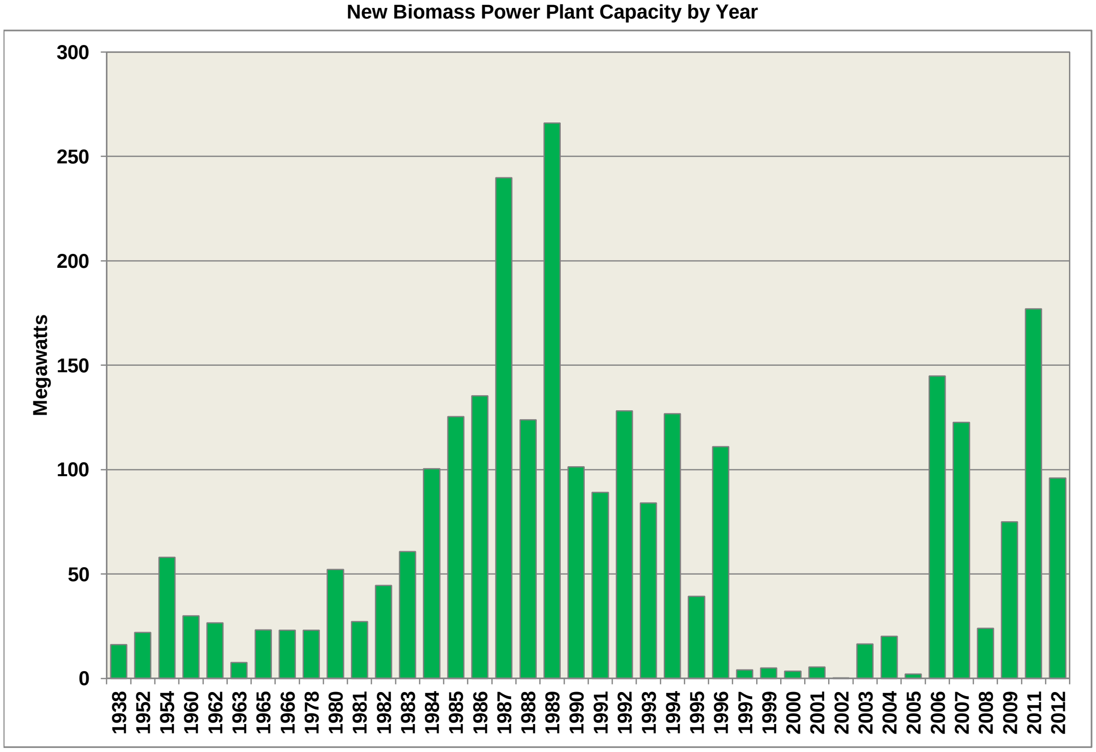
Notes:
— Information not available.
* Product prices are updated as of August 2010. Premium may also apply to small commercial customers. Large users may be able to negotiate price premiums.
** Product is sourced from Green-e and ERT-certified RECs. ERT also certifies the entire product portfolio.

Section: BIOPOWER

New Biomass Power Plants by Year



New Biomass Power Plant Capacity by Year



Source:

National Electric Energy System (NEEDS) Database for IPM 2006

http://epa.gov/airmarkets/progsregs/epa-ipm/BaseCasev410.html

Notes:

1. Only years in which new plants were brought online are shown.
2. Power plant capacity based on NEEDS 2010 Data

Section: BIOPOWER
Current Biomass Power Plants

Plant Name	Boiler/Generator/ Committed Unit	State Name	County	Capacity MW	Heat Rate (Btu/kWh)	Cogeneration	On-line Year
Kettle Falls Generating Station	B	Washington	Stevens	50.00	13,809	No	1983
J C McNeil	B	Vermont	Chittenden	52.00	14,736	No	1984
Mitchell	B	Georgia	Dougherty	96.00	8,911	No	2012
M L Hibbard	B	Minnesota	St. Louis	15.30	14,500	Yes	1988
M L Hibbard	B	Minnesota	St. Louis	33.30	14,500	Yes	1988
Hibbing	B	Minnesota	St. Louis	20.00	14,500	Yes	2007
Virginia	B	Minnesota	St. Louis	15.00	14,500	Yes	2007
Schiller	B	New Hampshire	Rockingham	36.97	9,540	No	2006
Bay Front	B	Wisconsin	Ashland	22.00	18,720	No	1954
Bay Front	B	Wisconsin	Ashland	30.00	12,513	No	1960
Bay Front	B	Wisconsin	Ashland	22.00	16,190	No	1952
E J Stoneman Station	B	Wisconsin	Grant	25.00	8,911	No	2009
E J Stoneman Station	B	Wisconsin	Grant	25.00	8,911	No	2009
Boralex Fort Fairfield	B	Maine	Aroostook	31.00	15,517	No	1987
Everett Cogen	B	Washington	Snohomish	36.00	15,517	Yes	1996
Fairhaven Power	B	California	Humboldt	17.30	15,517	No	1986
Sierra Pacific Lincoln Facility	G	California	Placer	17.22	15,517	Yes	2004
White Pine Electric Power	B	Michigan	Ontonagon	18.00	15,517	No	1954
White Pine Electric Power	B	Michigan	Ontonagon	18.00	15,517	No	1954
Worcester Energy	B	Maine	Washington	4.33	15,517	No	1989
Worcester Energy	B	Maine	Washington	4.33	15,517	No	1989
Worcester Energy	B	Maine	Washington	4.33	15,517	No	1989
Alabama River Pulp	B	Alabama	Monroe	22.32	15,517	Yes	1978
Leaf River Cellulose LLC	B	Mississippi	Perry	37.50	15,517	Yes	1984
Bridgewater Power LP	B	New Hampshire	Grafton	16.00	15,517	No	1987
Mecca Plant	B	California	Riverside	23.50	15,517	No	1991
Mecca Plant	B	California	Riverside	23.50	15,517	No	1991
Hillman Power LLC	B	Michigan	Montmorency	17.80	15,517	No	1987
SI Group Energy LLC	G	Florida	Jefferson	7.50	24,943	No	1990
Boralex Beaver Livermore Falls	B	Maine	Androscoggin	35.88	15,517	No	1992
Green Power Kenansville	B	North Carolina	Duplin	16.20	15,517	Yes	1986
Green Power Kenansville	B	North Carolina	Duplin	16.20	11,564	Yes	1986
Tracy Biomass	B	California	San Joaquin	18.75	15,517	No	1990
Craven County Wood Energy LP	B	North Carolina	Craven	48.00	15,517	No	1990
Agrilectric Power Partners Ltd	G	Louisiana	Calcasieu	1.30	16,136	No	1995
Agrilectric Power Partners Ltd	B	Louisiana	Calcasieu	10.90	15,517	No	1984
Domtar - Woodland Mill	B	Maine	Washington	23.00	15,517	Yes	1966
Burney Forest Products	B	California	Shasta	15.50	15,517	Yes	1989
Burney Forest Products	B	California	Shasta	15.50	15,517	Yes	1989
Collins Pine Project	B	California	Plumas	12.00	15,517	Yes	1985
Rapids Energy Center	B	Minnesota	Itasca	11.25	15,517	Yes	1980
Rapids Energy Center	B	Minnesota	Itasca	11.25	20,328	Yes	1980
Indeck Jonesboro Energy Center	B	Maine	Washington	26.80	15,517	No	1987
Indeck West Enfield Energy Center	B	Maine	Penobscot	25.60	15,517	No	1987
Rio Bravo Fresno	B	California	Fresno	24.30	15,517	No	1988
Rio Bravo Rocklin	B	California	Placer	24.40	15,517	No	1989
HL Power	B	California	Lassen	30.00	15,517	No	1989
Ogdensburg Power	G	New York	St. Lawrence	8.34	8,911	Yes	2009
Ogdensburg Power	G	New York	St. Lawrence	8.34	8,911	Yes	2009
Ogdensburg Power	G	New York	St. Lawrence	8.34	8,911	Yes	2009
Grayling Generating Station	B	Michigan	Crawford	36.20	15,517	No	1992
Woodland Biomass Power Ltd	B	California	Yolo	25.00	15,517	No	1989
AES Mendota	B	California	Fresno	25.00	15,517	No	1989
Hemphill Power & Light	B	New Hampshire	Sullivan	14.13	15,517	No	1987
Whitefield Power & Light	B	New Hampshire	Coos	14.50	15,517	No	1987
Delano Energy	B	California	Kern	27.00	15,517	No	1990
Delano Energy	B	California	Kern	22.00	15,517	No	1993
Biomass One LP	B	Oregon	Jackson	8.50	15,517	Yes	1985
Biomass One LP	B	Oregon	Jackson	14.00	15,517	Yes	1985
Pacific Lumber	B	California	Humboldt	8.67	15,517	Yes	1989
Pacific Lumber	B	California	Humboldt	8.67	15,517	Yes	1989
Pacific Lumber	B	California	Humboldt	16.17	15,517	Yes	1938
Sierra Power	G	California	Tulare	7.00	15,517	Yes	1985
Tillotson Rubber	B	New Hampshire	Coos	0.70	14,594	Yes	1978
Tamarack Energy Partnership	G	Idaho	Adams	5.80	15,943	Yes	1983
Sierra Pacific Burney Facility	B	California	Shasta	16.33	15,517	Yes	1986

Continued on next page

Current Biomass Power Plants
(Continued)

Plant Name	Boiler/Generator/Committed Unit	State Name	County	Capacity MW	Heat Rate (Btu/kWh)	Cogeneration	On-line Year
Sierra Pacific Loyalton Facility	B	California	Sierra	13.08	15,517	No	1989
Sierra Pacific Quincy Facility	B	California	Plumas	14.42	15,517	Yes	1986
Sierra Pacific Quincy Facility	B	California	Plumas	14.42	15,517	Yes	1986
Susanville	G	California	Lassen	11.00	16,506	No	1985
Susanville	G	California	Lassen	2.00	16,506	No	1985
Snider Industries	G	Texas	Harrison	5.00	15,517	Yes	1983
Pinetree Power Bethlehem	B	New Hampshire	Grafton	15.00	15,517	No	1987
Bucksport Mill	B	Maine	Hancock	23.25	15,517	Yes	1965
Boralex Chateaugay Power Station	B	New York	Franklin	18.00	15,517	No	1993
Wadham Energy LP	B	California	Colusa	25.50	15,517	No	1989
Mobile Energy Services LLC	B	Alabama	Mobile	14.35	15,517	Yes	1985
S D Warren Westbrook	B	Maine	Cumberland	11.88	15,517	Yes	1982
S D Warren Westbrook	B	Maine	Cumberland	26.88	15,517	Yes	1982
American Ref-Fuel of Niagara	B	New York	Niagara	9.00	15,517	Yes	1980
Bryant Sugar House	B	Florida	Palm Beach	4.42	15,517	Yes	1962
Bryant Sugar House	B	Florida	Palm Beach	4.42	15,517	Yes	1962
Bryant Sugar House	B	Florida	Palm Beach	4.42	15,517	Yes	1962
Bryant Sugar House	B	Florida	Palm Beach	4.42	15,517	Yes	1962
Bryant Sugar House	B	Florida	Palm Beach	4.42	15,517	Yes	1962
Bryant Sugar House	B	Florida	Palm Beach	4.42	15,517	Yes	1962
Pacific-Ultrapower Chinese Station	B	California	Tuolumne	19.80	15,517	No	1985
Potlatch Idaho Pulp Paper	B	Idaho	Nez Perce	27.20	15,517	Yes	1981
Potlatch Southern Wood Products	B	Arkansas	Bradley	10.00	15,517	Yes	1991
Boralex Stratton Energy	B	Maine	Franklin	45.70	15,517	No	1989
Pinetree Power Tamworth	B	New Hampshire	Carroll	20.00	15,517	No	1987
Viking Energy of McBain	B	Michigan	Missaukee	16.00	15,517	No	1988
Viking Energy of Northumberland	B	Pennsylvania	Northumberland	16.00	15,517	Yes	1988
Viking Energy of Lincoln	B	Michigan	Alcona	16.00	15,517	No	1989
Telogia Power	B	Florida	Liberty	12.50	15,517	No	1986
Stone Container Florence Mill	B	South Carolina	Florence	7.63	15,517	Yes	1963
Stone Container Hopewell Mill	B	Virginia	Hopewell (city)	20.35	15,517	Yes	1980
Wheelabrator Sherman Energy Facility	B	Maine	Penobscot	21.00	15,517	No	1986
Wheelabrator Shasta	G	California	Shasta	3.50	19,538	No	2000
Wheelabrator Shasta	B	California	Shasta	17.30	15,517	No	1987
Wheelabrator Shasta	B	California	Shasta	17.30	15,517	No	1987
Wheelabrator Shasta	B	California	Shasta	17.30	15,517	No	1987
Co-Gen LLC	G	Oregon	Grant	6.98	17,974	Yes	1986
Co-Gen II LLC	G	Oregon	Douglas	6.98	17,139	Yes	1987
Ryegate Power Station	B	Vermont	Caledonia	20.00	21,020	No	1992
Multitrade of Pittsylvania LP	B	Virginia	Pittsylvania	26.55	15,517	No	1994
Multitrade of Pittsylvania LP	B	Virginia	Pittsylvania	26.55	15,517	No	1994
Multitrade of Pittsylvania LP	B	Virginia	Pittsylvania	26.55	15,517	No	1994
Burney Mountain Power	B	California	Shasta	9.75	15,517	No	1985
Cadillac Renewable Energy	B	Michigan	Wexford	36.80	15,517	No	1993
Alabama Pine Pulp	B	Alabama	Monroe	32.09	15,517	Yes	1991
Mt Lassen Power	B	California	Lassen	10.50	15,517	No	1985
Pacific Oroville Power Inc	B	California	Butte	8.25	15,517	No	1985
Pacific Oroville Power Inc	B	California	Butte	8.25	15,517	No	1985
Sierra Pacific Sonora	G	California	Tuolumne	5.45	15,517	Yes	2001
Lyonsdale Biomass LLC	B	New York	Lewis	19.00	15,517	Yes	1992
Ridge Generating Station	B	Florida	Polk	47.10	15,517	No	1994
Pinetree Power Fitchburg	B	Massachusetts	Worcester	17.00	15,517	No	1992
Okeelanta Cogeneration	G	Florida	Palm Beach	74.90	15,517	Yes	2006
Okeelanta Cogeneration	B	Florida	Palm Beach	24.97	15,517	Yes	1996
Okeelanta Cogeneration	B	Florida	Palm Beach	24.97	15,517	Yes	1996
Okeelanta Cogeneration	B	Florida	Palm Beach	24.97	15,517	Yes	1996
Genesee Power Station LP	B	Michigan	Genesee	35.00	15,517	No	1995
Cox Waste to Energy	G	Kentucky	Taylor	3.00	15,517	Yes	1995
Cox Waste to Energy	G	Kentucky	Taylor	0.30	15,517	Yes	2002
Greenville Steam	B	Maine	Piscataquis	19.00	14,192	No	1988
Sauder Power Plant	G	Ohio	Fulton	3.60	18,060	Yes	1993
Sauder Power Plant	G	Ohio	Fulton	3.60	18,060	Yes	1993
J & L Electric	G	Maine	Franklin	0.35	15,517	Yes	1980
J & L Electric	G	Maine	Franklin	0.50	15,517	Yes	2004
Sierra Pacific Anderson Facility	G	California	Shasta	5.00	15,517	Yes	1999
Plummer Forest Products	G	Idaho	Benewah	5.77	16,912	Yes	1982
Fibrominn Biomass Power Plant	G	Minnesota	Swift	55.00	15,517	No	2007
Sierra Pacific Aberdeen	B	Washington	Grays Harbor	16.50	15,517	Yes	2003
McMinnville	G	Tennessee	Warren	1.80	12,397	No	2005
STEC-S LLC	B	Arkansas	Arkansas	2.00	15,517	Yes	1997

Continued on next page

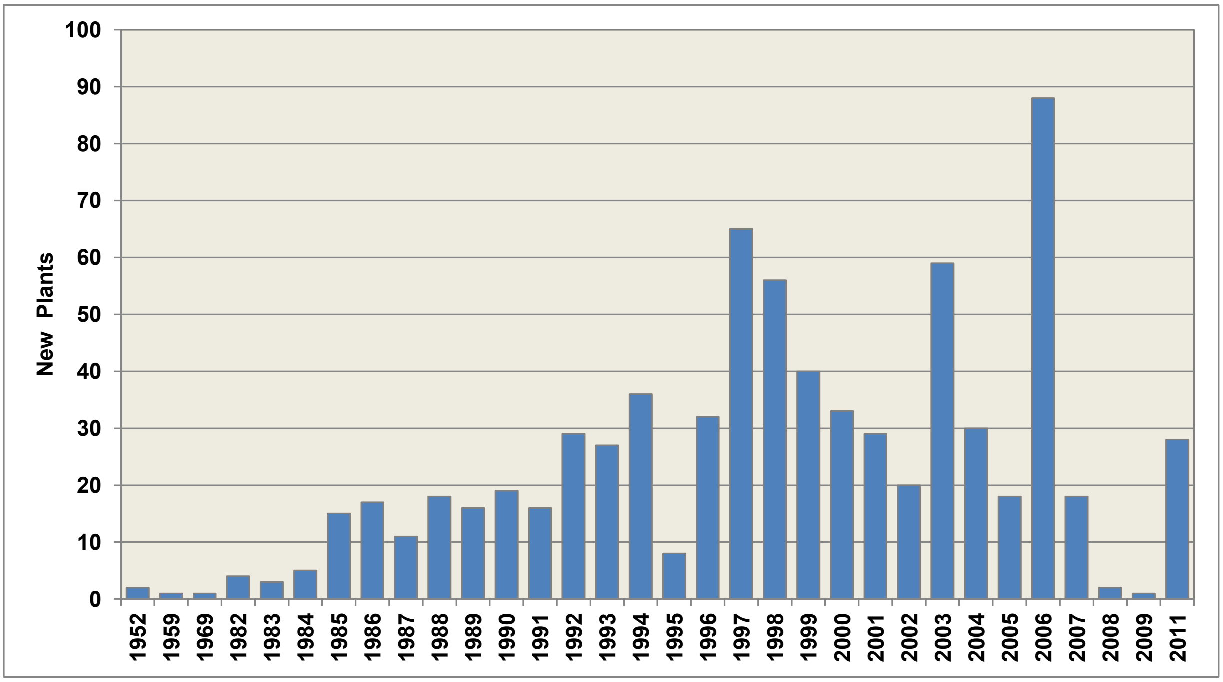
Current Biomass Power Plants
(Continued)

Plant Name	Boiler/Generator/ Committed Unit	State Name	County	Capacity MW	Heat Rate (Btu/kWh)	Cogeneration	On-line Year
STEC-S LLC	B	Arkansas	Arkansas	2.00	15,517	Yes	1997
Western Renewable	G	Arizona	Apache	2.50	9,650	No	2004
Sierra Pacific Burlington Facility	G	Washington	Skagit	25.00	15,517	Yes	2006
Snowflake White Moun	G	Arizona	Navajo	24.00	10,500	No	2008
APS Biomass I	G	Arizona	Eagar	2.85	15,517	No	2006
Central Minn. Ethano	C	Minnesota	NA	0.95	15,517	No	2006
Ware Cogeneration	G	Massachusetts	Hampshire	4.09	15,517	Yes	2006
Plant Carl Project	G	Georgia	Franklin	20.00	10,625	No	2007
Rough and Ready Lumb	G	Oregon	Josephine	1.70	10,500	No	2007
Lincoln Paper & Tissue	G	Maine	Penobscot	10.00	10,500	No	2007
Montagne Farms	G	Vermont	Franklin	0.30	15,517	No	2007
Green Mtn Dairy	G	Vermont	Franklin	0.30	15,517	No	2007
Berkshire Cow Power	G	Vermont	Franklin	0.30	15,517	No	2007
Blue Spruce Farm Ana	G	Vermont	Addison	0.30	15,517	No	2005
CA-S_CA_Biomass	C	California	NA	2.20	8,911	No	2011
ENTG_TX_Biomass	C	Texas	NA	14.20	8,911	No	2011
ERCT_TX_Biomass	C	Texas	NA	50.09	8,911	No	2011
MACW_PA_Biomass	C	Pennsylvania	NA	30.00	8,911	No	2011
MRO_MN_Biomass	C	Minnesota	NA	16.50	8,911	No	2011
NENG_ME_Biomass	C	Maine	NA	16.00	8,911	No	2011
NENG_NH_Biomass	C	New Hampshire	NA	17.50	8,911	No	2011
NWPE_NV_Biomass	C	Nevada	NA	1.00	8,911	No	2011
PNW_OR_Biomass	C	Oregon	NA	13.20	8,911	No	2011
PNW_WA_Biomass	C	Washington	NA	16.25	8,911	No	2011
SOU_AL_Biomass	C	Alabama	NA	0.03	8,911	No	2011

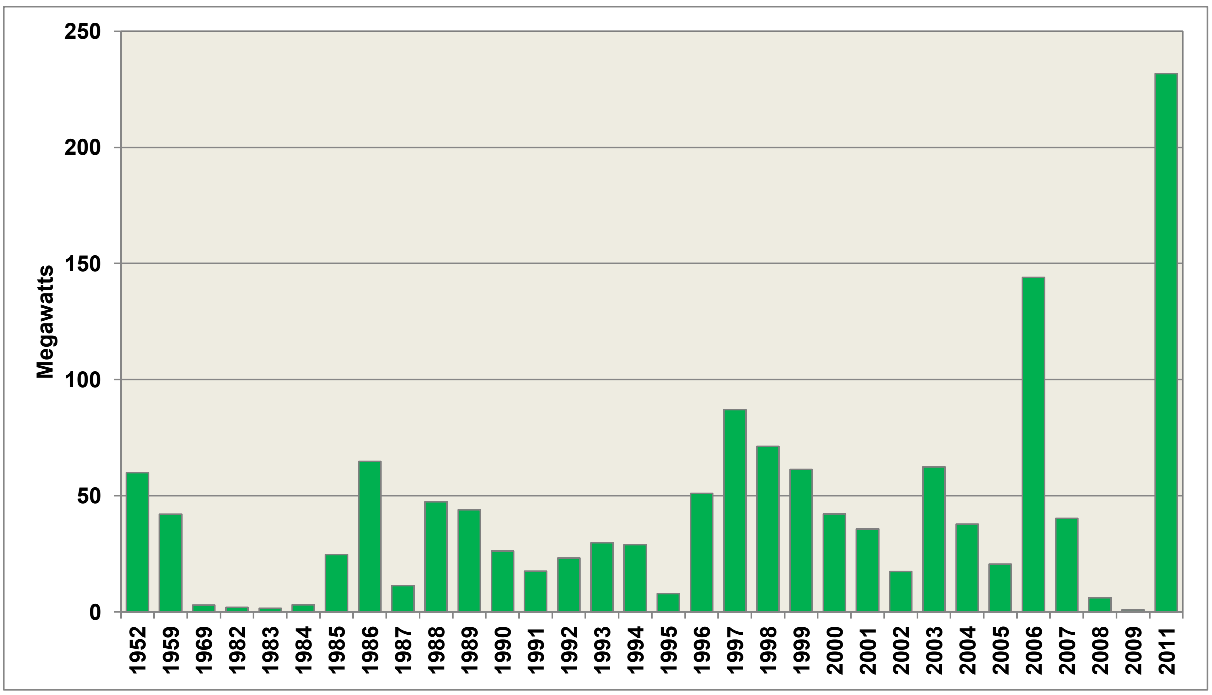
Source:
(National Electric Energy System (NEEDS) Database for IPM 2010.
http://epa.gov/airmarkets/progsregs/epa-ipm/BaseCasev410.html

[a] Data are not available

New Landfill Gas Power Plants by Year



New Landfill Gas Power Plant Capacity by Year



Source:
National Electric Energy System (NEEDS) Database for IPM 2010
http://epa.gov/airmarkets/progsregs/epa-ipm/BaseCasev410.html

Notes:
1. Only years in which new plants were brought online are shown.
2. Power plant capacity based on NEEDS 2010 Data.

Current Landfill Gas Power Plants

Plant Name	Boiler/Generator/ Committed Unit	State Name	County	Capacity MW	Heat Rate (Btu/kWh)	Cogeneration	On-line Year
Grayson	B	California	Los Angeles	42.00	13,698	No	1959
Pennsbury	G	Pennsylvania	Bucks	2.67	19,621	No	1987
Pennsbury	G	Pennsylvania	Bucks	2.67	19,621	No	1987
Fairless Hills	B	Pennsylvania	Bucks	30.00	13,682	Yes	1952
Fairless Hills	B	Pennsylvania	Bucks	30.00	13,682	Yes	1952
Girvin Landfill	G	Florida	Duval	3.00	13,595	No	1997
Coffin Butte	G	Oregon	Benton	0.75	12,758	No	1995
Coffin Butte	G	Oregon	Benton	0.75	12,758	No	1995
Coffin Butte	G	Oregon	Benton	0.75	12,758	No	1995
Roosevelt Biogas 1	G	Washington	Klickitat	2.10	11,900	No	1999
Roosevelt Biogas 1	G	Washington	Klickitat	2.10	11,900	No	1999
Roosevelt Biogas 1	G	Washington	Klickitat	2.10	11,900	No	1999
Roosevelt Biogas 1	G	Washington	Klickitat	2.10	11,900	No	1999
Roosevelt Biogas 1	G	Washington	Klickitat	2.10	11,900	No	2000
Elk City Station	G	Nebraska	Douglas	0.80	13,648	No	2009
Elk City Station	G	Nebraska	Douglas	0.80	13,682	No	2006
Elk City Station	G	Nebraska	Douglas	0.80	13,682	No	2002
Elk City Station	G	Nebraska	Douglas	0.80	13,682	No	2006
Elk City Station	G	Nebraska	Douglas	0.80	13,682	No	2002
Elk City Station	G	Nebraska	Douglas	0.80	13,682	No	2002
Elk City Station	G	Nebraska	Douglas	0.80	13,682	No	2006
Elk City Station	G	Nebraska	Douglas	0.80	13,682	No	2002
Horry Land Fill Gas Site	G	South Carolina	Horry	1.10	10,504	No	2003
Horry Land Fill Gas Site	G	South Carolina	Horry	1.10	10,504	No	2001
Horry Land Fill Gas Site	G	South Carolina	Horry	1.10	10,504	No	2001
Horry Land Fill Gas Site	G	South Carolina	Horry	1.10	13,682	No	2007
South West Landfill	G	Florida	Alachua	0.65	12,498	No	2003
South West Landfill	G	Florida	Alachua	0.65	12,498	No	2003
South West Landfill	G	Florida	Alachua	0.65	12,498	No	2003
Tri Cities	G	Arizona	Maricopa	0.80	12,081	No	2001
Tri Cities	G	Arizona	Maricopa	0.80	12,081	No	2001
Tri Cities	G	Arizona	Maricopa	0.80	12,081	No	2001
Tri Cities	G	Arizona	Maricopa	0.80	12,081	No	2001
Tri Cities	G	Arizona	Maricopa	0.80	12,081	No	2001
San Marcos	G	California	San Diego	0.70	16,716	No	1990
San Marcos	G	California	San Diego	0.70	16,716	No	1990
Sycamore San Diego	G	California	San Diego	0.70	17,446	No	1989
Sycamore San Diego	G	California	San Diego	0.70	17,446	No	1989
Sycamore San Diego	G	California	San Diego	2.80	13,000	No	2004
Newby Island I	G	California	Santa Clara	0.50	13,655	No	1984
Newby Island I	G	California	Santa Clara	0.50	13,655	No	1984
Newby Island I	G	California	Santa Clara	0.50	13,655	No	1984
Newby Island I	G	California	Santa Clara	0.50	13,655	No	1984
Newby Island II	G	California	Santa Clara	1.00	13,016	No	1989
Newby Island II	G	California	Santa Clara	1.00	13,016	No	1989
Newby Island II	G	California	Santa Clara	1.00	13,016	No	1989
Guadalupe Power Plant	G	California	Santa Clara	0.50	13,577	No	1983
Guadalupe Power Plant	G	California	Santa Clara	1.00	13,577	No	1987
Guadalupe Power Plant	G	California	Santa Clara	0.50	13,577	No	1983
Guadalupe Power Plant	G	California	Santa Clara	0.50	13,577	No	1983
Marsh Road Power Plant	G	California	San Mateo	0.50	15,903	No	1982
Marsh Road Power Plant	G	California	San Mateo	0.50	15,903	No	1982
Marsh Road Power Plant	G	California	San Mateo	0.50	15,903	No	1982
Marsh Road Power Plant	G	California	San Mateo	0.50	15,903	No	1982
American Canyon Power Plant	G	California	Napa	0.70	11,881	No	1985
American Canyon Power Plant	G	California	Napa	0.70	11,881	No	1985
Coyote Canyon Steam Plant	B	California	Orange	17.00	13,682	No	1989
Spadra Landfill Gas to Energy	B	California	Los Angeles	7.00	13,682	No	1990
Puente Hills Energy Recovery	B	California	Los Angeles	22.50	13,682	No	1986
Puente Hills Energy Recovery	B	California	Los Angeles	22.50	13,682	No	1986
Puente Hills Energy Recovery	G	California	Los Angeles	2.70	13,682	No	2006
Puente Hills Energy Recovery	G	California	Los Angeles	1.10	35,987	No	1984
Puente Hills Energy Recovery	G	California	Los Angeles	2.70	13,682	No	2006
Puente Hills Energy Recovery	G	California	Los Angeles	2.70	13,682	No	2006
Palos Verdes Gas to Energy	B	California	Los Angeles	2.00	13,682	No	1988
Palos Verdes Gas to Energy	B	California	Los Angeles	2.00	13,682	No	1988
Granger Electric Generating Station #2	G	Michigan	Clinton	0.80	13,682	No	1996
Granger Electric Generating Station #2	G	Michigan	Clinton	0.80	13,682	No	1991
Granger Electric Generating Station #2	G	Michigan	Clinton	0.80	13,682	No	1991
Granger Electric Generating Station #2	G	Michigan	Clinton	0.80	13,682	No	1997
Granger Electric Generating Station #2	G	Michigan	Clinton	0.80	13,682	No	1991
Al Turi	G	New York	Orange	0.80	16,730	No	1998
Al Turi	G	New York	Orange	0.70	16,730	No	1988
Al Turi	G	New York	Orange	0.70	16,730	No	1988
Al Turi	G	New York	Orange	0.70	16,730	No	1989
Al Turi	G	New York	Orange	0.70	16,730	No	1995
Lebanon Methane Recovery	G	Pennsylvania	Lebanon	0.60	13,970	No	1985
Lebanon Methane Recovery	G	Pennsylvania	Lebanon	0.60	13,970	No	1985
Olinda Landfill Gas Recovery Plant	G	California	Orange	1.70	12,319	No	1985
Olinda Landfill Gas Recovery Plant	G	California	Orange	1.70	12,319	No	1985
Olinda Landfill Gas Recovery Plant	G	California	Orange	1.70	12,319	No	1985
Marina Landfill Gas	G	California	Monterey	0.90	13,682	No	1997
Marina Landfill Gas	G	California	Monterey	0.90	13,682	No	2002
Marina Landfill Gas	G	California	Monterey	0.70	13,682	No	1994
Marina Landfill Gas	G	California	Monterey	0.90	13,682	No	1998

Continued on next page

Current Landfill Gas Power Plants
(Continued)

Plant Name	Boiler/Generator/ Committed Unit	State Name	County	Capacity MW	Heat Rate (Btu/kWh)	Cogeneration	On-line Year
Prince Georges County Brown Station	G	Maryland	Prince	0.74	13,682	No	1987
Prince Georges County Brown Station	G	Maryland	Prince	0.74	13,682	No	1987
Prince Georges County Brown Station	G	Maryland	Prince	0.74	13,682	No	1987
EQ Waste Energy Services	G	Michigan	Wayne	0.30	13,388	Yes	1986
EQ Waste Energy Services	G	Michigan	Wayne	0.30	13,388	Yes	1986
EQ Waste Energy Services	G	Michigan	Wayne	0.50	13,388	Yes	1986
EQ Waste Energy Services	G	Michigan	Wayne	0.30	13,388	Yes	1986
Archbald Power Station	B	Pennsylvania	Lackawanna	20.00	13,682	Yes	1988
Smithtown Energy Partners LP	G	New York	Suffolk	0.60	13,001	No	1988
Smithtown Energy Partners LP	G	New York	Suffolk	0.60	13,001	No	1988
Onondaga Energy Partners LP	G	New York	Onondaga	0.60	13,940	No	1988
Onondaga Energy Partners LP	G	New York	Onondaga	0.60	13,940	No	1988
Oceanside Energy	G	New York	Nassau	0.60	13,428	No	1990
Oceanside Energy	G	New York	Nassau	0.60	13,428	No	1990
Oceanside Energy	G	New York	Nassau	0.60	13,428	No	1990
Ridgewood Providence Power	G	Rhode Island	Providence	1.50	13,682	No	2005
Ridgewood Providence Power	G	Rhode Island	Providence	1.20	13,682	No	2004
Ridgewood Providence Power	G	Rhode Island	Providence	1.20	13,682	No	2004
Ridgewood Providence Power	G	Rhode Island	Providence	1.50	13,682	No	2005
Ridgewood Providence Power	G	Rhode Island	Providence	1.70	12,049	No	1990
Ridgewood Providence Power	G	Rhode Island	Providence	1.50	13,682	No	2005
Ridgewood Providence Power	G	Rhode Island	Providence	1.70	12,049	No	1990
Ridgewood Providence Power	G	Rhode Island	Providence	1.70	12,049	No	1990
Ridgewood Providence Power	G	Rhode Island	Providence	1.70	12,049	No	1990
Ridgewood Providence Power	G	Rhode Island	Providence	1.50	13,682	No	2005
Ridgewood Providence Power	G	Rhode Island	Providence	1.70	12,049	No	1990
Ridgewood Providence Power	G	Rhode Island	Providence	1.70	12,049	No	1990
Ridgewood Providence Power	G	Rhode Island	Providence	1.70	12,049	No	1990
Ridgewood Providence Power	G	Rhode Island	Providence	1.70	12,049	No	1990
Ridgewood Providence Power	G	Rhode Island	Providence	1.70	12,049	No	1997
Settlers Hill Gas Recovery	G	Illinois	Kane	2.90	18,229	No	1988
Settlers Hill Gas Recovery	G	Illinois	Kane	2.90	18,229	No	1998
New Milford Gas Recovery	G	Connecticut	Litchfield	1.60	17,053	No	1991
Monroe Livingston Gas Recovery	G	New York	Monroe	0.80	13,303	No	1988
Monroe Livingston Gas Recovery	G	New York	Monroe	0.80	13,303	No	1988
Monroe Livingston Gas Recovery	G	New York	Monroe	0.80	13,303	No	1988
Milam Gas Recovery	G	Illinois	St. Clair	0.80	12,168	No	1991
Milam Gas Recovery	G	Illinois	St. Clair	0.80	12,168	No	1991
Milam Gas Recovery	G	Illinois	St. Clair	0.80	12,168	No	1993
High Acres Gas Recovery	G	New York	Monroe	0.80	11,773	No	1991
High Acres Gas Recovery	G	New York	Monroe	0.80	11,773	No	1991
High Acres Gas Recovery	G	New York	Monroe	0.80	11,773	No	1991
High Acres Gas Recovery	G	New York	Monroe	0.80	11,773	No	1991
DFW Gas Recovery	G	Texas	Denton	2.90	20,551	No	1988
DFW Gas Recovery	G	Texas	Denton	2.90	20,551	No	1988
Chestnut Ridge Gas Recovery	G	Tennessee	Anderson	0.80	12,912	No	1992
Chestnut Ridge Gas Recovery	G	Tennessee	Anderson	0.80	12,912	No	1992
Chestnut Ridge Gas Recovery	G	Tennessee	Anderson	0.80	12,912	No	1992
Chestnut Ridge Gas Recovery	G	Tennessee	Anderson	0.80	12,912	No	1992
Altamont Gas Recovery	G	California	Alameda	1.30	13,825	No	2002
Altamont Gas Recovery	G	California	Alameda	2.90	17,435	No	1969
Altamont Gas Recovery	G	California	Alameda	1.30	13,825	No	2002
Altamont Gas Recovery	G	California	Alameda	2.90	17,435	No	1989
CSL Gas Recovery	G	Florida	Broward	2.90	11,860	No	1989
CSL Gas Recovery	G	Florida	Broward	2.90	11,860	No	1989
CSL Gas Recovery	G	Florida	Broward	2.90	11,860	No	1989
CSL Gas Recovery	G	Florida	Broward	2.20	11,860	No	2000
CID Gas Recovery	G	Illinois	Cook	2.90	19,778	No	1989
CID Gas Recovery	G	Illinois	Cook	2.90	19,778	No	1989
Lake Gas Recovery	G	Illinois	Cook	2.90	19,330	No	1988
Lake Gas Recovery	G	Illinois	Cook	2.90	19,330	No	1993
Lake Gas Recovery	G	Illinois	Cook	2.90	19,330	No	1993
Metro Gas Recovery	G	Wisconsin	Milwaukee	0.80	14,317	No	2000
Metro Gas Recovery	G	Wisconsin	Milwaukee	0.80	14,317	No	2000
Metro Gas Recovery	G	Wisconsin	Milwaukee	0.80	14,317	No	2000
Metro Gas Recovery	G	Wisconsin	Milwaukee	0.80	14,317	No	2000
Metro Gas Recovery	G	Wisconsin	Milwaukee	2.90	18,504	No	1985
Metro Gas Recovery	G	Wisconsin	Milwaukee	2.90	18,504	No	1985
Omega Hills Gas Recovery	G	Wisconsin	Washington	2.90	19,141	No	1985
Omega Hills Gas Recovery	G	Wisconsin	Washington	2.90	19,141	No	1985
Omega Hills Gas Recovery	G	Wisconsin	Washington	3.00	19,141	No	2001
Stowe Power Production Plant	G	Pennsylvania	Montgomery	2.90	19,113	No	1989
Stowe Power Production Plant	G	Pennsylvania	Montgomery	2.90	19,113	No	1991
Tazewell Gas Recovery	G	Illinois	Tazewell	0.80	12,246	No	1989
Tazewell Gas Recovery	G	Illinois	Tazewell	0.80	12,246	No	1989
Tazewell Gas Recovery	G	Illinois	Tazewell	0.80	12,246	No	1999
Taylor Energy Partners LP	G	Pennsylvania	Lackawanna	0.60	13,982	No	1987
Taylor Energy Partners LP	G	Pennsylvania	Lackawanna	0.40	13,982	No	1987
Taylor Energy Partners LP	G	Pennsylvania	Lackawanna	0.40	13,982	No	1987
Taylor Energy Partners LP	G	Pennsylvania	Lackawanna	0.40	13,982	No	1987
Lafayette Energy Partners LP	G	New Jersey	Sussex	0.50	15,927	No	1990
Lafayette Energy Partners LP	G	New Jersey	Sussex	0.50	15,927	No	1990
Nove Power Plant	G	California	Contra Costa	1.00	11,414	No	1985
Nove Power Plant	G	California	Contra Costa	1.00	11,414	No	1985
Nove Power Plant	G	California	Contra Costa	1.00	11,414	No	1987

Continued on next page

Current Landfill Gas Power Plants
(Continued)

Plant Name	Boiler/Generator/Committed Unit	State Name	County	Capacity MW	Heat Rate (Btu/kWh)	Cogeneration	On-line Year
Winnebago County Landfill Gas	G	Wisconsin	Winnebago	0.90	11,900	No	2000
Winnebago County Landfill Gas	G	Wisconsin	Winnebago	0.90	11,900	No	2000
Winnebago County Landfill Gas	G	Wisconsin	Winnebago	0.90	11,900	No	2000
I 95 Municipal Landfill Phase I	G	Virginia	Fairfax	0.80	11,123	No	1992
I 95 Municipal Landfill Phase I	G	Virginia	Fairfax	0.80	11,123	No	1992
I 95 Municipal Landfill Phase I	G	Virginia	Fairfax	0.80	11,123	No	1992
I 95 Municipal Landfill Phase I	G	Virginia	Fairfax	0.80	11,123	No	1992
Otay	G	California	San Diego	1.70	10,135	No	1986
Otay	G	California	San Diego	1.70	10,135	No	1991
Salinas	G	California	Monterey	1.30	10,374	No	1986
Oxnard	G	California	Ventura	1.70	12,254	No	1985
Oxnard	G	California	Ventura	1.70	12,254	No	1991
Oxnard	G	California	Ventura	1.70	12,254	No	1985
BKK Landfill	G	California	Los Angeles	4.40	11,518	No	1999
BKK Landfill	G	California	Los Angeles	4.40	22,519	No	1993
Riverview Energy Systems	G	Michigan	Wayne	2.81	16,466	No	1988
Riverview Energy Systems	G	Michigan	Wayne	2.81	16,466	No	1988
Penrose Power Station	G	California	Los Angeles	1.70	12,426	No	1986
Penrose Power Station	G	California	Los Angeles	1.70	12,426	No	1986
Penrose Power Station	G	California	Los Angeles	1.70	12,426	No	1986
Penrose Power Station	G	California	Los Angeles	1.70	12,426	No	1986
Penrose Power Station	G	California	Los Angeles	1.70	12,426	No	1986
Toyon Power Station	G	California	Los Angeles	1.70	17,198	No	1986
Toyon Power Station	G	California	Los Angeles	1.70	17,198	No	1986
Toyon Power Station	G	California	Los Angeles	1.70	17,198	No	1986
Toyon Power Station	G	California	Los Angeles	1.70	17,198	No	1986
BJ Gas Recovery	G	Georgia	Gwinnett	0.80	12,577	No	1993
BJ Gas Recovery	G	Georgia	Gwinnett	0.80	12,577	No	1993
Sumpter Energy Associates	G	Michigan	Wayne	0.80	13,682	No	1992
Sumpter Energy Associates	G	Michigan	Wayne	0.80	13,682	No	1992
Sumpter Energy Associates	G	Michigan	Wayne	0.80	13,682	No	1992
Sumpter Energy Associates	G	Michigan	Wayne	0.80	13,682	No	1992
Sumpter Energy Associates	G	Michigan	Wayne	0.80	13,682	No	1992
Sumpter Energy Associates	G	Michigan	Wayne	0.80	13,682	No	1992
Sumpter Energy Associates	G	Michigan	Wayne	0.80	13,682	No	1992
Sumpter Energy Associates	G	Michigan	Wayne	0.80	13,682	No	1992
Sumpter Energy Associates	G	Michigan	Wayne	0.80	13,682	No	1992
Sumpter Energy Associates	G	Michigan	Wayne	0.80	13,682	No	1992
Sumpter Energy Associates	G	Michigan	Wayne	0.80	13,682	No	1998
Sumpter Energy Associates	G	Michigan	Wayne	0.80	13,682	No	1998
Sumpter Energy Associates	G	Michigan	Wayne	0.80	13,682	No	1998
Sumpter Energy Associates	G	Michigan	Wayne	0.80	13,682	No	1998
Sumpter Energy Associates	G	Michigan	Wayne	0.80	13,682	No	1998
Venice Resources Gas Recovery	G	Michigan	Shiawassee	0.80	15,045	No	1992
Venice Resources Gas Recovery	G	Michigan	Shiawassee	0.80	15,045	No	1992
Granger Electric Generating Station #1	G	Michigan	Clinton	0.80	13,682	No	1993
Granger Electric Generating Station #1	G	Michigan	Clinton	0.80	13,682	No	1997
Granger Electric Generating Station #1	G	Michigan	Clinton	0.80	13,682	No	1993
Granger Electric Generating Station #1	G	Michigan	Clinton	0.80	13,682	No	1994
MM Yolo Power LLC Facility	G	California	Yolo	0.45	20,277	No	1990
MM Yolo Power LLC Facility	G	California	Yolo	0.45	20,277	No	1990
MM Yolo Power LLC Facility	G	California	Yolo	0.60	20,277	No	1993
MM Yolo Power LLC Facility	G	California	Yolo	0.45	20,277	No	1990
Kankakee Gas Recovery	G	Illinois	Kankakee	0.80	12,214	No	1992
Kankakee Gas Recovery	G	Illinois	Kankakee	0.80	12,214	No	1992
Pheasant Run Landfill Gas Recovery	G	Wisconsin	Kenosha	0.80	13,103	No	2000
Pheasant Run Landfill Gas Recovery	G	Wisconsin	Kenosha	0.80	13,103	No	1992
Pheasant Run Landfill Gas Recovery	G	Wisconsin	Kenosha	0.80	13,103	No	2002
Pheasant Run Landfill Gas Recovery	G	Wisconsin	Kenosha	0.80	13,103	No	2002
Pheasant Run Landfill Gas Recovery	G	Wisconsin	Kenosha	0.80	13,103	No	2002
Pheasant Run Landfill Gas Recovery	G	Wisconsin	Kenosha	0.80	13,103	No	2002
Pheasant Run Landfill Gas Recovery	G	Wisconsin	Kenosha	0.80	13,103	No	1996
Pheasant Run Landfill Gas Recovery	G	Wisconsin	Kenosha	0.80	13,103	No	1992
Pheasant Run Landfill Gas Recovery	G	Wisconsin	Kenosha	0.80	13,103	No	2000
Pheasant Run Landfill Gas Recovery	G	Wisconsin	Kenosha	0.80	13,103	No	2000
Pheasant Run Landfill Gas Recovery	G	Wisconsin	Kenosha	0.80	13,103	No	2000
Woodland Landfill Gas Recovery	G	Illinois	Kane	0.80	12,961	No	1992
Woodland Landfill Gas Recovery	G	Illinois	Kane	0.80	12,961	No	1992
Turnkey Landfill Gas Recovery	G	New Hampshire	Strafford	2.90	17,180	No	1997
Turnkey Landfill Gas Recovery	G	New Hampshire	Strafford	0.80	13,952	No	1992
Turnkey Landfill Gas Recovery	G	New Hampshire	Strafford	0.80	13,952	No	1992
Turnkey Landfill Gas Recovery	G	New Hampshire	Strafford	0.80	13,952	No	1992
Turnkey Landfill Gas Recovery	G	New Hampshire	Strafford	2.90	17,180	No	1997
Turnkey Landfill Gas Recovery	G	New Hampshire	Strafford	0.80	13,952	No	1993
Metro Methane Recovery Facility	G	Iowa	Polk	0.80	12,425	No	1998
Metro Methane Recovery Facility	G	Iowa	Polk	0.80	12,425	No	1998
Metro Methane Recovery Facility	G	Iowa	Polk	0.80	12,425	No	1998
Metro Methane Recovery Facility	G	Iowa	Polk	0.80	12,425	No	1998
Metro Methane Recovery Facility	G	Iowa	Polk	0.80	12,425	No	1998
Metro Methane Recovery Facility	G	Iowa	Polk	0.80	12,425	No	1998
Metro Methane Recovery Facility	G	Iowa	Polk	0.80	12,425	No	1998
Metro Methane Recovery Facility	G	Iowa	Polk	0.80	12,425	No	1998

Continued on next page

Current Landfill Gas Power Plants
(Continued)

Plant Name	Boiler/Generator/Committed Unit	State Name	County	Capacity MW	Heat Rate (Btu/kWh)	Cogeneration	On-line Year
I 95 Landfill Phase II	G	Virginia	Fairfax	0.80	10,907	No	1993
I 95 Landfill Phase II	G	Virginia	Fairfax	0.80	10,907	No	1993
I 95 Landfill Phase II	G	Virginia	Fairfax	0.80	10,907	No	1993
I 95 Landfill Phase II	G	Virginia	Fairfax	0.80	10,907	No	1993
Ottawa Generating Station	G	Michigan	Ottawa	0.80	13,682	No	1994
Ottawa Generating Station	G	Michigan	Ottawa	0.80	13,682	No	1994
Ottawa Generating Station	G	Michigan	Ottawa	0.80	13,682	No	1994
Ottawa Generating Station	G	Michigan	Ottawa	0.80	13,682	No	1994
Ottawa Generating Station	G	Michigan	Ottawa	0.80	13,682	No	1994
Ottawa Generating Station	G	Michigan	Ottawa	0.80	13,682	No	1994
Grand Blanc Generating Station	G	Michigan	Genesee	0.80	13,682	No	1994
Grand Blanc Generating Station	G	Michigan	Genesee	0.80	13,682	No	2003
Grand Blanc Generating Station	G	Michigan	Genesee	0.80	13,682	No	1994
Grand Blanc Generating Station	G	Michigan	Genesee	0.80	13,682	No	1994
Grand Blanc Generating Station	G	Michigan	Genesee	0.80	13,682	No	2000
Suffolk Energy Partners LP	G	Virginia	Suffolk	0.70	13,030	No	1994
Suffolk Energy Partners LP	G	Virginia	Suffolk	0.70	13,030	No	1994
Suffolk Energy Partners LP	G	Virginia	Suffolk	0.70	13,030	No	1994
Suffolk Energy Partners LP	G	Virginia	Suffolk	0.70	13,030	No	1994
Seneca Energy	G	New York	Seneca	0.77	11,036	No	1996
Seneca Energy	G	New York	Seneca	0.77	11,036	No	1996
Seneca Energy	G	New York	Seneca	0.77	11,036	No	1998
Seneca Energy	G	New York	Seneca	0.77	11,036	No	1996
Seneca Energy	G	New York	Seneca	0.77	11,036	No	1996
Seneca Energy	G	New York	Seneca	0.77	11,036	No	1998
Seneca Energy	G	New York	Seneca	0.77	11,036	No	1996
Seneca Energy	G	New York	Seneca	0.77	11,036	No	1998
Seneca Energy	G	New York	Seneca	0.77	11,036	No	1997
Seneca Energy	G	New York	Seneca	0.77	11,036	No	1997
Seneca Energy	G	New York	Seneca	0.77	11,036	No	1998
Seneca Energy	G	New York	Seneca	0.77	11,036	No	1998
Seneca Energy	G	New York	Seneca	0.77	11,036	No	1998
Seneca Energy	G	New York	Seneca	0.77	11,036	No	1998
Seneca Energy	G	New York	Seneca	1.60	13,682	No	2006
Seneca Energy	G	New York	Seneca	1.60	13,682	No	2006
Seneca Energy	G	New York	Seneca	1.60	13,682	No	2006
Seneca Energy	G	New York	Seneca	1.60	13,682	No	2006
Outagamie County Co-Generation Facility	G	Wisconsin	Outagamie	0.80	13,682	Yes	1991
Outagamie County Co-Generation Facility	G	Wisconsin	Outagamie	0.80	13,682	No	1991
Outagamie County Co-Generation Facility	G	Wisconsin	Outagamie	0.80	13,682	No	1991
Peoples Generating Station	G	Michigan	Genesee	2.20	11,900	No	1995
Adrian Energy Associates LLC	G	Michigan	Lenawee	0.80	12,942	No	1994
Adrian Energy Associates LLC	G	Michigan	Lenawee	0.80	12,942	No	1994
Adrian Energy Associates LLC	G	Michigan	Lenawee	0.80	12,942	No	1994
Brent Run Generating Station	G	Michigan	Genesee	0.80	13,682	No	1998
Brent Run Generating Station	G	Michigan	Genesee	0.80	13,682	No	1998
Twin Bridges Gas Recovery	G	Indiana	Hendricks	0.80	13,682	No	2002
Twin Bridges Gas Recovery	G	Indiana	Hendricks	0.80	12,070	No	1994
Twin Bridges Gas Recovery	G	Indiana	Hendricks	0.80	12,070	No	1994
Twin Bridges Gas Recovery	G	Indiana	Hendricks	0.80	13,682	No	2002
Twin Bridges Gas Recovery	G	Indiana	Hendricks	0.80	13,682	No	2002
Twin Bridges Gas Recovery	G	Indiana	Hendricks	0.80	12,070	No	1994
Twin Bridges Gas Recovery	G	Indiana	Hendricks	0.80	13,682	No	2002
Twin Bridges Gas Recovery	G	Indiana	Hendricks	0.80	12,070	No	1994
Prairie View Gas Recovery	G	Indiana	St. Joseph	0.80	11,428	No	1994
Prairie View Gas Recovery	G	Indiana	St. Joseph	0.80	11,428	No	1994
Prairie View Gas Recovery	G	Indiana	St. Joseph	0.80	11,428	No	1994
Prairie View Gas Recovery	G	Indiana	St. Joseph	0.80	11,428	No	1994
Keystone Landfill	G	Pennsylvania	Lackawanna	0.70	12,162	No	1994
Keystone Landfill	G	Pennsylvania	Lackawanna	0.70	12,162	No	1994
Keystone Landfill	G	Pennsylvania	Lackawanna	0.70	12,162	No	1994
Keystone Landfill	G	Pennsylvania	Lackawanna	0.70	12,162	No	1994
Keystone Landfill	G	Pennsylvania	Lackawanna	0.70	12,162	No	1994
Keystone Landfill	G	Pennsylvania	Lackawanna	0.70	12,162	No	1994
Keystone Landfill	G	Pennsylvania	Lackawanna	0.70	12,162	No	1994
EKS Landfill	G	Minnesota	Dakota	1.50	12,157	No	1994
EKS Landfill	G	Minnesota	Dakota	1.50	12,157	No	1994
EKS Landfill	G	Minnesota	Dakota	0.80	12,157	No	1994
Deercroft Gas Recovery	G	Indiana	La Porte	0.80	12,063	No	1999
Deercroft Gas Recovery	G	Indiana	La Porte	0.80	12,063	No	1999
Deercroft Gas Recovery	G	Indiana	La Porte	0.80	12,063	No	1999
Deercroft Gas Recovery	G	Indiana	La Porte	0.80	12,063	No	1999
Ocean County Landfill	G	New Jersey	Ocean	9.60	11,900	No	2007
Ocean County Landfill	G	New Jersey	Ocean	0.80	11,900	No	1997
Ocean County Landfill	G	New Jersey	Ocean	0.80	11,900	No	1997
Ocean County Landfill	G	New Jersey	Ocean	0.80	11,900	No	1997
Ocean County Landfill	G	New Jersey	Ocean	0.80	11,900	No	1997
Ocean County Landfill	G	New Jersey	Ocean	0.80	11,900	No	1997
Ocean County Landfill	G	New Jersey	Ocean	0.80	11,900	No	1997
Salem Energy Systems LLC	G	North Carolina	Forsyth	3.30	15,751	No	1996
Pine Tree Acres	G	Michigan	Macomb	0.80	11,900	No	1998
Pine Tree Acres	G	Michigan	Macomb	0.80	11,900	No	1998
Pine Tree Acres	G	Michigan	Macomb	0.80	11,900	No	1998
Pine Tree Acres	G	Michigan	Macomb	0.80	11,900	No	2003

Continued on next page

Current Landfill Gas Power Plants
(Continued)

Plant Name	Boiler/Generator/Committed Unit	State Name	County	Capacity MW	Heat Rate (Btu/kWh)	Cogeneration	On-line Year
Pine Tree Acres	G	Michigan	Macomb	0.80	11,900	No	2003
Pine Tree Acres	G	Michigan	Macomb	0.80	11,900	No	1998
Pine Tree Acres	G	Michigan	Macomb	0.80	11,900	No	1998
Four Hills Nashua Landfill	G	New	Hillsborough	0.70	15,844	No	1996
Four Hills Nashua Landfill	G	New	Hillsborough	0.46	15,844	No	1996
Mallard Ridge Gas Recovery	G	Wisconsin	Walworth	0.80	11,607	No	1996
Mallard Ridge Gas Recovery	G	Wisconsin	Walworth	0.80	11,607	No	1996
Mallard Ridge Gas Recovery	G	Wisconsin	Walworth	0.80	11,607	No	1997
Greene Valley Gas Recovery	G	Illinois	DuPage	2.90	18,396	No	1998
Greene Valley Gas Recovery	G	Illinois	DuPage	2.90	18,396	No	1996
Greene Valley Gas Recovery	G	Illinois	DuPage	2.90	18,396	No	1996
Biodyne Pontiac	G	Illinois	Livingston	4.20	17,835	No	2001
Biodyne Pontiac	G	Illinois	Livingston	4.20	17,835	No	1999
Biodyne Pontiac	G	Illinois	Livingston	4.20	10,000	No	2000
Biodyne Peoria	G	Illinois	Peoria	0.80	13,682	No	1997
Biodyne Peoria	G	Illinois	Peoria	0.80	13,682	No	1997
Biodyne Peoria	G	Illinois	Peoria	0.80	13,682	No	1997
Biodyne Peoria	G	Illinois	Peoria	0.80	13,682	No	1997
Biodyne Peoria	G	Illinois	Peoria	0.80	13,682	No	1997
Biodyne Springfield	G	Illinois	Sangamon	0.60	13,682	No	1997
Biodyne Springfield	G	Illinois	Sangamon	0.60	13,682	No	1997
Biodyne Springfield	G	Illinois	Sangamon	0.60	13,682	No	1997
Biodyne Springfield	G	Illinois	Sangamon	0.60	13,682	No	1997
Biodyne Lyons	G	Illinois	Cook	0.90	13,682	No	1997
Biodyne Lyons	G	Illinois	Cook	0.90	13,682	No	1997
Biodyne Lyons	G	Illinois	Cook	0.90	13,682	No	1997
Lakeview Gas Recovery	G	Pennsylvania	Erie	3.00	12,399	No	1997
Lakeview Gas Recovery	G	Pennsylvania	Erie	3.00	12,399	No	1997
O'Brien Biogas IV LLC	G	New Jersey	Middlesex	9.50	18,797	No	1997
Taunton Landfill	G	Massachusetts	Bristo	0.88	11,445	No	1997
Taunton Landfill	G	Massachusetts	Bristo	0.88	11,445	No	1997
Miramar Landfill Metro Biosolids Center	G	California	San Diego	1.56	11,855	Yes	1997
Miramar Landfill Metro Biosolids Center	G	California	San Diego	1.56	11,855	Yes	1997
Miramar Landfill Metro Biosolids Center	G	California	San Diego	1.56	11,855	Yes	1997
Miramar Landfill Metro Biosolids Center	G	California	San Diego	1.56	11,855	Yes	1997
Lowell Landfill	G	Massachusetts	Middlesex	0.78	10,726	No	1997
Lowell Landfill	G	Massachusetts	Middlesex	0.78	10,726	No	1997
Modern Landfill Production Plant	G	Pennsylvania	York	3.00	11,900	No	1998
Modern Landfill Production Plant	G	Pennsylvania	York	3.00	11,900	No	1998
Modern Landfill Production Plant	G	Pennsylvania	York	3.00	11,900	No	1998
Albany Landfill Gas Utilization Project	G	New York	Albany	0.90	11,306	No	1998
Albany Landfill Gas Utilization Project	G	New York	Albany	0.90	11,306	No	1998
Prince William County Landfill	G	Virginia	Prince William	0.89	10,740	No	1998
Prince William County Landfill	G	Virginia	Prince William	0.89	10,740	No	1998
Balefill Landfill Gas Utilization Pro	G	New Jersey	Bergen	1.80	11,640	No	1998
Balefill Landfill Gas Utilization Pro	G	New Jersey	Bergen	1.80	11,640	No	1998
Visalia Landfill Gas Utilization Project	G	California	Tulare	0.78	14,756	No	1998
Visalia Landfill Gas Utilization Project	G	California	Tulare	0.78	14,756	No	1998
Lopez Landfill Gas Utilization Project	G	California	Los Angeles	2.73	12,256	No	1998
Lopez Landfill Gas Utilization Project	G	California	Los Angeles	2.73	12,256	No	1998
Volusia Landfill Gas Utilization Project	G	Florida	Volusia	1.85	10,712	No	1998
Volusia Landfill Gas Utilization Project	G	Florida	Volusia	1.85	10,712	No	1998
Hartford Landfill Gas Utilization Proj	G	Connecticut	Hartford	0.63	12,127	No	1998
Hartford Landfill Gas Utilization Proj	G	Connecticut	Hartford	0.63	12,127	No	1998
Hartford Landfill Gas Utilization Proj	G	Connecticut	Hartford	0.63	12,127	No	1998
Blackburn Landfill Co-Generation	G	North Carolina	Catawba	1.00	12,328	Yes	1999
Blackburn Landfill Co-Generation	G	North Carolina	Catawba	1.00	12,328	Yes	1999
Blackburn Landfill Co-Generation	G	North Carolina	Catawba	0.90	12,328	Yes	2002
Atascosita	G	Texas	Harris	1.70	11,048	No	2003
Atascosita	G	Texas	Harris	1.70	11,048	No	2003
Atascosita	G	Texas	Harris	1.70	11,048	No	2003
Atascosita	G	Texas	Harris	1.70	13,682	No	2004
Atascosita	G	Texas	Harris	1.70	11,048	No	2003
Atascosita	G	Texas	Harris	1.70	11,048	No	2003
Baytown	G	Texas	Chambers	1.00	11,270	No	2003
Baytown	G	Texas	Chambers	1.00	11,270	No	2003
Baytown	G	Texas	Chambers	1.00	11,270	No	2003
Baytown	G	Texas	Chambers	1.00	11,270	No	2003
Bluebonnet	G	Texas	Harris	1.00	11,718	No	2003
Bluebonnet	G	Texas	Harris	1.00	11,718	No	2003
Bluebonnet	G	Texas	Harris	1.00	11,718	No	2003
Bluebonnet	G	Texas	Harris	1.00	11,718	No	2003
Coastal Plains	G	Texas	Galveston	1.70	11,045	No	2003
Coastal Plains	G	Texas	Galveston	1.70	11,045	No	2003
Coastal Plains	G	Texas	Galveston	1.70	11,045	No	2003
Coastal Plains	G	Texas	Galveston	1.70	11,045	No	2003
Conroe	G	Texas	Montgomery	1.00	11,830	No	2003
Conroe	G	Texas	Montgomery	1.00	11,830	No	2003
Conroe	G	Texas	Montgomery	1.00	11,830	No	2003
Security	G	Texas	Liberty	1.70	10,637	No	2003
Security	G	Texas	Liberty	1.70	10,637	No	2003
East Bridgewater	G	Massachusetts	Plymouth	0.90	14,237	No	1997
East Bridgewater	G	Massachusetts	Plymouth	0.90	14,237	No	1997
East Bridgewater	G	Massachusetts	Plymouth	0.90	14,237	No	1997

Continued on next page

Current Landfill Gas Power Plants
(Continued)

Plant Name	Boiler/Generator/ Committed Unit	State Name	County	Capacity MW	Heat Rate (Btu/kWh)	Cogeneration	On-line Year
East Bridgewater	G	Massachusetts	Plymouth	0.90	14,237	No	1997
East Bridgewater	G	Massachusetts	Plymouth	0.90	14,237	No	1997
East Bridgewater	G	Massachusetts	Plymouth	0.90	14,237	No	1997
Randolph Electric	G	Massachusetts	Norfolk	0.90	13,798	No	2000
Randolph Electric	G	Massachusetts	Norfolk	0.90	13,798	No	2000
Randolph Electric	G	Massachusetts	Norfolk	0.90	13,798	No	2000
Halifax Electric	G	Massachusetts	Plymouth	0.90	13,498	No	1997
Halifax Electric	G	Massachusetts	Plymouth	0.90	13,498	No	1997
Halifax Electric	G	Massachusetts	Plymouth	0.90	13,498	No	1997
Richmond Electric	G	Virginia	Henrico	0.90	13,182	No	1993
Richmond Electric	G	Virginia	Henrico	0.90	13,182	No	1993
Sunset Farms	G	Texas	Travis	0.90	13,072	No	1996
Sunset Farms	G	Texas	Travis	0.90	13,682	No	2004
Sunset Farms	G	Texas	Travis	0.90	13,072	No	1996
Sunset Farms	G	Texas	Travis	0.90	13,072	No	1996
Fall River Electric	G	Massachusetts	Bristo	0.90	13,448	No	2000
Fall River Electric	G	Massachusetts	Bristo	0.90	13,448	No	2000
Fall River Electric	G	Massachusetts	Bristo	4.40	13,079	No	2000
Chicopee Electric	G	Massachusetts	Hampden	0.90	13,921	No	1993
Chicopee Electric	G	Massachusetts	Hampden	0.90	13,921	No	1993
Rockford Electric	G	Illinois	Ogle	0.90	15,737	No	1996
Rockford Electric	G	Illinois	Ogle	0.90	15,737	No	1996
Mallard Lake Electric	G	Illinois	DuPage	3.80	9,800	No	1997
Mallard Lake Electric	G	Illinois	DuPage	3.80	9,800	No	1997
Mallard Lake Electric	G	Illinois	DuPage	3.80	9,800	No	1997
Quad Cities	G	Illinois	Rock Island	0.90	16,940	No	1998
Quad Cities	G	Illinois	Rock Island	1.00	16,940	No	2002
South Barrington Electric	G	Illinois	DuPage	0.80	12,910	No	1997
South Barrington Electric	G	Illinois	DuPage	0.80	12,910	No	1997
Lyon Development	G	Michigan	Oakland	0.90	16,859	No	1993
Lyon Development	G	Michigan	Oakland	0.90	16,859	No	1993
Lyon Development	G	Michigan	Oakland	0.90	16,859	No	1993
Lyon Development	G	Michigan	Oakland	0.90	16,859	No	1993
Lyon Development	G	Michigan	Oakland	0.90	16,859	No	1993
Arbor Hills	G	Michigan	Washtenaw	3.80	13,682	No	1996
Arbor Hills	G	Michigan	Washtenaw	3.80	13,682	No	1996
Arbor Hills	G	Michigan	Washtenaw	3.80	13,682	No	1996
C & C Electric	G	Michigan	Calhoun	0.90	13,078	No	1995
C & C Electric	G	Michigan	Calhoun	0.90	13,078	No	1995
C & C Electric	G	Michigan	Calhoun	0.90	13,078	No	1995
C & C Electric	G	Michigan	Calhoun	2.30	13,078	No	2007
Pine Bend	G	Minnesota	Dakota	3.80	11,860	No	1996
Pine Bend	G	Minnesota	Dakota	3.80	11,860	No	1996
Pine Bend	G	Minnesota	Dakota	6.00	11,860	No	1996
Charlotte Motor Speedway	G	North Carolina	Cabarrus	4.30	15,603	No	1999
Prima Desheha Landfill	G	California	Orange	2.70	13,849	No	1999
Prima Desheha Landfill	G	California	Orange	2.70	13,849	No	1999
North City Cogen Facility	G	California	San Diego	0.88	14,554	No	1999
North City Cogen Facility	G	California	San Diego	0.88	14,554	No	1999
North City Cogen Facility	G	California	San Diego	0.88	14,554	No	1999
North City Cogen Facility	G	California	San Diego	0.88	14,554	No	1999
Tajiguas Landfill	G	California	Santa Barbara	2.70	11,359	No	2000
HMDC Kingsland Landfill	G	New Jersey	Bergen	0.97	11,668	No	1998
HMDC Kingsland Landfill	G	New Jersey	Bergen	0.97	11,668	No	1998
HMDC Kingsland Landfill	G	New Jersey	Bergen	0.97	11,668	No	1998
Cuyahoga Regional Landfill	G	Ohio	Cuyahoga	1.80	11,088	No	1999
Cuyahoga Regional Landfill	G	Ohio	Cuyahoga	1.80	11,088	No	1999
Monmouth Landfill Gas to Energy	G	New Jersey	Monmouth	7.40	19,760	No	1998
MM Nashville	G	Tennessee	Davidson	0.80	11,549	No	2000
MM Nashville	G	Tennessee	Davidson	0.80	11,549	No	2000
Sonoma Central Landfill Phase I	G	California	Sonoma	0.70	13,634	No	1993
Sonoma Central Landfill Phase I	G	California	Sonoma	0.70	13,634	No	1993
Sonoma Central Landfill Phase I	G	California	Sonoma	0.70	13,634	No	1993
Sonoma Central Landfill Phase I	G	California	Sonoma	0.70	13,634	No	1993
Sonoma Central Landfill Phase II	G	California	Sonoma	0.70	13,643	No	1996
Sonoma Central Landfill Phase II	G	California	Sonoma	0.70	13,643	No	1996
Sonoma Central Landfill Phase II	G	California	Sonoma	0.70	13,643	No	1996
Sonoma Central Landfill Phase II	G	California	Sonoma	0.70	13,643	No	1996
Model City Energy Facility	G	New York	Niagara	0.77	14,280	No	2001
Model City Energy Facility	G	New York	Niagara	0.77	14,280	No	2001
Model City Energy Facility	G	New York	Niagara	0.77	14,280	No	2001
Model City Energy Facility	G	New York	Niagara	0.77	14,280	No	2001
Model City Energy Facility	G	New York	Niagara	0.77	14,280	No	2001
Model City Energy Facility	G	New York	Niagara	0.77	14,280	No	2001
Model City Energy Facility	G	New York	Niagara	0.77	14,280	No	2001
Roxana Resource Recovery	G	Illinois	Madison	0.90	10,870	No	1999
Roxana Resource Recovery	G	Illinois	Madison	0.90	10,870	No	1999
Roxana Resource Recovery	G	Illinois	Madison	0.90	10,870	No	1999
Roxana Resource Recovery	G	Illinois	Madison	0.90	10,870	No	1999
Streator Energy Partners LLC	G	Illinois	La Salle	0.90	10,686	No	1999
Devonshire Power Partners LLC	G	Illinois	Cook	1.00	11,273	No	1997
Devonshire Power Partners LLC	G	Illinois	Cook	1.00	11,273	No	1997
Devonshire Power Partners LLC	G	Illinois	Cook	1.00	11,273	No	1997
Devonshire Power Partners LLC	G	Illinois	Cook	1.00	11,273	No	1997
Devonshire Power Partners LLC	G	Illinois	Cook	1.00	11,273	No	1997

Continued on next page

Current Landfill Gas Power Plants
(Continued)

Plant Name	Boiler/Generator/ Committed Unit	State Name	County	Capacity MW	Heat Rate (Btu/kWh)	Cogeneration	On-line Year
Brickyard Energy Partners LLC	G	Illinois	Vermilion	0.90	11,267	No	1999
Brickyard Energy Partners LLC	G	Illinois	Vermilion	0.90	11,267	No	1999
Brickyard Energy Partners LLC	G	Illinois	Vermilion	0.90	11,267	No	1999
Dixon/Lee Energy Partners LLC	G	Illinois	Lee	0.90	10,414	No	1999
Dixon/Lee Energy Partners LLC	G	Illinois	Lee	0.90	10,414	No	1999
Dixon/Lee Energy Partners LLC	G	Illinois	Lee	0.90	10,414	No	1999
Dixon/Lee Energy Partners LLC	G	Illinois	Lee	0.90	10,414	No	1999
Upper Rock Energy Partners LLC	G	Illinois	Rock Island	0.90	11,216	No	2000
Upper Rock Energy Partners LLC	G	Illinois	Rock Island	0.90	11,216	No	2000
Upper Rock Energy Partners LLC	G	Illinois	Rock Island	0.90	11,216	No	2000
Green Knight Energy Center	G	Pennsylvania	Northhampton	2.40	18,344	No	2001
Green Knight Energy Center	G	Pennsylvania	Northhampton	2.40	18,344	No	2001
Green Knight Energy Center	G	Pennsylvania	Northhampton	2.40	18,344	No	2001
Kiefer Landfill	G	California	Sacramento	2.80	13,682	No	1999
Kiefer Landfill	G	California	Sacramento	2.80	13,682	No	1999
Kiefer Landfill	G	California	Sacramento	2.80	13,682	No	1999
Riveside Resource Recovery LLC	G	Illinois	Will	0.90	10,960	No	1997
Avon Energy Partners LLC	G	Illinois	Cook	0.90	10,378	No	1997
Avon Energy Partners LLC	G	Illinois	Cook	0.90	10,378	No	1997
Dane County Landfill #2 Rodefeld	G	Wisconsin	Dane	0.80	10,822	No	2004
Dane County Landfill #2 Rodefeld	G	Wisconsin	Dane	1.60	13,682	No	2004
Dane County Landfill #2 Rodefeld	G	Wisconsin	Dane	0.80	10,822	No	1997
Dane County Landfill #2 Rodefeld	G	Wisconsin	Dane	0.80	10,822	No	1997
P.E.R.C.	G	Washington	Pierce	0.75	15,885	No	1999
P.E.R.C.	G	Washington	Pierce	0.75	15,885	No	1999
P.E.R.C.	G	Washington	Pierce	0.75	15,885	No	1999
Countyside Genco LLC	G	Illinois	Lake	1.30	13,682	No	2000
Countyside Genco LLC	G	Illinois	Lake	1.30	13,682	No	2000
Countyside Genco LLC	G	Illinois	Lake	1.30	13,682	No	2000
Countyside Genco LLC	G	Illinois	Lake	1.30	13,682	No	2000
Countyside Genco LLC	G	Illinois	Lake	1.30	13,682	No	2000
Countyside Genco LLC	G	Illinois	Lake	1.30	13,682	No	2000
Morris Genco LLC	G	Illinois	Grundy	1.30	13,682	No	2001
Morris Genco LLC	G	Illinois	Grundy	1.30	13,682	No	2001
Morris Genco LLC	G	Illinois	Grundy	1.30	13,682	No	2001
Barre	G	Massachusetts	Worcester	0.40	12,310	No	1996
Barre	G	Massachusetts	Worcester	0.40	12,310	No	1996
Brookhaven Facility	G	New York	Suffolk	1.20	10,485	No	1997
Brookhaven Facility	G	New York	Suffolk	1.20	10,485	No	1997
Brookhaven Facility	G	New York	Suffolk	1.20	10,485	No	1998
Brookhaven Facility	G	New York	Suffolk	1.20	10,485	No	1998
Dunbarton Energy Partners LP	G	New	Hillsborough	0.60	11,751	No	1996
Dunbarton Energy Partners LP	G	New	Hillsborough	0.60	11,751	No	2001
Veolia Glacier Ridge Landfill	G	Wisconsin	Dodge	0.90	13,682	No	2001
Veolia Glacier Ridge Landfill	G	Wisconsin	Dodge	0.90	13,682	No	2001
RCWMD Badlands Landfill Gas Project	G	California	Riverside	1.00	13,682	No	2001
Sonoma Central Landfill Phase III	G	California	Sonoma	0.70	13,643	No	2004
Sonoma Central Landfill Phase III	G	California	Sonoma	0.70	13,643	No	2004
Ridgeview	G	Wisconsin	Manitowoc	0.80	13,682	No	2006
Ridgeview	G	Wisconsin	Manitowoc	0.80	11,087	No	2002
Ridgeview	G	Wisconsin	Manitowoc	0.80	11,087	No	2002
Ridgeview	G	Wisconsin	Manitowoc	0.80	13,682	No	2006
Ridgeview	G	Wisconsin	Manitowoc	0.80	11,087	No	2003
Ridgeview	G	Wisconsin	Manitowoc	0.80	11,087	No	2002
Ridgeview	G	Wisconsin	Manitowoc	0.80	13,682	No	2006
Ridgeview	G	Wisconsin	Manitowoc	0.80	13,682	No	2006
Ridgeview	G	Wisconsin	Manitowoc	0.80	13,682	No	2006
Ridgeview	G	Wisconsin	Manitowoc	0.80	13,682	No	2006
PG Cnty Brown Station Road II	G	Maryland	Prince George's	0.98	13,682	No	2003
PG Cnty Brown Station Road II	G	Maryland	Prince George's	0.98	13,682	No	2003
PG Cnty Brown Station Road II	G	Maryland	Prince George's	0.98	13,682	No	2003
PG Cnty Brown Station Road II	G	Maryland	Prince George's	0.98	13,682	No	2003
Berlin	G	Wisconsin	Green Lake	0.82	11,900	No	2001
Berlin	G	Wisconsin	Green Lake	0.82	11,900	No	2001
Berlin	G	Wisconsin	Green Lake	0.80	11,900	No	2001
BFI Tessman Rd Landfill	G	Texas	Bexar	1.40	13,682	No	2003
Lee County Landfill	G	South Carolina	Lee	1.90	10,123	No	2005
Lee County Landfill	G	South Carolina	Lee	1.90	10,123	No	2005
Lee County Landfill	G	South Carolina	Lee	1.90	10,123	No	2005
Lee County Landfill	G	South Carolina	Lee	1.90	13,682	No	2007
Anderson Regional Landfill	G	South Carolina	Anderson	5.30	13,682	No	2006
Richland County Landfill	G	South Carolina	Richland	5.30	13,682	No	2006
Seven Mile Creek LFG	G	Wisconsin	Eau Claire	0.80	13,682	No	2006
Seven Mile Creek LFG	G	Wisconsin	Eau Claire	0.83	10,123	No	2004
Seven Mile Creek LFG	G	Wisconsin	Eau Claire	0.83	10,123	No	2004
Seven Mile Creek LFG	G	Wisconsin	Eau Claire	0.83	10,123	No	2004
Colton Landfill	G	California	San Bernardino	1.27	12,143	No	2003
Mid Valley Landfill	G	California	San Bernardino	1.27	12,178	No	2003
Mid Valley Landfill	G	California	San Bernardino	1.27	12,178	No	2003
Milliken Landfill	G	California	San Bernardino	1.07	12,157	No	2003
Milliken Landfill	G	California	San Bernardino	1.07	12,157	No	2003
Ontario LFGTE	G	New York	Ontario	0.80	11,148	No	2003
Ontario LFGTE	G	New York	Ontario	0.80	11,148	No	2003
Ontario LFGTE	G	New York	Ontario	0.80	10,500	No	2005
Ontario LFGTE	G	New York	Ontario	0.80	10,500	No	2005
Ontario LFGTE	G	New York	Ontario	0.80	10,500	No	2005
Ontario LFGTE	G	New York	Ontario	0.80	11,148	No	2003
Ontario LFGTE	G	New York	Ontario	0.80	11,148	No	2003

Continued on next page

Current Landfill Gas Power Plants
(Continued)

Plant Name	Boiler/Generator/Committed Unit	State Name	County	Capacity MW	Heat Rate (Btu/kWh)	Cogeneration	On-line Year
Bavarian LFGTE	G	Kentucky	Boone	0.80	13,343	No	2003
Bavarian LFGTE	G	Kentucky	Boone	0.80	13,343	No	2003
Bavarian LFGTE	G	Kentucky	Boone	0.80	13,343	No	2003
Bavarian LFGTE	G	Kentucky	Boone	0.80	13,343	No	2003
Green Valley LFGTE	G	Kentucky	Greenup	0.80	13,556	No	2003
Green Valley LFGTE	G	Kentucky	Greenup	0.80	13,556	No	2003
Green Valley LFGTE	G	Kentucky	Greenup	0.80	13,556	No	2003
Laurel Ridge LFGTE	G	Kentucky	Laurel	0.80	13,231	No	2003
Laurel Ridge LFGTE	G	Kentucky	Laurel	0.80	13,231	No	2003
Laurel Ridge LFGTE	G	Kentucky	Laurel	0.80	13,231	No	2003
Laurel Ridge LFGTE	G	Kentucky	Laurel	0.80	11,021	No	2006
Laurel Ridge LFGTE	G	Kentucky	Laurel	0.80	13,231	No	2003
Hardin County LFGTE	G	Kentucky	Hardin	0.80	13,682	No	2006
Hardin County LFGTE	G	Kentucky	Hardin	0.80	13,682	No	2006
Hardin County LFGTE	G	Kentucky	Hardin	0.80	13,682	No	2006
Fauquier Landfill Gas	G	Virginia	Fauquier	1.00	13,682	No	2004
Fauquier Landfill Gas	G	Virginia	Fauquier	1.00	13,682	No	2004
Modern Innovative Energy LLC	G	New York	Niagara	1.60	13,682	No	2006
Modern Innovative Energy LLC	G	New York	Niagara	1.60	13,682	No	2006
Modern Innovative Energy LLC	G	New York	Niagara	1.60	13,682	No	2006
Modern Innovative Energy LLC	G	New York	Niagara	1.60	13,682	No	2006
Colonie LFGTE Facility	G	New York	Albany	1.60	13,682	No	2006
Colonie LFGTE Facility	G	New York	Albany	1.60	13,682	No	2006
Colonie LFGTE Facility	G	New York	Albany	1.60	13,682	No	2006
Pendleton County LFGTE	G	Kentucky	Pendleton	0.80	13,682	No	2007
Pendleton County LFGTE	G	Kentucky	Pendleton	0.80	13,682	No	2007
Pendleton County LFGTE	G	Kentucky	Pendleton	0.80	13,682	No	2007
Pendleton County LFGTE	G	Kentucky	Pendleton	0.80	13,682	No	2007
Noble Hill Landfill	G	Missouri	Greene	3.00	13,682	No	2006
AMERESCO Chicopee Energy	G	Massachusetts	Hampden	1.90	13,648	No	2004
AMERESCO Chicopee Energy	G	Massachusetts	Hampden	1.90	13,648	No	2004
AMERESCO Chicopee Energy	G	Massachusetts	Hampden	1.90	13,648	No	2004
AMERESCO Janesville	G	Wisconsin	Rock	1.00	13,682	No	2004
AMERESCO Janesville	G	Wisconsin	Rock	1.00	13,682	No	2004
AMERESCO Janesville	G	Wisconsin	Rock	1.00	13,682	No	2004
AMERESCO Santa Cruz Energy	G	California	Santa Cruz	1.00	13,682	No	2006
AMERESCO Santa Cruz Energy	G	California	Santa Cruz	1.00	13,682	No	2006
AMERESCO Santa Cruz Energy	G	California	Santa Cruz	1.00	13,682	No	2006
AMERESCO Delaware South	G	Delaware	Sussex	1.00	13,682	No	2006
AMERESCO Delaware South	G	Delaware	Sussex	1.00	13,682	No	2006
AMERESCO Delaware South	G	Delaware	Sussex	1.00	13,682	No	2006
AMERESCO Delaware South	G	Delaware	Sussex	1.00	13,682	No	2006
AMERESCO Delaware South	G	Delaware	Sussex	1.00	11,430	No	2008
AMERESCO Delaware Central	G	Delaware	Kent	1.00	13,682	No	2006
AMERESCO Delaware Central	G	Delaware	Kent	1.00	13,682	No	2006
AMERESCO Delaware Central	G	Delaware	Kent	1.00	13,682	No	2006
Oak Ridge	G	Indiana	Cass	0.80	13,682	No	2003
Oak Ridge	G	Indiana	Cass	0.80	13,682	No	2003
Oak Ridge	G	Indiana	Cass	0.80	13,682	No	2003
Oak Ridge	G	Indiana	Cass	0.80	13,682	No	2003
Jay County	G	Indiana	Jay	0.80	13,682	No	2005
Jay County	G	Indiana	Jay	0.80	13,682	No	2005
Jay County	G	Indiana	Jay	0.80	13,682	No	2005
Jay County	G	Indiana	Jay	0.80	13,682	No	2005
Liberty	G	Indiana	White	0.80	13,682	No	2005
Liberty	G	Indiana	White	0.80	13,682	No	2005
Liberty	G	Indiana	White	0.80	13,682	No	2005
Liberty	G	Indiana	White	0.80	13,682	No	2005
Deertrack Park Gas Recovery	G	Wisconsin	Jefferson	0.80	13,682	No	2006
Deertrack Park Gas Recovery	G	Wisconsin	Jefferson	0.80	13,682	No	2006
Deertrack Park Gas Recovery	G	Wisconsin	Jefferson	0.80	13,682	No	2006
Deertrack Park Gas Recovery	G	Wisconsin	Jefferson	0.80	13,682	No	2006
Lake Mills Gas Recovery	G	Iowa	Winnebago	0.80	13,682	No	2006
Lake Mills Gas Recovery	G	Iowa	Winnebago	0.80	13,682	No	2006
Lake Mills Gas Recovery	G	Iowa	Winnebago	0.80	13,682	No	2006
Lake Mills Gas Recovery	G	Iowa	Winnebago	0.80	13,682	No	2006
Lake Mills Gas Recovery	G	Iowa	Winnebago	0.80	13,682	No	2006
Lake Mills Gas Recovery	G	Iowa	Winnebago	0.80	13,682	No	2006
Springhill Gas Recovery	G	Florida	Jackson	0.80	13,682	No	2006
Springhill Gas Recovery	G	Florida	Jackson	0.80	13,682	No	2006
Springhill Gas Recovery	G	Florida	Jackson	0.80	13,682	No	2006
Springhill Gas Recovery	G	Florida	Jackson	0.80	13,682	No	2006
Springhill Gas Recovery	G	Florida	Jackson	0.80	13,682	No	2006
Springhill Gas Recovery	G	Florida	Jackson	0.80	13,682	No	2006
Two Pine Gas Recovery	G	Arkansas	Pulaski	0.80	13,682	No	2006
Two Pine Gas Recovery	G	Arkansas	Pulaski	0.80	13,682	No	2006
Two Pine Gas Recovery	G	Arkansas	Pulaski	0.80	13,682	No	2006
Two Pine Gas Recovery	G	Arkansas	Pulaski	0.80	13,682	No	2006
Two Pine Gas Recovery	G	Arkansas	Pulaski	0.80	13,682	No	2006
Two Pine Gas Recovery	G	Arkansas	Pulaski	0.80	13,682	No	2006
Timberline Trails Gas Recovery	G	Wisconsin	Rusk	0.80	13,682	No	2006
Timberline Trails Gas Recovery	G	Wisconsin	Rusk	0.80	13,682	No	2006
Timberline Trails Gas Recovery	G	Wisconsin	Rusk	0.80	13,682	No	2006
Timberline Trails Gas Recovery	G	Wisconsin	Rusk	0.80	13,682	No	2006

Continued on next page

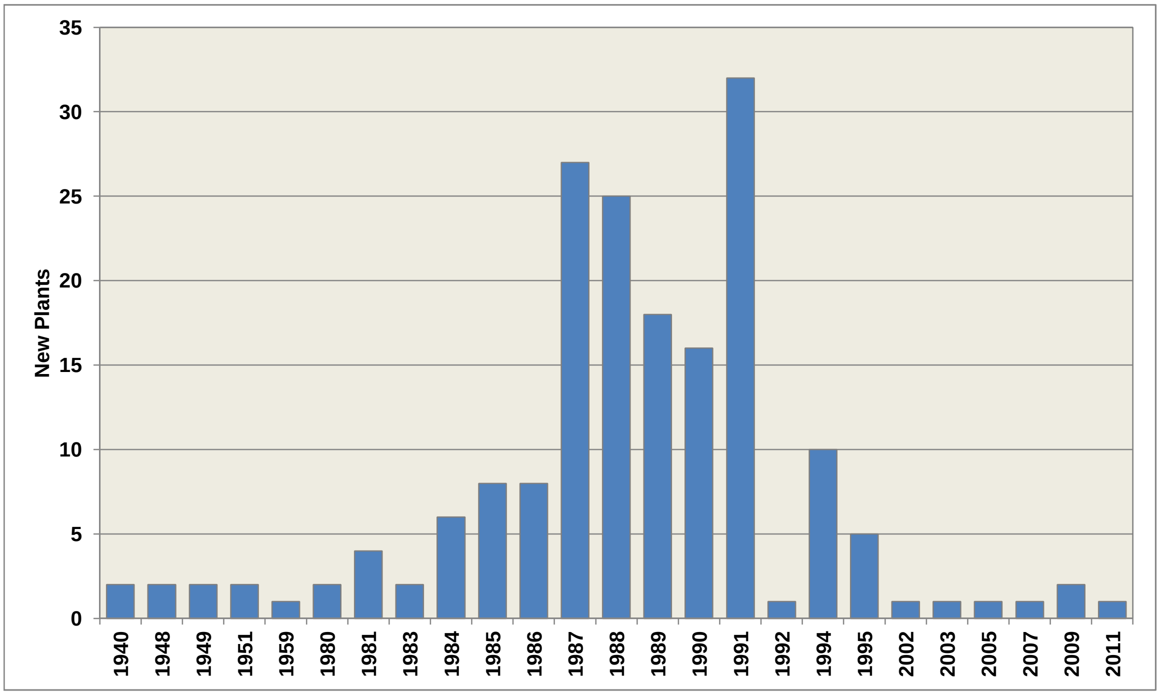
Current Landfill Gas Power Plants
(Continued)

Plant Name	Boiler/Generator/Committed Unit	State Name	County	Capacity MW	Heat Rate (Btu/kWh)	Cogeneration	On-line Year
Bradley Gas Recovery	G	California	Los	1.30	13,682	No	2004
Bradley Gas Recovery	G	California	Los	1.30	13,682	No	2004
Bradley Gas Recovery	G	California	Los	1.30	13,682	No	2004
Bradley Gas Recovery	G	California	Los	1.30	13,682	No	2004
Bradley Gas Recovery	G	California	Los	1.30	13,682	No	2004
El Sobrante Gas Recovery	G	California	Riversid	1.30	13,682	No	2004
El Sobrante Gas Recovery	G	California	Riversid	1.30	13,682	No	2004
El Sobrante Gas Recovery	G	California	Riversid	1.30	13,682	No	2004
Simi Valley	G	California	Ventura	1.30	13,682	No	2004
Simi Valley	G	California	Ventura	1.30	13,682	No	2004
Salt Lake Energy Systems	G	Utah	Salt	1.50	13,682	No	2006
Salt Lake Energy Systems	G	Utah	Salt	0.77	13,682	No	2006
Salt Lake Energy Systems	G	Utah	Salt	0.77	13,682	No	2006
Eastern Landfill Gas LLC	G	Maryland	Baltimor	1.00	13,682	No	2006
Eastern Landfill Gas LLC	G	Maryland	Baltimor	1.00	13,682	No	2006
Eastern Landfill Gas LLC	G	Maryland	Baltimor	1.00	13,682	No	2006
American Canyon SLF	G	California	Napa	0.21	13,682	No	2006
Burlington County SL	G	New Jersey	Burlingt	7.20	13,682	No	2006
Cedar Hills LF	G	Washington	King	26.00	13,682	No	2006
Chittenden County LF	G	Vermont	Chittend	0.09	13,682	No	2006
Clinton LF #2	G	Illinois	De Witt	3.20	13,682	No	2006
Fort Worth Regional	G	Texas	Tarrant	1.60	13,682	No	2006
Frey Farm Landfill	G	Pennsylvania	Lancast	3.20	13,682	No	2006
Glendale Road LF	G	Massachusett	Hampsh	0.80	13,682	No	2006
Kiefer LF	G	California	Sacram	3.00	13,682	No	2006
Los Angeles Landfill	G	New Mexico	Bernalill	0.07	13,682	No	2006
Los Reales LFG Expan	G	Arizona	Pima	1.90	13,682	No	2006
Orange County LF	G	New York	Orange	2.12	13,682	No	2006
Seminole Road MSW La	G	Georgia	Dekalb	3.20	13,682	No	2006
Warren County LF	G	New Jersey	Warren	3.80	13,682	No	2006
Waste Disposal Engin	G	Minnesota	Anoka	0.22	13,682	No	2006
Texas Mandate Landfill Gas	C	Texas	NA	5.00	13,682	No	2007
Texas Mandate Landfill Gas	C	Texas	NA	5.00	13,648	No	2008
Tullytown LF	G	Pennsylvania	Bucks	2.20	13,648	No	2007
Coventry LFG	G	Vermont	Orleans	1.60	10,265	No	2007
GROWS LF	G	Pennsylvania	Bucks	2.50	10,500	No	2007
Seccra LF	G	Pennsylvania	Chester	0.84	10,500	No	2007
Sauk County LF	G	Wisconsin	Sauk	0.36	10,500	No	2007
Cape May County SLF	G	New Jersey	Cape	0.30	10,500	No	2007
Newland Park SLF	G	Maryland	Wicomi	3.10	10,500	No	2007
Dry Creek Landfill	G	Oregon	Jackson	3.20	10,500	No	2007
East Windsor NORCAP	G	Connecticut	Hartford	3.00	13,682	No	2007
CA-N_CA_Landfill Gas	C	California	NA	16.80	13,648	No	2011
CA-S_CA_Landfill Gas	C	California	NA	8.00	13,648	No	2011
COMD_IL_Landfill Gas	C	Illinois	NA	6.40	13,648	No	2011
ERCT_TX_Landfill Gas	C	Texas	NA	6.40	13,648	No	2011
GWAY_MO_Landfill Gas	C	Missouri	NA	5.27	13,648	No	2011
MACS_MD_Landfill Gas	C	Maryland	NA	4.50	13,648	No	2011
MACW_PA_Landfill Gas	C	Pennsylvania	NA	21.70	13,648	No	2011
MECS_MI_Landfill Gas	C	Michigan	NA	8.00	13,648	No	2011
MRO_MN_Landfill Gas	C	Minnesota	NA	3.20	13,648	No	2011
MRO_WI_Landfill Gas	C	Wisconsin	NA	3.15	13,648	No	2011
NENG_ME_Landfill Gas	C	Maine	NA	3.00	13,648	No	2011
NENG_MA_Landfill Gas	C	Massachusett	NA	3.80	13,648	No	2011
PNW_ID_Landfill Gas	C	Idaho	NA	3.20	13,648	No	2011
PNW_OR_Landfill Gas	C	Oregon	NA	4.00	13,648	No	2011
RFCO_IN_Landfill Gas	C	Indiana	NA	12.52	13,648	No	2011
RFCO_OH_Landfill Gas	C	Ohio	NA	13.42	13,648	No	2011
RFCP_OH_Landfill Gas	C	Ohio	NA	4.80	13,648	No	2011
RMPA_CO_Landfill Gas	C	Colorado	NA	6.20	13,648	No	2011
TVAK_KY_Landfill Gas	C	Kentucky	NA	1.60	13,648	No	2011
UPNY_NY_Landfill Gas	C	New York	NA	14.40	13,648	No	2011
VACA_NC_Landfill Gas	C	North	NA	8.40	13,648	No	2011
VACA_SC_Landfill Gas	C	South	NA	6.40	13,648	No	2011
VAPW_VA_Landfill Gas	C	Virginia	NA	30.94	13,648	No	2011
WUMS_WI_Landfill Gas	C	Wisconsin	NA	7.55	13,648	No	2011
MACE_NJ_Landfill Gas	C	New Jersey	NA	3.80	13,648	No	2011
FRCC_FL_Landfill Gas	C	Florida	NA	20.75	13,648	No	2011
MACE_MD_Landfill Gas	C	Maryland	NA	2.00	13,648	No	2011
MACE_PA_Landfill Gas	C	Pennsylvania	NA	1.60	13,648	No	2011

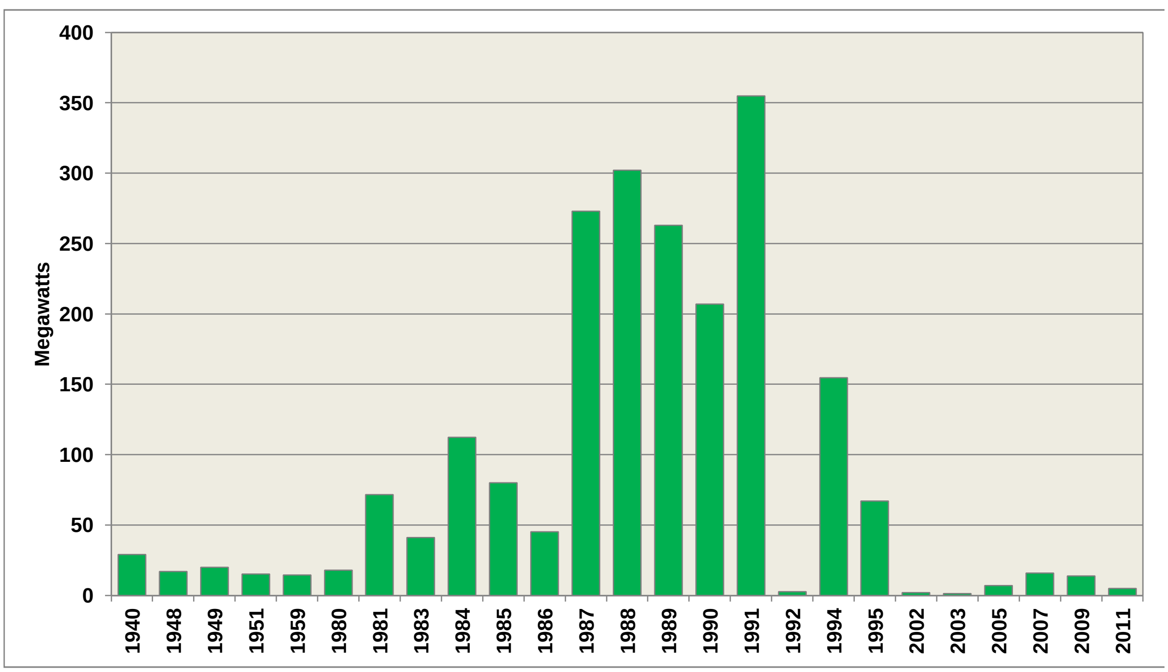
Source:
National Electric Energy System (NEEDS) Database for IPM 2010.
http://epa.gov/airmarkets/progsregs/epa-ipm/BaseCasev410.html

[a] Data are not available

Section: BIOPOWER
New Municipal Solid Waste Power Plants by Year



Municipal Solid Waste Power Plant Capacity by Year
(Megawatt Hours)



Source:
National Electric Energy System (NEEDS) Database for IPM 2010.
http://epa.gov/airmarkets/progsregs/epa-ipm/BaseCasev410.html

Notes:
1. Only years in which new plants were brought online are shown.
2. Power plant capacity based on NEEDS 2010 Data.

Current Municipal Solid Waste Power Plants

Plant Name	Boiler/Generator/ Committed Unit	State Name	County	Capacity MW	Heat Rate (Btu/kWh)	Cogeneration	On-line Year
French Island	B	Wisconsin	La Crosse	14.50	10,400	N	1940
French Island	B	Wisconsin	La Crosse	14.50	10,400	N	1940
Red Wing	B	Minnesota	Goodhue	10.00	20,114	N	1949
Red Wing	B	Minnesota	Goodhue	10.00	19,817	N	1949
Wilmarth	B	Minnesota	Blue Earth	9.00	19,243	N	1948
Wilmarth	B	Minnesota	Blue Earth	8.00	19,266	N	1948
Elk River	B	Minnesota	Sherburne	7.80	14,800	N	1951
Elk River	B	Minnesota	Sherburne	7.50	14,800	N	1951
Elk River	B	Minnesota	Sherburne	14.50	14,800	N	1959
Covanta Warren Energy	B	New Jersey	Warren	5.00	18,843	N	1988
Covanta Warren Energy	B	New Jersey	Warren	5.00	19,338	N	1988
Covanta Hennepin Energy	B	Minnesota	Hennepin	16.85	19,338	N	1989
Covanta Hennepin Energy	B	Minnesota	Hennepin	16.85	19,338	N	1989
Greater Detroit Resource Recovery	B	Michigan	Wayne	21.20	19,338	Y	1988
Greater Detroit Resource Recovery	B	Michigan	Wayne	21.20	19,338	Y	1988
Greater Detroit Resource Recovery	B	Michigan	Wayne	21.20	19,338	Y	1988
Miami Dade County Resource Recovery	B	Florida	Miami Dade	17.91	19,338	N	1981
Miami Dade County Resource Recovery	B	Florida	Miami Dade	17.91	19,338	N	1981
Miami Dade County Resource Recovery	B	Florida	Miami Dade	17.91	19,338	N	1981
Miami Dade County Resource Recovery	B	Florida	Miami Dade	17.91	19,338	N	1981
Commerce Refuse To Energy	B	California	Los Angeles	9.00	19,338	N	1986
Harrisburg Facility	B	Pennsylvania	Dauphin	6.93	19,338	Y	2009
Harrisburg Facility	B	Pennsylvania	Dauphin	6.93	19,338	Y	2009
Harrisburg Facility	B	Pennsylvania	Dauphin	6.93	19,338	Y	2005
Bay Resource Management Center	B	Florida	Bay	5.00	19,338	N	1987
Bay Resource Management Center	B	Florida	Bay	5.00	19,338	N	1987
Dutchess Cnty Resource Recovery	G	New York	Dutchess	7.20	28,175	N	1987
Maine Energy Recovery	B	Maine	York	9.00	19,338	N	1987
Maine Energy Recovery	B	Maine	York	9.00	19,338	N	1987
Charleston Resource Recovery Facility	B	South Carolina	Charleston	4.75	19,338	Y	1989
Charleston Resource Recovery Facility	B	South Carolina	Charleston	4.75	19,338	Y	1989
Camden Resource Recovery Facility	B	New Jersey	Camden	10.00	19,338	N	1991
Camden Resource Recovery Facility	B	New Jersey	Camden	10.00	19,338	N	1991
Camden Resource Recovery Facility	B	New Jersey	Camden	10.00	19,338	N	1991
Wheelabrator Hudson Falls	B	New York	Washington	5.75	19,338	N	1991
Wheelabrator Hudson Falls	B	New York	Washington	5.75	19,338	N	1991
Wheelabrator Baltimore Refuse	B	Maryland	City of Baltimore	20.43	19,338	Y	1984
Wheelabrator Baltimore Refuse	B	Maryland	City of Baltimore	20.43	19,338	Y	1984
Wheelabrator Baltimore Refuse	B	Maryland	City of Baltimore	20.43	19,338	Y	1984
Covanta Hempstead	B	New York	Nassau	23.67	19,338	N	1989
Covanta Hempstead	B	New York	Nassau	23.67	19,338	N	1989
Covanta Hempstead	B	New York	Nassau	23.67	19,338	N	1989
American Ref-Fuel of Essex	B	New Jersey	Essex	10.00	19,338	N	1990
American Ref-Fuel of Essex	B	New Jersey	Essex	10.00	19,338	N	1990
American Ref-Fuel of Essex	B	New Jersey	Essex	40.00	19,338	N	1990
American Ref-Fuel of SE CT	B	Connecticut	New London	8.00	19,338	N	1991
American Ref-Fuel of SE CT	B	Connecticut	New London	8.00	19,338	N	1991
Jackson County Resource Recovery	G	Michigan	Jackson	3.00	19,338	Y	1987
American Ref-Fuel of Delaware Valley	B	Pennsylvania	Delaware	13.33	18,434	N	1991
American Ref-Fuel of Delaware Valley	B	Pennsylvania	Delaware	13.33	18,434	N	1991
American Ref-Fuel of Delaware Valley	B	Pennsylvania	Delaware	13.33	18,434	N	1991
American Ref-Fuel of Delaware Valley	B	Pennsylvania	Delaware	13.33	18,434	N	1991
American Ref-Fuel of Delaware Valley	B	Pennsylvania	Delaware	13.33	18,434	N	1991
American Ref-Fuel of Delaware Valley	B	Pennsylvania	Delaware	13.33	18,434	N	1991
MMWAC Resource Recovery Facility	G	Maine	Androscoggin	2.70	19,338	N	1992
Penobscot Energy Recovery	B	Maine	Penobscot	10.60	19,338	N	1987
Penobscot Energy Recovery	B	Maine	Penobscot	10.60	19,338	N	1987
North County Regional Resource	B	Florida	Palm Beach	23.75	19,338	N	1989
North County Regional Resource	B	Florida	Palm Beach	23.75	19,338	N	1989
York County Resource Recovery	B	Pennsylvania	York	9.50	19,338	N	1989
York County Resource Recovery	B	Pennsylvania	York	9.50	19,338	N	1989
York County Resource Recovery	B	Pennsylvania	York	9.50	19,338	N	1989
Regional Waste Systems	B	Maine	Cumberland	5.75	19,338	N	1988
Regional Waste Systems	B	Maine	Cumberland	5.75	19,338	N	1988
New Hanover County WASTEC	B	North Carolina	New Hanover	0.57	19,338	N	1991
New Hanover County WASTEC	B	North Carolina	New Hanover	0.57	19,338	N	1991
New Hanover County WASTEC	B	North Carolina	New Hanover	0.57	19,338	N	1991
New Hanover County WASTEC	G	North Carolina	New Hanover	1.90	29,317	N	2002
Pioneer Valley Resource Recovery	G	Massachusetts	Hampden	7.50	22,403	N	1988
SEMASS Resource Recovery	B	Massachusetts	Plymouth	26.67	19,338	N	1988
SEMASS Resource Recovery	B	Massachusetts	Plymouth	26.67	19,338	N	1988
SEMASS Resource Recovery	B	Massachusetts	Plymouth	26.67	19,338	N	1988
Olmsted Waste Energy	G	Minnesota	Olmsted	1.30	19,338	Y	1987
Olmsted Waste Energy	G	Minnesota	Olmsted	1.40	19,338	Y	1987
American Ref-Fuel of Niagara	B	New York	Niagara	9.00	19,338	Y	1980
American Ref-Fuel of Niagara	B	New York	Niagara	9.00	19,338	Y	1980
Covanta Lake County Energy	B	Florida	Lake	6.25	19,338	N	1990
Covanta Lake County Energy	B	Florida	Lake	6.25	19,338	N	1990
Covanta Marion Inc	B	Oregon	Marion	5.75	19,338	Y	1986
Covanta Marion Inc	B	Oregon	Marion	5.75	19,338	Y	1986
Covanta Stanislaus Energy	B	California	Stanislaus	9.00	19,338	N	1988
Covanta Stanislaus Energy	B	California	Stanislaus	9.00	19,338	N	1988
Covanta Indianapolis Energy	G	Indiana	Marion	5.00	19,338	Y	1988

Continued on next page

Current Municipal Solid Waste Power Plants
(Continued)

Plant Name	Boiler/Generator/ Committed Unit	State Name	County	Capacity MW	Heat Rate (Btu/kWh)	Cogeneration	On-line Year
Covanta Bristol Energy	B	Connecticut	Hartford	6.60	19,338	N	1987
Covanta Bristol Energy	B	Connecticut	Hartford	6.60	19,338	N	1987
Covanta Babylon Energy	B	New York	Suffolk	7.18	19,338	N	1989
Covanta Babylon Energy	B	New York	Suffolk	7.18	19,338	N	1989
Huntington Resource Recovery Facility	B	New York	Suffolk	8.33	19,338	N	1991
Huntington Resource Recovery Facility	B	New York	Suffolk	8.33	19,338	N	1991
Huntington Resource Recovery Facility	B	New York	Suffolk	8.33	19,338	N	1991
Montgomery County Resource Recovery	B	Maryland	Montgomery	18.00	19,338	N	1995
Montgomery County Resource Recovery	B	Maryland	Montgomery	18.00	19,338	N	1995
Montgomery County Resource Recovery	B	Maryland	Montgomery	18.00	19,338	N	1995
Covanta Fairfax Energy	B	Virginia	Fairfax	19.75	19,338	N	1990
Covanta Fairfax Energy	B	Virginia	Fairfax	19.75	19,338	N	1990
Covanta Fairfax Energy	B	Virginia	Fairfax	19.75	19,338	N	1990
Covanta Fairfax Energy	B	Virginia	Fairfax	19.75	19,338	N	1990
Covanta Haverhill	B	Massachusetts	Essex	21.39	19,338	N	1989
Covanta Haverhill	B	Massachusetts	Essex	21.39	19,338	N	1989
Onondaga County Resource Recovery	B	New York	Onondaga	10.00	19,338	N	1994
Onondaga County Resource Recovery	B	New York	Onondaga	10.00	19,338	N	1994
Onondaga County Resource Recovery	B	New York	Onondaga	10.00	19,338	N	1994
Covanta Alexandria/Arlington Energy	B	Virginia	Alexandria (city)	9.67	19,338	N	1987
Covanta Alexandria/Arlington Energy	B	Virginia	Alexandria (city)	9.67	19,338	N	1987
Covanta Alexandria/Arlington Energy	B	Virginia	Alexandria (city)	9.67	19,338	N	1987
Covanta Wallingford Energy	B	Connecticut	New Haven	2.12	19,338	N	1988
Covanta Wallingford Energy	B	Connecticut	New Haven	2.12	19,338	N	1988
Covanta Wallingford Energy	B	Connecticut	New Haven	2.12	19,338	N	1988
Pasco Cnty Solid Waste Resource	B	Florida	Pasco	8.67	19,338	N	1991
Pasco Cnty Solid Waste Resource	B	Florida	Pasco	8.67	19,338	N	1991
Pasco Cnty Solid Waste Resource	B	Florida	Pasco	8.67	19,338	N	1991
Southeast Resource Recovery	B	California	Los Angeles	9.32	19,338	Y	1988
Southeast Resource Recovery	B	California	Los Angeles	9.32	19,338	Y	1988
Southeast Resource Recovery	B	California	Los Angeles	9.32	19,338	Y	1988
Hillsborough County Resource Recovery	B	Florida	Hillsborough	8.67	19,338	N	1987
Hillsborough County Resource Recovery	B	Florida	Hillsborough	8.67	19,338	N	1987
Hillsborough County Resource Recovery	B	Florida	Hillsborough	8.67	19,338	N	1987
Lancaster County Resource Recovery	B	Pennsylvania	Lancaster	10.80	19,338	N	1990
Lancaster County Resource Recovery	B	Pennsylvania	Lancaster	10.80	19,338	N	1990
Lancaster County Resource Recovery	B	Pennsylvania	Lancaster	10.80	19,338	N	1990
Kent County Waste to Energy Facility	B	Michigan	Kent	7.85	19,338	Y	1989
Kent County Waste to Energy Facility	B	Michigan	Kent	7.85	19,338	Y	1989
Wheelabrator Claremont Facility	G	New Hampshire	Sullivan	2.25	22,443	N	1986
Wheelabrator Claremont Facility	G	New Hampshire	Sullivan	2.25	21,020	N	1986
Wheelabrator Concord Facility	B	New Hampshire	Merrimack	7.00	19,338	N	1988
Wheelabrator Concord Facility	B	New Hampshire	Merrimack	7.00	19,338	N	1988
McKay Bay Facility	B	Florida	Hillsborough	4.50	19,338	N	1985
McKay Bay Facility	B	Florida	Hillsborough	4.50	19,338	N	1985
McKay Bay Facility	B	Florida	Hillsborough	4.50	19,338	N	1985
McKay Bay Facility	B	Florida	Hillsborough	4.50	19,338	N	1985
Wheelabrator North Andover	B	Massachusetts	Essex	15.00	19,338	N	1985
Wheelabrator North Andover	B	Massachusetts	Essex	15.00	19,338	N	1985
Wheelabrator Millbury Facility	B	Massachusetts	Worcester	20.00	19,338	N	1987
Wheelabrator Millbury Facility	B	Massachusetts	Worcester	20.00	19,338	N	1987
Wheelabrator Saugus	B	Massachusetts	Essex	16.00	19,338	N	1985
Wheelabrator Saugus	B	Massachusetts	Essex	16.00	19,338	N	1985
Wheelabrator Westchester	B	New York	Westchester	17.00	19,338	N	1984
Wheelabrator Westchester	B	New York	Westchester	17.00	19,338	N	1984
Wheelabrator Westchester	B	New York	Westchester	17.00	19,338	N	1984
Wheelabrator Bridgeport	B	Connecticut	Fairfield	19.40	19,338	N	1988
Wheelabrator Bridgeport	B	Connecticut	Fairfield	19.40	19,338	N	1988
Wheelabrator Bridgeport	B	Connecticut	Fairfield	19.40	19,338	N	1988
Pinellas County Resource Recovery	B	Florida	Pinellas	17.00	19,338	N	1986
Pinellas County Resource Recovery	B	Florida	Pinellas	20.55	19,338	N	1983
Pinellas County Resource Recovery	B	Florida	Pinellas	20.55	19,338	N	1983
Wheelabrator Gloucester LP	B	New Jersey	Gloucester	6.00	19,338	N	1990
Wheelabrator Gloucester LP	B	New Jersey	Gloucester	6.00	19,338	N	1990
Wheelabrator Spokane	B	Washington	Spokane	11.35	19,338	N	1991
Wheelabrator Spokane	B	Washington	Spokane	11.35	19,338	N	1991
Wheelabrator South Broward	B	Florida	Broward	19.30	19,338	N	1991
Wheelabrator South Broward	B	Florida	Broward	19.30	19,338	N	1991
Wheelabrator South Broward	B	Florida	Broward	19.30	19,338	N	1991
Oswego County Energy Recovery	G	New York	Oswego	1.67	19,338	Y	1986
Oswego County Energy Recovery	G	New York	Oswego	1.67	19,338	Y	1986
Union County Resource Recovery	B	New Jersey	Union	12.50	19,338	N	1994
Union County Resource Recovery	B	New Jersey	Union	12.50	19,338	N	1994
Union County Resource Recovery	B	New Jersey	Union	12.50	19,338	N	1994
MacArthur Waste to Energy Facility	B	New York	Suffolk	5.50	19,338	N	1990
MacArthur Waste to Energy Facility	B	New York	Suffolk	5.50	19,338	N	1990
Lee County Solid Waste Energy	G	Florida	Lee	16.00	19,338	N	2007
Lee County Solid Waste Energy	B	Florida	Lee	19.50	19,338	N	1994
Lee County Solid Waste Energy	B	Florida	Lee	19.50	19,338	N	1994
Wheelabrator North Broward	B	Florida	Broward	18.67	19,338	N	1991
Wheelabrator North Broward	B	Florida	Broward	18.67	19,338	N	1991
Wheelabrator North Broward	B	Florida	Broward	18.67	19,338	N	1991
Montenay Montgomery LF	B	Pennsylvania	Montgomery	14.00	19,338	N	1991
Montenay Montgomery LF	B	Pennsylvania	Montgomery	14.00	19,338	N	1991

Continued on next page

Current Municipal Solid Waste Power Plants
(Continued)

Plant Name	Boiler/Generator/Committed Unit	State Name	County	Capacity MW	Heat Rate (Btu/kWh)	Cogeneration	On-line Year
Wheelabrator Falls	B	Pennsylvania	Bucks	24.05	19,338	N	1994
Wheelabrator Falls	B	Pennsylvania	Bucks	24.05	19,338	N	1994
Wheelabrator Lisbon	B	Connecticut	New London	6.50	19,338	N	1995
Wheelabrator Lisbon	B	Connecticut	New London	6.50	19,338	N	1995
Covanta Mid-Connecticut Energy	B	Connecticut	Hartford	18.69	19,338	N	1987
Covanta Mid-Connecticut Energy	B	Connecticut	Hartford	18.69	19,338	N	1987
Covanta Mid-Connecticut Energy	B	Connecticut	Hartford	18.69	19,338	N	1987
SPSA Waste To Energy Power Plant	B	Virginia	Portsmouth (city)	11.63	19,338	Y	1987
SPSA Waste To Energy Power Plant	B	Virginia	Portsmouth (city)	11.63	19,338	Y	1987
SPSA Waste To Energy Power Plant	B	Virginia	Portsmouth (city)	11.63	19,338	Y	1987
SPSA Waste To Energy Power Plant	B	Virginia	Portsmouth (city)	11.63	19,338	Y	1987
Perham Incinerator	G	Minnesota	Otter Tail	1.24	19,338	Y	2003
MRO_MN_Municipal Solid Waste	C	Minnesota	NA	5.00	19,338	N	2011

Source:
National Electric Energy System (NEEDS) Database for IPM 2010.
http://epa.gov/airmarkets/progsregs/epa-ipm/BaseCasev410.html

Green Pricing Programs, which allow consumers to purchase electricity generated from renewable resources, had more than one million customers in 2009. Ninety-four percent of those were residential customers.

Net metering allows customers to sell any excess power generated over their load requirement back to the distributor to offset consumption. As with green pricing, most of the net metering customers were residential (91%).

Section: BIOPOWER
Green Pricing and Net Metering Customers, 2002 - 2009

	Green Pricing			Net Metering		
Year	**Residential**	**Non Residential**	**Total**	**Residential**	**Non Residential**	**Total**
2002	688,069	23,481	711,550	3,559	913	4,472
2003	819,579	57,547	877,126	5,870	943	6,813
2004	864,794	63,539	928,333	14,114	1,712	15,826
2005	871,774	70,998	942,772	19,244	1,902	21,146
2006	606,919	35,937	642,856	30,689	2,930	33,619
2007	773,391	62,260	835,651	44,886	3,943	48,829
2008	918,284	64,711	982,995	64,400	5,609	70,009
2009	1,058,185	65,593	1,123,778	88,222	8,284	96,506

Source:
U.S. Department of Energy, Energy Information Administration, *Electric Power Annual 2009*, Washington, D.C., 2009.

Section: BIOPOWER
Capacity Additions and Retirements by Energy Source, 2009

Energy Source	Generator Addition				Generator Retirements			
	Number of Generators	Generator Nameplate Capacity	Net Summer Capacity	Net Winter Capacity	Number of Generators	Generator Nameplate Capacity	Net Summer Capacity	Net Winter Capacity
		megawatts				megawatts		
Coal	13	2,021	1,793	1,793	12	537	529	528
Petroleum	25	93	48	83	41	623	540	567
Natural Gas	76	10,760	9,403	10,170	79	5,940	5,634	5,657
Other Gases[a]	--	--	--	--	3	51	46	46
Hydroelectric Conventional	8	26	26	26	5	14	3	4
Wind	120	9,581	9,410	9,443	1	2	2	2
Solar Thermal & Photovoltaic	20	88	82	80	--	--	--	--
Wood and Wood Derived Fuels[b]	3	99	89	89	4	22	21	21
Geothermal	13	199	164	193	14	21	9	14
Other Biomass[c]	104	278	264	261	13	39	32	32
Total	**382**	**23,144**	**21,279**	**22,138**	**172**	**7,249**	**6,815**	**6,870**

Source:
U.S. Department of Energy, Energy Information Administration, *Electric Power Annual 2009* , Washington, D.C., 2009.

[a] Blast furnace gas, propane gas, and other manufactured and waste gases derived from fossil fuels.
[b] Wood/wood waste solids (including paper pellets, railroad ties, utility poles, wood chips, bark and wood waste solids), wood waste liquids (red liquor, sludge wood, spent sulfite liquor, and other wood-based liquids) and black liquor.
[c] Municipal solid waste, landfill gas, sludge waste, agricultural byproducts, other biomass solids, other biomass liquids, and other biomass gases (including digester gases, methane, and other biomass gases).

Note:
Capacity by energy source is based on the capacity associated with the energy source reported as the most predominant (primary) one, where more than one energy source is associated with a generator.

Section: BIOPOWER
Coal Displacement Calculation, 2010

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	Hydropower	PV	Solar Thermal
(A) Capacity (kW)	37,870,000	2,410,000	7,560,000	77,570,000	2,340,000	610,000
(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)	119,426,832,000	19,000,440,000	52,980,480,000	300,301,647,108	4,612,140,000	1,303,838,400
(E) Conversion Efficiency (Btu/kWh)	9,854	9,854	9,854	9,854	9,854	9,854
(F) Total Output (Million Btu)	1,176,832,003	187,230,336	522,069,650	2,959,172,431	45,448,028	12,848,024
(G) Coal Heat Rate (Btu per short ton)	19,933,000	19,933,000	19,933,000	19,933,000	19,933,000	19,933,000
(H) Coal (short tons)	59,039,382	9,392,983	26,191,223	148,455,949	2,280,040	644,560

Sources: Capacity, EIA, Annual Energy Outlook 2011, DOE/EIA-0383 (2011) Washington, D.C., April 26, 2011, Summary Case Table 16.
Capacity Factor: National Renewable Energy Laboratory, Power Technologies Energy Data Book, Table 12.1, http://www.nrel.gov/analysis/power_databook/chapter12.html
Annual Hours: National Renewable Energy Laboratory, Power Technologies Energy Data Book, Table 12.1, http://www.nrel.gov/analysis/power_databook/chapter12.html
Conversion Efficiency: EIA, Annual Energy Review 2009, DOE/EIA-0384 (2009), Washington, D.C., August 19, 2010, Table A6.
Heat Rate: Annual Energy Outlook 2011, DOE/EIA-0383 (2011), Washington, D.C., April 2011, Table G1.

Renewable Energy Impacts Calculation, 2010

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	Hydropower	PV	Solar Thermal
(A) Capacity (kW)	37,870,000	2,410,000	7,560,000	77,570,000	2,340,000	610,000
(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)	119,426,832,000	19,000,440,000	52,980,480,000	300,301,647,108	4,612,140,000	1,303,838,400
(E) Competing Heat Rate (Btu/kWh)	9,854	9,854	9,854	9,854	9,854	9,854
(F) Annual Output (Trillion Btu)	1,176.8	187.2	522.1	2,959.2	45.4	12.8
(G) Carbon Coefficient (MMTCB/Trillion Btu)	0.01783	0.01783	0.01783	0.01783	0.01783	0.01783
(H) Annual Carbon Displaced (MMTC)	20.983	3.172	8.328	54.635	0.100	0.128

Sources: Capacity, EIA, Annual Energy Outlook 2011, DOE/EIA-0383 (2011) Washington, D.C., April 26, 2011, Summary Case Table 16.
Capacity Factor: National Renewable Energy Laboratory, Power Technologies Energy Data Book, Table 12.1,
http://www.nrel.gov/analysis/power_databook/chapter12.html
Annual Hours: National Renewable Energy Laboratory, Power Technologies Energy Data Book, Table 12.1,
http://www.nrel.gov/analysis/power_databook/chapter12.html
Competing Heat Rate: EIA, Annual Energy Review 2009, DOE/EIA-0384 (2009), Washington, D.C., August 19, 2010, Table A6.
Carbon Coefficient: DOE, GPRA2003 Data Call, Appendix B, page B-16, 2003.

Section: BIOPOWER
Number of Home Electricity Needs Met Calculation, 2010

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)	37,870,000	2,410,000	7,560,000	77,570,000	2,340,000	610,000
(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)	119,426,832,000	19,000,440,000	52,980,480,000	300,301,647,108	4,612,140,000	1,303,838,400
(E) Average Annual Household Electricity Consumption (kWh)	12,696	12,696	12,696	12,696	12,696	12,696
(F) Number of Households	9,406,857	1,496,602	4,173,097	23,653,769	363,283	102,699

Source:

Sources: Capacity, EIA, Annual Energy Outlook 2011, DOE/EIA-0383 (2011) Washington, D.C., April 26, 2011, Summary Case Table 16.

Capacity Factor: National Renewable Energy Laboratory, Power Technologies Energy Data Book, Table 12.1, http://www.nrel.gov/analysis/power_databook/chapter12.html

Annual Hours: National Renewable Energy Laboratory, Power Technologies Energy Data Book, Table 12.1, http://www.nrel.gov/analysis/power_databook/chapter12.html

Household Electricity Consumption: Annual Energy Outlook 2011, DOE/EIA-0383 (2011) Washington, D.C., April 26, 2011, Summary/Reference Case Table 4.

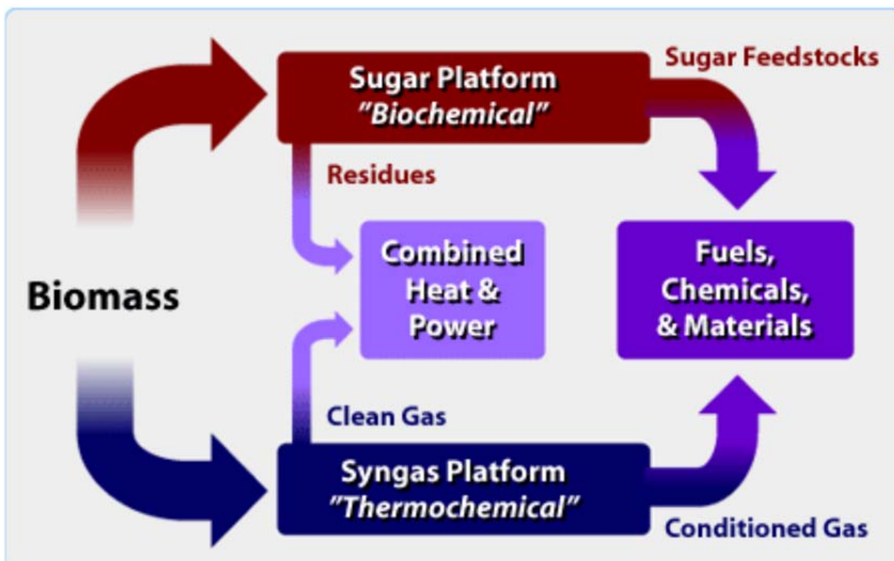
BIOREFINERIES

Contents	Data Type	Updated
Biorefineries Overview	**Text**	09/30/2011
Active U.S. Department of Energy Biorefinery Projects	Table	09/30/2011
Active ARRA U.S. Department of Energy Biorefinery Projects	Table	09/302011
Integrated Biorefinery Project Locations	*Figure-Map*	09/30/2011
Fuels, Technologies and Feedstocks in Planned Biorefineries as of 2008	Table	09/30/2011
Integrated Biorefinery Projects Receiving DOE Funds	Table	09/30/2011
Recently Completed U.S. Department of Energy Biorefinery Projects	Table	09/30/2011

Biorefineries Overview

As a petroleum refinery uses petroleum as the major input and processes it into many different products, a biorefinery uses biomass as the major input and processes it into many different products. Wet-mill and dry-mill corn processing plants and pulp and paper mills can be categorized as biorefineries since they produce multiple products from biomass. Ethanol production facilities produce ethanol and other products from the sugar and starch components of biomass. As of August 2011, the Renewable Fuels Association listed 214 operating ethanol biorefineries with a total production capacity of 14,787 million gallon per year (MGY). Distillers grains, a high-value, protein rich product being used for livestock feed is the major co-product of the existing drymill ethanol biorefineries. Wet-mill ethanol biorefineries have the capacity to produce high fructose corn syrup, and a wide variety of chemical feedstocks such as citric acid, lactic acid, lysine and other products as well as ethanol. Research over the past several years has developed several technologies that have the capability of converting many types of lignocellulosic biomass resources into a wide range of products. The goal 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. Pulp and paper mills are existing biorefineries that produce heat, and electricity as well as pulp or paper and some chemicals, but they also have the potential of producing very large amounts of biofuels and biomass power from processing residuals such as bark and black liquor.

Two of the emerging biorefinery platforms are the sugar platform and the thermochemical platform (also known as the syngas platform) illustrated below. 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.



New technologies are being explored for integrating the production of biomass-derived fuels and other products, such as 1,3 propandiol, polylactic acid, and isosorbide, in a single facility.

Figure Source: National Renewable Energy Laboratory, Biomass Program, September 2011. http://www.nrel.gov/biomass/biorefinery.html

Below are ten projects relevant to the development of biorefinery technologies that have been awarded by the U.S. Department of Energy.

Section: BIOREFINERIES

Active U.S. Department of Energy Biorefinery Projects as of September 2011

Project name	Lead Partner/ Project Period	Project cost	Project Description and Status
Integrated Biorefinery for Conversion of Biomass to Ethanol, Power and Heat	Abengoa Bioenergy	N/A	Construction of a 1,200 tons per day commercial biorefinery producing cellulosic ethanol and also power and heat to operate the facility. Agricultural residues would be converted via enzymatic hydrolysis to sugars and fermented into cellulosic ethanol. Agricultural residues along with ethanol plant residual solids and waste water treatment biogas, will be used to generate the necessary heat and power to make the facility energy self-sufficient. Current Status: Award Date: September 2007. Record of Decision was issued January 2011 and supplementary analysis issued July 2011.
Design, construct, build and operate a commercial processing plant as part of an integrated biorefinery to produce lignocellulosic ethanol primarily from corn cobs.	POET Project Liberty	N/A	Demonstration of the benefits of integrating an innovative lignocellulose-to-ethanol biochemical process into an existing dry-grind corn processing infrastructure on a commercial scale. 700 dry metric tonnes per day of lignocellulose, primarily from corn cobs, will be processed to produce 25 million gallons of lignocellulosic ethanol per year. Up to 80% of the corn dry mill's existing natural gas use will be displaced through renewable, alternative energy. Current Status: Award Date: September 2008.
A commercial-scale biorefinery converting biomass into biofuels and power.	Range Fuels	N/A	Plant uses a thermo-chemical process to combine pressure, heat, steam and biomass to produce synthesis gas, or syngas, a mixture ofhydrogen and oxygen that can be converted to a wide range of products. Current Status: Award Date: November 2007.
Demonstration Plant - Biomass to Fischer-Tropsch Green Diesel	Flambeau River Biofuels	N/A	Construction and operation of a thermal gasification and gas-to-liquids plant ingegrated into the Park Falls Mill to produce green diesel for transportation fuel, waxes, and heat and power that replaces natural gas. The plant will produce 1,190 barrels per day of clean, zero sulfur renewable biofuels, waxes, and heat and power that replaces existing natural gas use from forest biomass. Current Status: Award Date: September 2008
Integrated Biorefinery Demonstration Plant producing Cellulosic Ethanol and Biochemicals from woody biomass.	Lignol Innovations, Inc	N/A	Plant for the continuous production of cellulosic ethanol, high purity lignin and furfural from hardwoods. Plant will process 100 tpd of woody biomass, initially local hardwood which is plentiful, and in future test campaigns, softwood and agricultural residues. Current Status: Award Date: TBD
Mascoma Frontier Biorefinery Project	Mascoma Corp.	N/A	Project would initially produce up to 40 million gallons per year of denatured enthanol from approximately 1,300 dry metric tonnes per day of cellulosic materials consisting primarily of wood wastes. Current Status: Award Date: February 2009
NewPage: Project Independence	NewPage Corp.	N/A	Construct & operate a thermal gasification and gas-to-liquids plant integrated into Wisconsic Rapids Mills to replace natural gas use and produce liquid biofuels that will be converted into renewable diesel. Current Status: Award 1 Sept. 2008; Award 2 TBD.
Pacific Ethanol	Pacific Ethanol Inc.	N/A	Design, construct and operate a feedstock flexible demonstration facility producing cellulosic ethanol. Capacity of 2.7 mill gallons of ethanol per year. Current Status: Operational 2009
Red Shield Acquisition	Red Shield Acquisition	N/A	Construct integrated biorefinery that will extract hemicelluloses from wood chips to make biofuel and other specialty chemicals at existing pulp mill. Cellulose & lignin will be maintained in the pulp manufacturing process. Facility will produce 1.5 million gallons per year of Current Status: Award Date: January 2010
Verenium: Jennings 1.4 MGY Demonstration Plant	Verenium Corp.	N/A	Project is operating the demonstration facility to validate findings from the pilot plant operation in the production of cellulosic ethanol from purpose-grown energy crops and agricultural residuals. This demonstration facility is fully integrated from feedstock pretreatment to recovery and distillation of the biofuel product. Current Status: Award Date: September 2008

Source:

U. S. Department of Energy, Energy Efficiency and Renewable Energy, Biomass Program, September 2011, http://www1.eere.energy.gov/biomass/factsheets.html

Websites of all companies serving as project leaders or key partners on the DOE funded projects.

Below are nineteen projects relevant to the development of biorefinery technologies that have been awarded under the American Recovery and Reinvestment Act (ARRA) of 2009 by the U.S. Department of Energy.

Section: BIOREFINERIES
Active ARRA U.S. Department of Energy Biorefinery Projects as of September 2011

Project name	Lead Partner/ Project Period	Project cost	Project Description and Status
Integrated Pilot Plant to Convert Corn Stover to Fuel and Chemicals	Archer Daniels Midland	N/A	A process has been developed to pretreat and pelletize corn stover, increasing its density by a factor of three. A higher density allows use of ADM's existing agricultural transportation infrastructure for long term storage and reduced transportation costs. Current Status; Award Date: TBD
Integrated Pilot-Scale Biorefinery for Producing Ethanol from Hybrid Algae	Algenol Biofuels, Inc.	N/A	An integrated pilot-scale biorefinery will be constructed that will convert carbon dioxide into ethanol. Algenol is targeting the development of hybrid algae that produce 6,000 galls of ethanol per acre, per year.The biorefinery will consume 2 dry tons of carbon dioxide per day and will produce more than 100,000 gallons of fuel ethanol per year.
Conversion of sweet sorghum biomass to hydrocarbon diesel and chemicals	Amyris Integrated Biorefinery	N/a	Process uses low-risk, yeast-based fermentation of traditional or lignocellulosic-derived sugar feedstocks. The fermentation intermediate is readily recovered as water-immiscible oil. Fermentation waste is treated by anaerobic digestion to reduce effluent and utilize residual sugars for biogas production. Biogas is then converted to hydrogen via steam-methane reformation for use in finishing reactions for a variety of products. Current Status: Award Date: November 2009. Commercial Production: Targeted for 2013.
Alpena Prototype Biorefinery	Alpena Prototype Biorefinery	N/A	Alpena Prototype Biorefinery will be used to demonstrate a modular, technically successful, and financially viable process of making cellulosic ethanol from woody biomass extract in wood processing facilities. It will produce 894,200 USG per year of cellulosic ethanol and 696,000 gallons per year of aqueous potassium acetate. Current Status: Awarded April 2010.
BlueFire Fulton Renewable Energy Project	BlueFire Renewables	$320 Million	The Project would produce in excess of 18 million gallons per year of denatured ethanol from approximately 700 metric dry tons per day of cellulosic materials consisting primarily of wood wastes. Current Status: Award dates: September 2007 and December 2009. Engineering, procurement and construction contract has been awarded to Mastec North America. A front-end level 3 engineering design effort has been completed.
Integrated Pilot Project for Fuel Production by Thermochemical Conversion of Woodwaste	ClearFuels-Rentech	N/A	ClearFuels has developed a process to thermochemically convert a variety of feedstock types that, when combined with Rentech's technology, are anticipated to provide direct replacements for diesel and jet fuel. Current Status: Awarded January 2011. Anticipated operational date: late 2015
Elevance Integrated Biorefinery	Elevance Renewable Sciences	N/A	Process uses novel catalyst developed in the US to convert renewable natural oils into fuels and chemicals. Data will be generated specific for high potential U.S. feedstocks to assist in the design of key sections of a biorefinery which will convert natural oils into fuels and chemicals using the Grubbs olefin metathesis catalyst, develop a non site-specific process design and detailed angeineering, and perform an analysis of the sensitivity of the economics of the process using algae oil. Current Status: Award Date: December, 2009
Enerkem to Use Sorted Waste as Feedstock in Biorefinery	Enerkem	N/A	Biorefinery will convert heterogeneous (mixed) sorted municipal solid waste into ethanol. By converting waste into transportation fuels, the project will increase U.S. energy security, create jobs, reduce greenhouse emissions, and extend the life of the landfill by diverting incoming volume. Current Status: Award Date: March 2010
Gasoline and Diesel from Wood, Agricultural Waste, and Algae R&D	Gas Technology Institute	N/A	GTI will conduct R&D on integrated hydropyrolysis and hydroconversion for the economic conversion of wood, agricultural waste, and algae biomass into fungible gasoline and diesel. Current Status: Award Date: Early 2010
Green Gasoline from Wood Pilot Biorefinery Demonstration Project	Haldor Topsoe, Inc.	N/A	A new economical thermochemical process for the converstion of wood waste and woody biomass to gasoline will be demonstrated. Wood waste and non-merchantable wood product will be sourced from UPM-Kymmene, a pulp and paper company. Current Status: Award Date: Early 2010. Beginning operations by mid-year 2012.
Pilot Integrated Cellulosic Biorefinery Operations to Fuel Ethanol	ICM, Inc.	N/A	Operate the pilot cellulosic integrated biorefinery ujsing a biochemical platform pretreatment and enzymatic hydrolysis technology coupled with a robust C5/C6 co-fermenting organism to refine cellulosic biomass into fuel ethanol and co-products. Proposed process addresses pretreatment, hydroloysis, fermentation, and feed production which represent key technologies needed for the cost effective production of ethanol from cellulosic biomass. Current Status: Awarded January 2010.
INEOS Bio Commercializes bioenergy technolgy in Florida	INEOS New Plant BioEnergy	N/A	Utilizing a unique combination of gasification and fermentation processes, the facility will demonstrate key equipment at full commercial scale using vegetative, yard, and municipal solid waste as feedstock which will be heated to produce a synthesis gas that is cooled and cleaned before being fed to naturally occurring bacteria. These bacteria convert the synthesis gas into ethanol, which is purified for use as fuel in the transportation market. Current Status: Award Date: September 2010
Logos Technologies, Inc. Pilot CCM Biorefinery	Logos Technolgies, Inc., & EdiniQ, Inc.	N/A	Demonstrate advanced technologies and methods to convert non-food, cellulosic feedstocks into ethanol in an economically and environmentally compelling way. Current Status: Award Date: TBD
Myriant Succinic Acid Biorefinery (MySAB) Demonstration Facility	Myriant Technologies, Inc.	N/A	Facility will validate the production of succinic acid using proprietary, integrated, biocatalytic processes to displace petroleum based production of this plantform chemical. Produce succinic acid, an industrial organic chemical building block that can be used in the production of plymers, solvents and pigments. Current Status: Award Date: March, 2010
Demonstration of a Pilot, Fully Integrated Biorefinery for the Efficient Production of Clean, Synthetic Diesel Fuel from Biomass	Renewable Energy Institute International, Red Lion Bio-Energy, & Pacific Renewable Fuels	N/A	Demonstrate a pilot, pre-commercial integrated biorefinery for the production of high-quality synthetic diesel fuels from agriculture and forest residues using advanced thermochemical and catalytic conversion technologies. Current Status: Award Date: TBD
Sapphire Energy Integrated Algal Biorefinery (IABR)	Sapphire Energy Inc.	N/A	IABR will be built in Luna Country that will benefically reuse carbon dioxide to produce green crude oil from algae. The oil will be refined to produce jet fuel and diesel. Current Status: Award Date: TBD

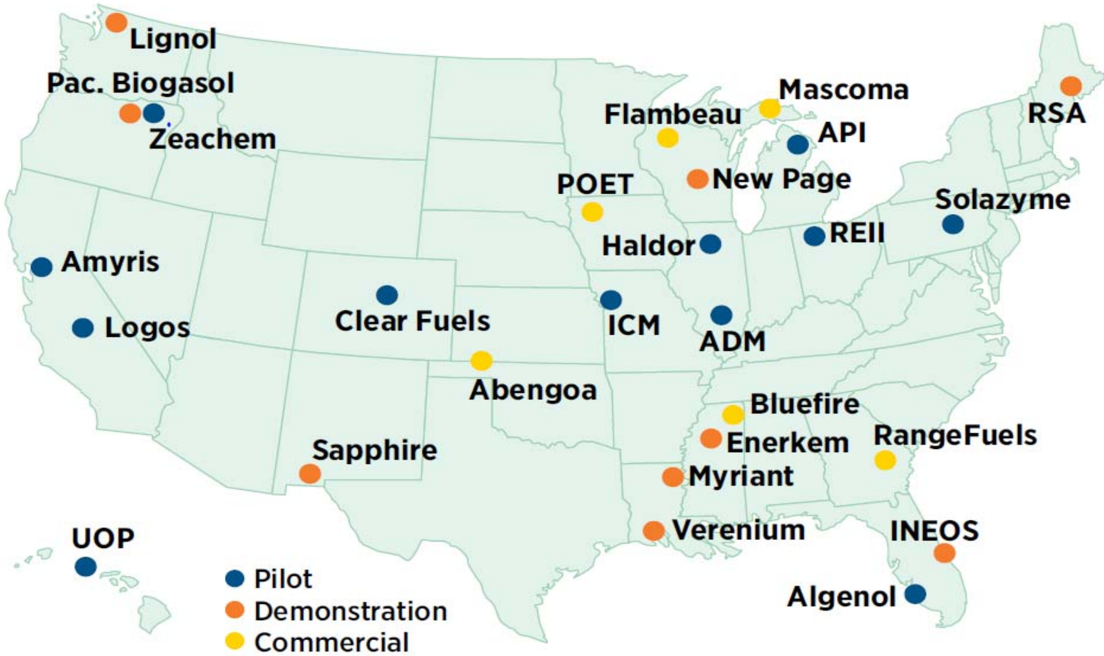
Project name	Lead Partner/ Project Period	Project cost	Project Description and Status
Solazyme Integrated Biorefinery: Diesel Fuels from Heterotrophic Algae	Solazyme, Inc.	NA	Demonstrate integrated scale-up of heterotrophic algal oil biomanufacturing process, validate the projected commecial-scale economics of producing multiple advanced biofuels, and collect the data necessary to complete design of the first commercial-scale facility. Demonstrate production of algal oil derived entirely from lignocellulosic feedstocks, as well as other feedstocks. Biofuels derived from these feedstocks will reduce lifecycle greenhouse gas emissions by over 90%. Current Status: Award Date: TBD
Sustainable Transport Fuels from Biomass and Algal Residues via Integrated Pyrolysis and Catalytic Hydroconversion	UOP, LLC	NA	A fully integrated process to convert high impact gasoline, diesel and jet range hydrocarbon. Feeds will be converted to fuels via integrated pyrolysis and hydro-conversion. Team members will demonstrate fungibility of the fuels within the refinery, determine fuel properties and accelerate qualification and acceptance as liquid transportation fuels. Current Status: ward Date: Early 2010
High-Yield Hybrid Cellulosic Ethanol Process Using High-Impact Feedstock for Commercialization by 2013	ZeaChem, Inc.	N/A	Biorefinery will convert 10 bone-dry tons per day of cellulosic feedstock into ethanol. A 95% reduction in life cycle greenhouse gas emissions for fuel production is anticipated in the commercial biorefineries as compared to conventional gasoline. Facility will use a hybrid of biochemical and thermochemical fractionation to separate the feedstock into a sugar-rich stream and a lignin-rich stream. The sugar stream is converted into acetic acid using naturally occurring bacteria, or acetogens, which produce no carbon dioxide during fermentation process and enabling 100% carbon conversion. Current Status: Award Date: TBD

Source:

U. S. Department of Energy, Energy Efficiency and Renewable Energy, Biomass Program, September 2011, http://www1.eere.energy.gov/biomass/factsheets.html

Websites of all companies serving as project leaders or key partners on the DOE funded projects.

Integrated Biorefinery Project Locations



Source:

U.S. Department of Energy, Energy Efficiency and Renewable Energy, Biomass Program, November 2010.
http://www1.eere.energy.gov/biomass/pdfs/ibr_portfolio_overview.pdf

Section: BIOREFINERIES
Fuels, Technologies and Feedstocks in Planned Biorefineries as of 2008

Liquid Fuel Types Planned		
Ethanol	Propanol	Biogasoline
Methanol	Fischer-Tropsch diesel fuel	Lignocellulosic biodiesel
Bio-butanol	Renewable Crude Oil	Jet Fuel

Technologies Involved in Producton of Biofuels and Bioproducts	
Weak Acid Hydrolysis	Component of ethanol production, see BIOFUELS "The Ethanol Production Process - Dry Milling"
Enzymatic hydrolysis	Component of ethanol production, see BIOFUELS "The Ethanol Production Process - Dry Milling"
Engineered microbes	Component of ethanol production, see BIOFUELS "The Ethanol Production Process - Dry Milling"
Specialty enzymes	Component of ethanol production, see BIOFUELS "The Ethanol Production Process - Dry Milling"
Steam explosion hydrolysis	Alternative to weak acid hydrolysis for feedstock pretreatment
Strong acid hydrolysis	Alternative to weak acid hydrolysis for feedstock pretreatment
Hydrogenolysis process	One of several patent descriptions found at http://www.patentstorm.us/patents/4661643
Organosolv process	One of several patent descriptions found at http://www.patentgenius.com/patent/4470851.html
Fischer-Tropsch process	See http://wikipedia.org/wiki/Fischer-Tropsch for explanation
Gasification*	A thermochemical process creating a synthesis gas that can be transformed by catalysts or microbes to biofuels/bioproducts
Biomass Fractionation*	Separation of biomass components prior to pretreatment for a wide variety of possible end-products
Proprietary technologies*	Several proprietary technologies have been proposed

Feedstocks Planned for Production of New Biofuels and Bioproducts	
Agricultural Residues	**Industry and Municipal Residuals**
Citrus Waste	Municipal solid waste
Corn cobs, fiber and stover	Yellow/trap grease
Grain, rice and wheat straw	Construction waste
Leafy material	Urban wood waste
Energy Crops	**Other Woody Biomass**
Miscanthus	Hazardous forest fuels (thinning & slash)
Specially bred energy cane	Material from habitat restoration
Switchgrass	Logging and mill residues
Poplar, willow, and pine trees	

Source:
The information presented above is largely derived from the fact sheet on cellulosic biofuels developed in July 2008 by Justin Mattingly, Fahran Robb, and Jetta Wong of the Environmental and Energy Study Institute (www.eesi.org). Oak Ridge National Laboratory staff added links for additional information.

Note: More information can be found at:
http://www1.eere.energy.gov/biomass/factsheets.html

SECTION: BIOREFINERIES
Integrated Biorefinery Projects Receiving DOE Funds

Project	Location	Scale	Conversion Technology
Abengoa	Hugoton, KS	Commercial	Biochemical
Bluefire LLC	Fulton, MS	Commercial	Biochemical
Flambeau	Park Falls, WI	Commercial	Thermo - Gasification
Mascoma	Kinross, MI	Commercial	Biochemical
POET	Emmetsburg, IA	Commercial	Biochemical
Rangefuels	Soperton, GA	Commercial	Thermo - Gasification
Enerkem	Pontotoc, MS	Demonstration	Thermo - Gasification
INEOS New Planet Bioenergy LLC	Vero Beach, FL	Demonstration	Hybrid
Lignol	Washington	Demonstration	Biochemical
New Page	Wisconsin Rapids, WI	Demonstration	Thermo - Gasification
Pacific Ethanol	Boardman, OR	Demonstration	Biochemical
RSA	Old Town, ME	Demonstration	Biochemical
Sapphire Energy Inc.	Columbus, NM	Demonstration	Algae/CO2
Verenium	Jennings, LA	Demonstration	Biochemical
Myriant	Lake Providence, LA	Demonstration	Biochemical
Algenol Biofuels Inc	Fort Myers, FL	Pilot	Algae/CO2
American Process Inc.	Alpena, MI	Pilot	Biochemical
Amyris Biotechnologies Inc.	Emeryville, CA	Pilot	Biochemical
Archer Daniels Midland	Decatur, IL	Pilot	Biochemical
ClearFuels Technology	Commerce City, CO	Pilot	Thermo - Gasification
Haldor Topsoe Inc.	Des Plaines, IL	Pilot	Thermo - Gasification
ICM Inc.	St. Joseph, MO	Pilot	Biochemical
Logos Technologies	Visalia, CA	Pilot	Biochemical
Renewable Energy Institute International	Toledo, OH	Pilot	Thermo - Gasification
Solazyme Inc.	Riverside, PA	Pilot	Algae/Sugar
UOP LLC	Kapolei, HI	Pilot	Thermo - Pyrolysis
ZeaChem Inc.	Boardman, OR	Pilot	Hybrid

Source:
U.S. Department of Energy, Energy Efficiency and Renewable Energy, Biomass Program, November 2010.
http://www1.eere.energy.gov/biomass/pdfs/ibr_portfolio_overview.pdf

Below are nine projects relevant to the development of biorefinery technologies that were initiated during the 2000 to 2003 time frame by the U.S. Department of Energy. All projects have ended, some of the project partners are now involved in new biorefinery projects, while others have abandoned their efforts in this area.

Section: BIOREFINERIES

Recently Completed U.S. Department of Energy Biorefinery Projects

Project name	Lead Partner/ Project Period	Project cost	Project Description and Status
Making Industrial Biorefining Happen	Cargill-Dow LLC FY 2003-2007	$26 million	Develop and build a pilot-scale biorefinery that produces sugars and chemicals such as lactic acid and ethanol from grain. Current Status: Cargill Dow LLC is now known as NatureWorks LLC following Cargill's acquisition of The Dow Chemical Companies interest in the venture. The NatureWorks LLC website suggests that all products are currently made from corn starch.
Integrated Corn-Based Biorefinery	E.I. du Pont de Nemours & Co., Inc. FY 2003-2007	$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. Current status. Du Pont is making major investments in bioenergy technologies. The chemical 1,3 propanediol is now being commercial produced at DuPont Tate & Lyle Bio Products, LLC. in Loudon, Tennessee. DuPont and Genencor formed a joint venture company, DuPont Danisco Cellulosic Ethanol LLC, in May 2008 and this company is now the lead partner on the biorefinery project in Vonore, TN.
Advancing Biorefining of Distillers' Grain and Corn Stover Blends: Pre-Commercialization of a Biomass-Derived Process Technology	Abengoa Bioenergy Corporation FY 2003-2007	$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.
Big Island Demonstration project - Black Liquor	Georgia Pacific FY 2000 - 2007	NA	The project involved the design and operation of a black liquor gasifier that was to be integrated into Georgia-Pacific's Big Island facility in Virginia. This project anticipated helping pulp and paper mills with the replacement of recovery boilers that are reaching retirement. Current Status: The gasifier was built but the design did not function as anticipated and no current information can be located regarding any further work on the gasifier.
Collection, Commercial Processing, and Utilization of Corn Stover/Making Industrial Biorefining	Cargill-Dow LLC FY 2003-2007	NA	Develop new technologies that assist in the harvesting, transport, storage, and separation of corn residues. Engineer a fermentation system that will meet the performance targets for the commercial manufacture of lactic acid and ethanol from corn stover. Current Status: See description above.
Enhancement of Co-Products from Bioconversion of Muncipal Solid Waste	Masada OxyNol, LLC FY 2001 - 2004	NA	The unit operations of the Masada OxyNol^{TM} process were to be examined and research focused on improving conversion efficiencies, mitigating scale-up risks, and improving the co-product quality and marketability. Current Status: The company now called Pencor-Masada Oxynol signed an agreement in 2004 with the city of Middletown, New York to build a waste-to-ethanol plant with a projected completion date in 2008. As of December 2007 the company was still trying to attract investors. The companies website still indicates that the project is proceeding, though the city has taken the company to court for failing to meet deadlines.
A New Biorefinery Platform Intermediate	Cargill, Inc. FY 2003 - 2007	$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. Current Status: Cargill does make ethanol from corn starch at multiple locations. Their website suggests that the only current involvement in cellulosic ethanol is the funding provided to Iowa State University that includes money for an economic analysis of corn stover production, harvest, handling and storage.
A Second Generation Dry Mill Biorefinery	Broin and Associates FY 2003 - 2007	$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. Current Status: Broin and Associates, now called POET, is pursuing "Project Liberty", a project that is constructing a cellulosic ethanol production stream at their Scotland N.D. corn to ethanol facility. This project was awarded DOE funding in February 2007 and corn cobs were harvested in 2007 as feedstock for the facility.
Separation of Corn Fiber and Conversion to Fuels and Chemicals Phase II: Pilot-Scale Operation	National Corn Growers Association FY 2003 - 2007	$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. Current Status: ADM a partner in the NCGA project announced in August 2008 that it was partnering with John Deere to harvest,

Sources:

U. S. Department of Energy, Energy Efficiency and Renewable Energy, Biomass Program, October, 2011,
http://www1.eere.energy.gov/biomass/factsheets.html

Websites of all companies serving as project leaders or key partners on the DOE funded projects.

FEEDSTOCKS

Contents	Data Type	Updated
Primary Biomass Feedstocks	**Text**	09/30/2011
Grains		
Barley: Area, Yield, Production and Value, 1996-2009	Table	04/15/2011
Barley: Area, Yield and Production by State, 2007-2009	Table	04/15/2011
Barley Production Costs and Returns per Planted Acre by Region, Excluding Government Payments, 2009-2010	Table	06/21/2011
Corn Baseline Projections, 2009-2020	Table	04/18/2011
Corn Used for Ethanol Production, 1985-2010	*Figure*	04/18/2011
Corn Usage by Segment, 2010	*Figure*	04/18/2011
Corn: Price per Bushel, 1975-2010	*Figure*	04/15/2011
Corn: Area, Yield, Production, and Value, 1996-2009	Table	04/18/2011
Corn: Area, Yield, and Production, by State, 2007-2009	Table	04/18/2011
Corn for Grain, Harvested Acres, 2007	*Figure-Map*	09/26/2011
Corn Acres, Planted and Harvested, 1975-2010	*Figure*	04/18/2011
Corn Yield, 1975-2010	*Figure*	04/18/2011
Corn: Supply and Dissappearance, 1996-2010	Table	04/18/2011
Corn for Grain: Marketing Year Average Price and Value by State, Crops of 2007, 2008, and 2009	Table	04/18/2011
Corn Production Costs and Returns per Planted Acre by Region, Excluding Government Payments, 2009-2010	Table	06/21/2011
Oats: Area, Yield, Production and Value, 1996-2009	Table	04/18/2011
Oats: Area, Yield and Production by State, 2007-2009	Table	04/18/2011
Oats Production Costs and Returns per Planted Acre by Region, Excluding Government Payments, 2009-2010	Table	06/21/2011
Rice: Area, Yield, Production and Value, 1996-2009	Table	04/18/2011
Rice: Area, Yield and Production by State, 2007-2009	Table	04/18/2011
Rice Production Costs and Returns per Planted Acre by Region, Excluding Government Payments, 2009-2010	Table	06/21/2011
Sorghum for Grain, Harvested Acres, 2007	*Figure-Map*	09/26/2011
Sorghum: Price per Bushel, 1975-2009	*Figure*	04/18/2011
Sorghum: Area, Yield, Production and Value, 1996-2009	Table	04/18/2011
Sorghum: Area, Yield and Production by State, 2006-2009	Table	04/18/2011
Sorghum Production Costs and Returns per Planted Acre by Region, Excluding Government Payments, 2009-2010	Table	06/21/2011
Wheat Baseline Projections, 2009-2021	Table	04/18/2011
Wheat: Price per Bushel, 1975-2009	*Figure*	04/18/2011
Wheat: Area, Yield, Production, and Value, 1996-2009	Table	04/18/2011

Wheat: Area, Yield, and Production, by State, 2007-2009	Table	04/18/2011
Wheat: Supply and Dissappearance, 1996-2009	Table	04/18/2011
Wheat: Marketing Year Average Price and Value by State, Crop of 2007, 2008, and 2009	Table	04/18/2011
Wheat Production Costs and Returns per Planted Acre by Region, Excluding Government Payments, 2009-2010	Table	06/21/2011
Oilseeds		
Oil per Acre Production for Various Crops	Table	04/18/2011
Camelina: Area, Yield, and Value in Montana	Table	09/30/2011
Cotton: Area, Yield, Production and Value, 1996-2009	Table	04/18/2011
Cotton: Area, Yield and Production by State, Crop of 2007, 2008, and 2009	Table	04/18/2011
Cotton Production Costs and Returns per Planted Acre by Region, Excluding Government Payments, 2009-2010	Table	06/21/2011
Soybeans and Products Baseline Projections, 2009 - 2020	Table	09/30/2011
Soybeans: Price per Bushel, 1975-2009	*Figure*	04/18/2011
Soybeans: Area, Yield, Production and Value, 1996-2009	Table	07/26/2011
Soybeans: Area, Yield, and Production by State, 2007-2009	Table	04/18/2011
Soybeans: Supply and Disappearance, 1995-2008	Table	04/18/2011
Soybeans for Beans: Marketing Year Average Price and Value by State, Crop of 2007, 2008, and 2009	Table	04/18/2011
Soybeans for Beans, Harvested Acres, 2007	*Figure-Map*	09/302011
Soybean Production Costs and Returns per Planted Acre by Region, Excluding Government Payments, 2009-2010	Table	06/21/2011
Algae		
Oil Content in Selected Algal Species	Table	09/30/2011
Agricultural Resources		
Corn Stover Residue Yield for Reduced Tillage and No-till Production, 2012	*Figure-Map*	09/30/2011
Primary Forest Resources		
Spatial Distribution of Logging Residues at $20 and $40 per Dry Ton	*Figure-Map*	09/30/2011
Spatial Availability of Other Removal Residues at $40 per Dry Ton	*Figure-Map*	09/30/2011
Spatial Distribution of Simulated Forest Residue Thinnings at $30 and $60 per Dry Ton	*Figure-Map*	09/30/2011
Secondary Biomass Feedstocks	**Text**	09/30/2011
U.S. Forest Service - Woody Biomass Utilization Grantees, 2009 & 2010	Table	09/30/2011
Manure		
Feedlot Capacity and Distribution, 2004	*Figure-Map*	09/30/2011
Mill Wastes		
Primary Mill Residue Production and Use by State, 2007	Table	09/30/2011
Unused Mill Residues by County	*Figure-Map*	09/30/2011
Pellet Fuels		
North American Pellet Capacity, 2003-2009	*Figure*	09/30/2011

Pellet and Cordwood Appliance Shipments from Manufacturers, 1998-2010	Table	4/18/2011
Tertiary Biomass Feedstocks	**Text**	09/30/2011
Urban Residues		
Spatial Availability of Urban Wood Waste (Municipal Solid Waste) and Construction and Demolition Wood Residues	*Figure-Map*	09/30/2011
Landfill Gas		
Landfill Gas Projects and Candidate Landfills by State, April 2011	Table	6/21/2011
Feedstock Characteristics (See Appendix B)		

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. Nonetheless, 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.

Barley: Area, Yield, Production, and Value, 1996-2009

Year	Area		Yield per harvested acre	Production	Marketing year average price per bushel received by farmers	Value of production
	Planted[a]	Harvested				
	1,000 Acres	1,000 Acres	Bushels	1,000 Bushels	Dollars	1,000 Dollars
1996	7,094	6,707	58.5	392,433	2.74	1,080,940
1997	6,706	6,198	58.1	359,878	2.38	861,620
1998	6,325	5,854	60.1	351,569	1.98	685,734
1999	4,983	4,573	59.5	271,996	2.13	578,425
2000	5,801	5,200	61.1	317,804	2.11	647,966
2001	4,951	4,273	58.1	248,329	2.22	535,110
2002	5,008	4,123	55.0	226,906	2.72	605,635
2003	5,348	4,727	58.9	278,283	2.83	755,140
2004	4,527	4,021	69.6	279,743	2.48	698,184
2005	3,875	3,269	64.8	211,896	2.53	527,633
2006	3,452	2,951	61.1	180,165	2.85	498,691
2007	4,018	3,502	60.0	210,110	4.02	834,954
2008	4,246	3,779	63.6	240,193	5.37	1,259,357
2009[b]	3,567	3,113	73.0	227,323	4.40	917,500

Source: U.S. Department of Agriculture, *2010 Agricultural Statistics*, Table 1-53 and previous annual editions.
http://www.nass.usda.gov/Publications/Ag_Statistics/index.asp

[a] Barley sown for all purposes, including barley sown in the preceding fall.
[b] Preliminary

Section: FEEDSTOCKS

Barley: Area, Yield, and Production, by State, 2007-2009

	Area planted[a]			Area harvested			Yield per harvested acre			Production		
	2007	2008	2009[b]	2007	2008	2009[b]	2007	2008	2009[b]	2007	2008	2009[b]
	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
Arizona	33	42	48	31	40	45	110	120	115	3,410	4,800	5175
California	85	95	90	40	60	55	64	55	54	2,560	3,300	2970
Colorado	60	80	78	58	72	77	120	120	135	6,960	8,640	10395
Delaware	21	25	28	19	22	26	78	80	70	1,482	1,760	1820
Idaho	570	600	530	550	580	510	78	86	95	42,900	49,880	48450
Kansas	20	17	14	13	10	9	52	37	51	676	370	459
Kentucky[c]	10	8	***	3	7	***	37	88	***	111	616	***
Maine	18	20	16	17	19	15	65	55	55	1105	1045	825
Maryland	45	45	55	30	35	48	82	90	70	2,460	3,150	3360
Michigan	14	12	13	13	10	11	51	46	51	663	460	561
Minnesota	130	125	95	110	110	80	54	65	61	5,940	7,150	4,880
Montana	900	860	870	720	740	720	44	51	57	31,680	37,740	41,040
Nevada[c]	3	3	***	1	1	***	90	100	***	90	100	***
New Jersey[c]	3	3	***	2	2	***	68	71	***	136	142	***
New York	13	13	12	11	9	10	49	52	53	539	468	530
North Carolina	22	21	23	14	14	19	49	71	60	686	994	1,140
North Dakota	1,470	1,650	1210	1,390	1,540	1,130	56	56	70	77,840	86,240	79,100
Ohio[c]	4	6	***	3	5	***	53	72	***	159	360	***
Oregon	63	57	40	53	42	32	53	50	60	2,809	2,100	1,920
Pennsylvania	55	60	60	42	55	45	73	75	75	3,066	4,125	3,375
South Dakota	56	63	48	29	43	22	40	41	54	1,160	1,763	1,188
Utah	38	40	40	22	27	30	81	85	85	1,782	2,295	2,550
Virginia	48	63	67	30	36	43	71	85	74	2,130	3,060	3,182
Washington	235	205	105	225	195	97	62	57	64	13,950	11,115	6,208
Wisconsin	40	43	45	23	30	25	57	54	59	1,311	1,620	1,475
Wyoming	62	90	80	53	75	64	85	92	105	4,505	6,900	6,720
US	**4,018**	**4,246**	**3567**	**3,502**	**3,779**	**3,113**	**60**	**63.6**	**73**	**210,110**	**210,110**	**227,323**

Source:
U.S. Department of Agriculture, *2010 Agricultural Statistics*, Table 1-56,
http://www.nass.usda.gov/Publications/Ag_Statistics/index.asp

[a] Includes area planted in the preceding fall.
[b] Preliminary
[c] Estimates discontinued in 2009

Section: FEEDSTOCKS
Barley Production Costs and Returns per Planted Acre by Region, Excluding Government Payments, 2009-2010[a]
(dollars per planted acre)

Item	United States 2009	United States 2010	Northern Great Plains 2009	Northern Great Plains 2010	Basin and Range 2009	Basin and Range 2010	Fruitful Rim 2009	Fruitful Rim 2010	Northern Crescent 2009	Northern Crescent 2010	Heartland 2009	Heartland 2010
Gross value of production												
Primary product: Barley grain	294.58	239.14	255.00	192.55	270.92	220.99	440.08	377.63	265.21	190.50	206.58	141.35
Secondary product: Barley silage, straw, grazing	11.94	11.98	5.59	5.12	11.56	10.59	16.53	15.13	75.62	69.24	18.57	17.01
Total, gross value of production	**306.52**	**251.12**	**260.59**	**197.67**	**282.48**	**231.58**	**456.61**	**392.76**	**340.83**	**259.74**	**225.15**	**158.36**
Operating costs:												
Seed	14.09	12.66	11.64	10.14	15.32	13.35	18.38	16.02	18.47	16.09	15.31	13.34
Fertilizer [b]	52.57	41.78	41.98	32.23	63.11	48.45	70.01	53.75	56.44	43.33	50.49	38.76
Chemicals	15.26	15.09	14.97	14.74	15.05	14.82	19.19	18.89	3.53	3.48	6.18	6.09
Custom operations[c]	9.36	9.78	7.11	7.11	8.32	8.32	13.79	13.79	18.50	18.50	15.14	15.14
Fuel, lube, and electricity	19.58	25.92	12.64	15.69	18.79	23.33	39.20	48.66	16.64	20.66	12.51	15.52
Repairs	18.41	19.00	17.20	17.53	18.67	19.03	23.16	23.61	11.75	11.98	11.64	11.86
Purchased irrigation water	3.07	3.50	0.90	0.91	4.60	4.65	7.60	7.69	2.69	2.72	0.74	0.75
Interest on operating inputs	0.19	0.13	0.15	0.10	0.21	0.13	0.28	0.18	0.19	0.12	0.16	0.10
Total, operating costs	**132.53**	**127.86**	**106.59**	**98.45**	**144.07**	**132.08**	**191.61**	**182.59**	**128.21**	**116.88**	**112.17**	**101.56**
Allocated overhead:												
Hired labor	4.06	4.43	2.35	2.37	3.31	3.35	9.48	9.58	2.58	2.61	2.57	2.60
Opportunity cost of unpaid labor	26.41	27.58	21.23	21.45	33.17	33.53	32.12	32.47	35.70	36.08	26.62	26.91
Capital recovery of machinery and equipment	95.74	98.77	93.45	95.97	95.99	98.58	110.59	113.58	62.97	64.67	62.16	63.84
Opportunity cost of land (rental rate)	80.64	88.28	52.03	53.58	101.98	105.00	135.42	139.44	77.30	79.59	84.37	86.87
Taxes and insurance	10.35	10.44	10.71	10.86	10.33	10.48	10.61	10.77	5.91	6.00	6.86	6.96
General farm overhead	10.47	10.81	9.78	9.97	10.34	10.54	12.66	12.90	9.73	9.92	8.84	9.01
Total, allocated overhead	**227.67**	**240.31**	**189.55**	**194.20**	**255.12**	**261.48**	**310.88**	**318.74**	**194.19**	**198.87**	**191.42**	**196.19**
Total, costs listed	**360.20**	**368.17**	**296.14**	**292.65**	**399.19**	**393.56**	**502.49**	**501.33**	**322.40**	**315.75**	**303.59**	**297.75**
Value of production less total costs listed	-53.68	-117.05	-35.55	-94.98	-116.71	-161.98	-45.88	-108.58	18.43	-56.01	-78.44	-139.39
Value of production less operating costs	173.99	123.26	154.00	99.22	138.41	99.50	265.00	210.17	212.62	142.86	112.98	56.80
Supporting information:												
Yield (bushels per planted acre)	62.41	61.16	60.00	56.30	52.10	54.70	81.80	79.50	51.10	50.80	39.20	38.10
Price (dollars per bushel at harvest)	4.72	3.91	4.25	3.42	5.20	4.04	5.38	4.75	5.19	3.75	5.27	3.71
Enterprise size (planted acres) [a]	219	219	342	342	194	194	266	266	33	33	87	87
Production practices: [a]												
Feed barley (percent of acres)	23	23	8	8	49	49	41	41	96	96	34	34
Malt barley (percent of acres)	77	77	92	92	51	51	59	59	*	*	66	66
Spring barley (percent of acres)	97	97	100	100	99	99	91	91	52	52	100	100
Winter barley (percent of acres)	*	*	0	0	*	*	9	9	47	47	0	0
Dryland (percent of acres)	80	80	94	94	70	70	38	38	98	98	100	100
Irrigated (percent of acres)	20	20	6	6	30	30	62	62	*	*	0	0
Straw harvested (percent of acres)	23	23	12	12	29	29	45	45	87	87	28	28

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

[a] Developed from survey base year, 2003.
[b] Cost of commercial fertilizers, soil conditioners, and manure.
[c] 0.1 to less than 5 percent.

Corn Baseline Projections, 2009 - 2020

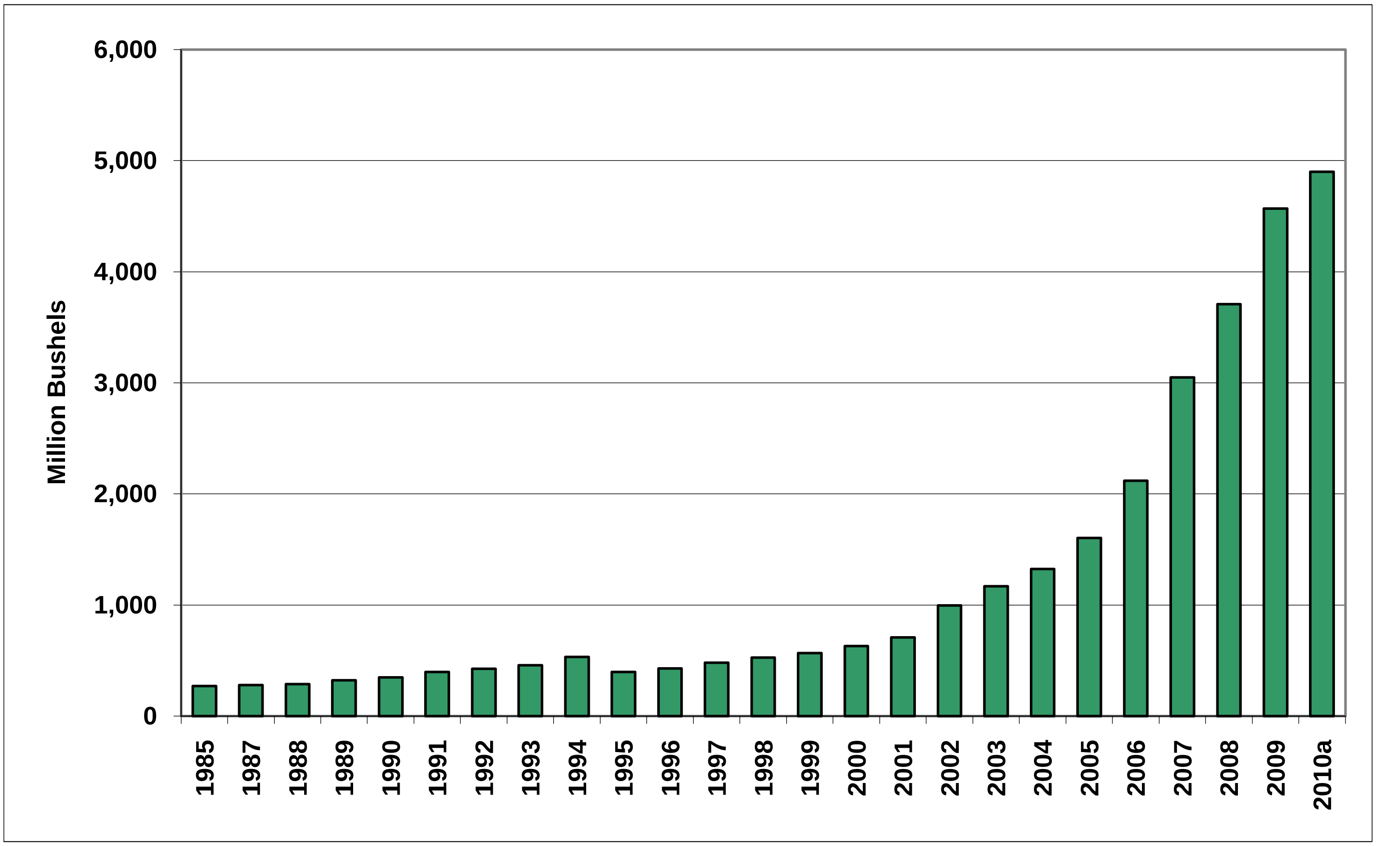
Item	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/2019	2019/2020	2020/2021
Area (million acres):												
Planted acres	86.5	88.2	92.0	91.5	91.0	90.5	90.5	90.5	91.0	91.5	92.0	92.0
Harvested acres	79.6	81.3	84.9	84.4	83.9	83.4	83.4	83.4	83.9	84.4	84.9	84.9
Yields (bushels per acre):												
Yield/harvested acre	164.7	154.3	162.0	164.0	166.0	168.0	170.0	172.0	174.0	176.0	178.0	180.0
Supply and use (million bushels):												
Beginning stocks	1,673	1,708	827	1,127	1,332	1,437	1,447	1,442	1,342	1,262	1,227	1,242
Production	13,110	12,540	13,755	13,840	13,925	14,010	14,180	14,345	14,600	14,855	15,110	15,280
Imports	8	10	10	10	10	10	10	10	10	10	10	10
Supply	14,792	14,257	14,592	14,977	15,267	15,457	15,637	15,797	15,952	16,127	16,347	16,532
Feed & residual	5,159	5,300	5,200	5,300	5,400	5,500	5,600	5,700	5,750	5,800	5,875	5,950
Food, seed, & industrial	5,938	6,180	6,265	6,320	6,380	6,435	6,495	6,605	6,740	6,850	6,930	6,990
Ethanol for fuel	4,568	4,800	4,875	4,925	4,975	5,025	5,075	5,175	5,300	5,400	5,475	5,525
Domestic	11,097	11,480	11,465	11,620	11,780	11,935	12,095	12,305	12,490	12,650	12,805	12,940
Exports	1,987	1,950	2,000	2,025	2,050	2,075	2,100	2,150	2,200	2,250	2,300	2,350
Total use	13,084	13,430	13,465	13,645	13,830	14,010	14,195	14,455	14,690	14,900	15,105	15,290
Ending stocks	1,708	827	1,127	1,332	1,437	1,447	1,442	1,342	1,262	1,227	1,242	1,242
Stocks/use ratio, percent	13.1	6.2	8.4	9.8	10.4	10.3	10.2	9.3	8.6	8.2	8.2	8.1
Prices (dollars per bushel):												
Farm price	3.55	5.20	4.80	4.30	4.10	4.10	4.10	4.15	4.20	4.25	4.25	4.25
Variable costs of production (dollars):												
Per acre	299	287	304	310	314	318	323	329	335	341	347	353
Per bushel	1.82	1.86	1.87	1.89	1.89	1.90	1.90	1.91	1.93	1.94	1.95	1.96
Returns over variable costs (dollars per acre):												
Net returns	286	515	474	395	367	370	374	384	396	407	410	412

Source:

USDA Long-Term Agricultural, Projection Tables to 2020 , February 2011, Table 19 - U.S. corn projections,
http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1192

The figure below shows that corn use for ethanol production has increased by almost seven fold from 2001 to 2010.

Section: FEEDSTOCKS
Corn Used for Ethanol Production, 1985-2010



Source: National Corn Growers Association, *The World of Corn,* 2011 and previous annual editions, http://www.ncga.com

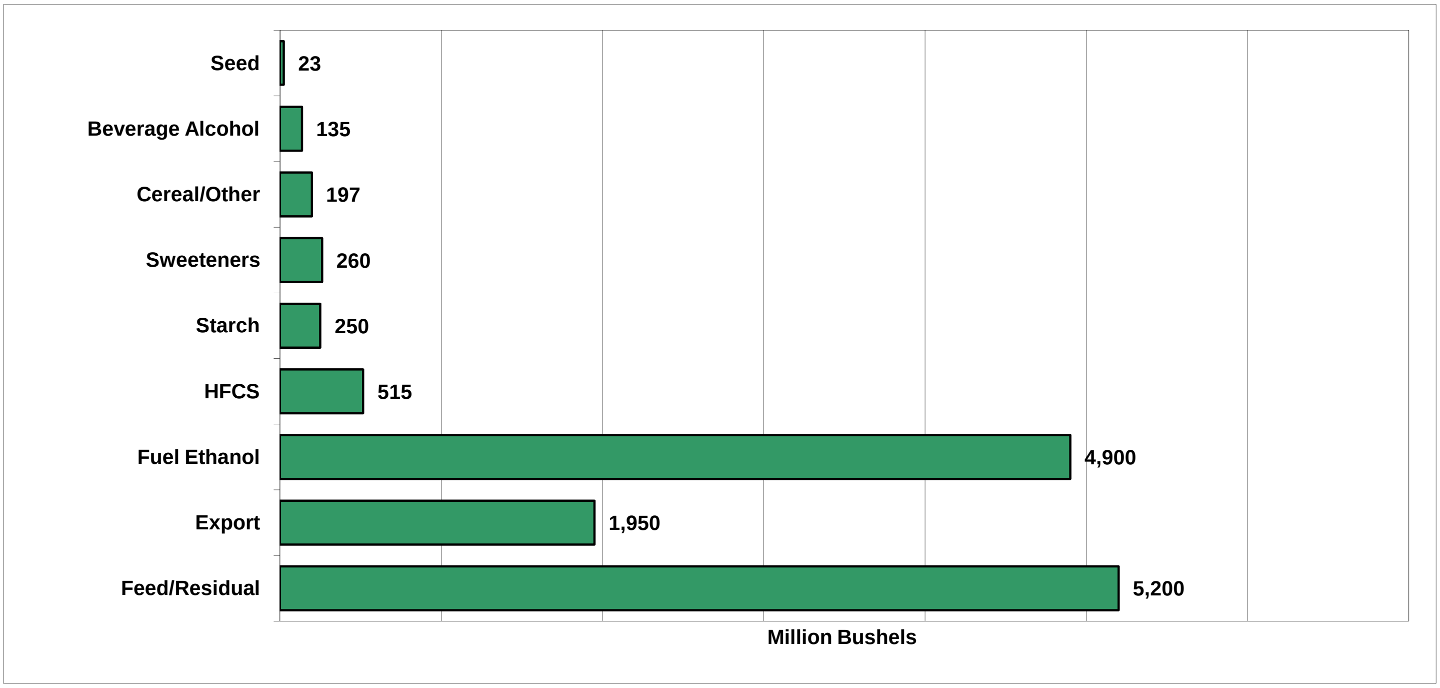
Note: Based on Marketing Year September - August (i.e., 1985 data are from September 1985-August 1986)

---

[a]Crop year ending 8/11. Includes approximately 102 billion bushels to be used as distillers grain for livestock feed.

In 2010, ethanol production accounted for about 36 percent of the overall corn consumption and more than double the amount used for export.

Section: FEEDSTOCKS
Corn Usage by Segment, 2010

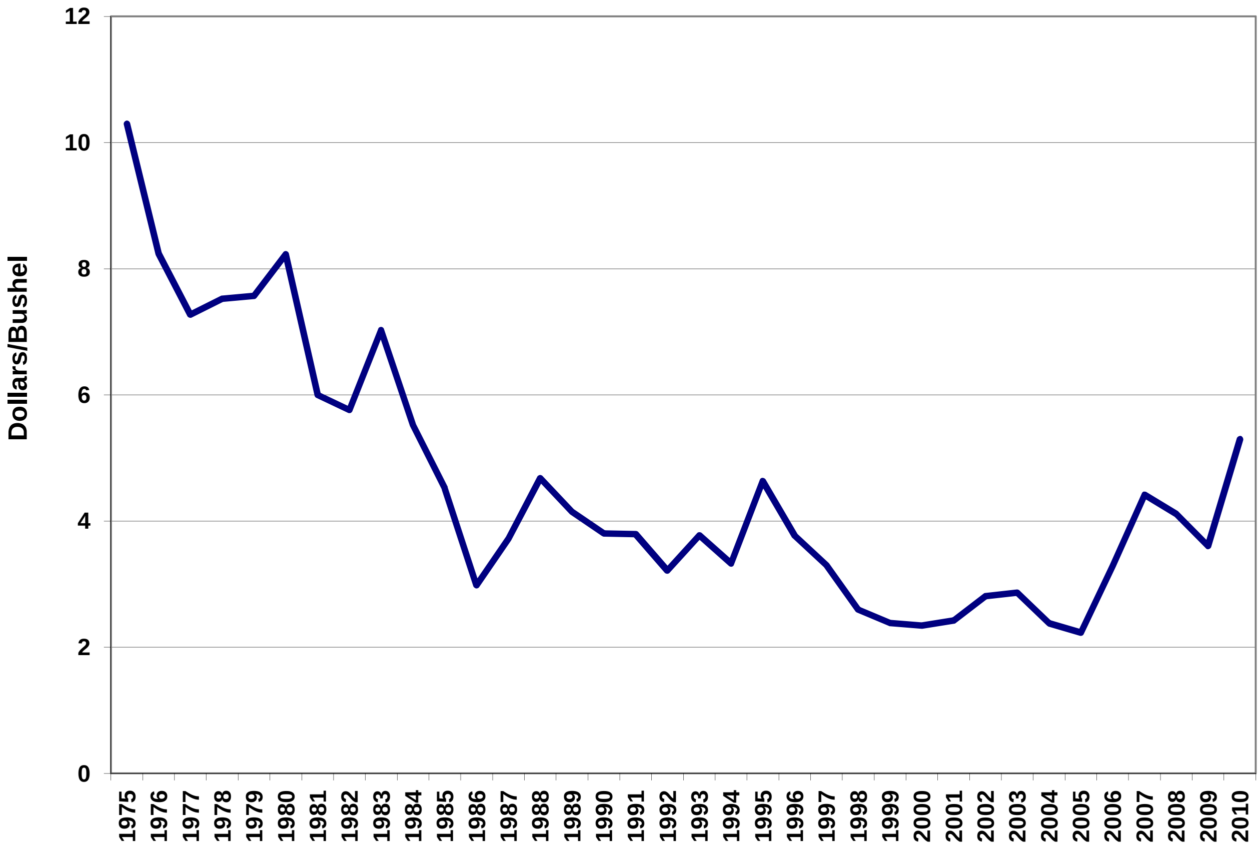


Source: National Corn Growers Association, *The World of Corn,* 2011
http://www.ncga.com/

Note: Crop year ending August 31, 2011.
HFCS - High Fructose Corn Syrup

Overall, the price for corn has been declining due to improvements in farming techniques. Though there has always been variation in corn price from year to year due to factors such as weather, affecting yield, much of the increase beginning in 2005 is likely attributable to increased demand for corn by ethanol producers.

Section: FEEDSTOCKS
Corn: Price per Bushel, 1975-2010



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

In the baseline year of 2001, 7.5% of all corn grain produced was used for ethanol production and by 2009 it rose to about 35%. Largely due to increased demand for ethanol, the acres of corn planted rose sharply in 2007 to 93 million acres but declined somewhat over the next two years; 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 of corn.

Section: FEEDSTOCKS
Corn: Area, Yield, Production, and Value, 1996-2009

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	10,087,292	2.42	24,472,254	6,583	16.3	107,378
2004	80,929	73,631	160.3	11,805,581	2.06	24,377,913	6,101	17.6	107,293
2005	81,779	75,117	147.9	11,112,187	2.00	22,194,287	5,930	18.0	106,486
2006	78,327	70,638	149.1	10,531,123	3.04	32,083,011	6,487	16.2	105,129
2007	93,527	86,520	150.7	13,073,875	4.20	54,666,959	6,060	17.5	106,229
2008	85,982	78,570	153.9	12,091,648	4.06	49,312,615	5,965	18.7	111,619
2009[a]	86,482	79,590	164.7	13,110,062	3.70	48,588,665	5,605	19.3	108,209

Source: U.S. Department of Agriculture, *2010 Agricultural Statistics* , Table 1-35 and previous annual editions.
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.

Section: FEEDSTOCKS
Corn: Area, Yield, and Production, by State, 2007-2009

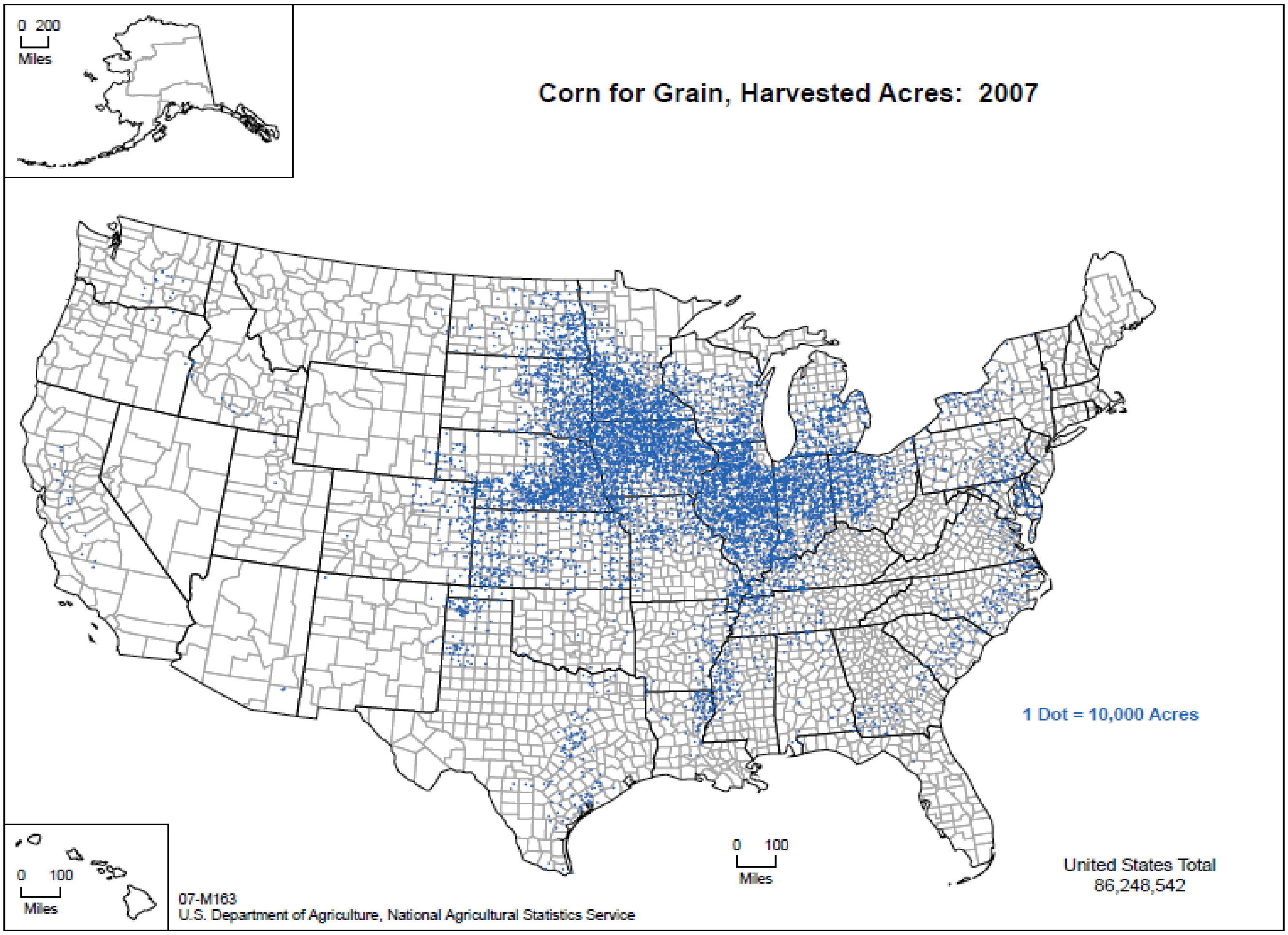
State	Area planted for all purposes			Corn for grain								
				Area harvested			Yield per harvested acre			Production		
	2007	2008	2009[a]	2007	2008	2009[a]	2007	2008	2009[a]	2007	2008	2009[a]
	1,000 Acres	1,000 Acres	1,000 Acres	1,000 Acres	1,000 Acres	1,000 Acres	Bushels	Bushels	Bushels	1,000 Bushels	1,000 Bushels	1,000 Bushels
Alabama	340	260	280	280	235	250	78	104	108	21,840	24,440	27,000
Arizona	55	50	50	22	15	20	185	165	175	4,070	2,475	3,500
Arkansas	610	440	430	590	430	410	169	155	148	99,710	66,650	60,680
California	650	670	550	190	170	160	182	195	180	34,580	33,150	28,800
Colorado	1,200	1,250	1,100	1,060	1,010	990	140	137	153	148,400	138,370	151,470
Connecticut	26	27	26	b	b	b	b	b	b	b	b	b
Delaware	195	160	170	185	152	163	99	125	145	18,315	19,000	23,635
Florida	70	70	70	35	35	37	90	105	100	3,150	3,675	3,700
Georgia	510	370	420	450	310	370	127	140	140	57,150	43,400	51,800
Idaho	320	300	300	105	80	80	170	170	180	17,850	13,600	14,400
Illinois	13,200	12,100	12,000	13,050	11,900	11,800	175	179	174	2,283,750	2,130,100	2,053,200
Indiana	6,500	5,700	5,600	6,370	5,460	5,460	154	160	171	980,980	873,600	933,660
Iowa	14,200	13,300	13,700	13,900	12,800	13,400	171	171	182	2,376,900	2,188,800	2,438,800
Kansas	3,900	3,850	4,100	3,680	3,630	3,860	138	134	155	507,840	486,420	598,300
Kentucky	1,440	1,210	1,220	1,340	1,120	1,150	128	136	165	171,520	152,320	189,750
Louisiana	740	520	630	730	510	610	163	144	132	118,990	73,440	80,520
Maine	28	29	28	b	b	b	b	b	b	b	b	b
Maryland	540	460	470	465	400	425	101	121	145	46,965	48,400	61,625
Massachusetts	18	19	17	b	b	b	b	b	b	b	b	b
Michigan	2,650	2,400	2,350	2,340	2,140	2,070	123	138	148	287,820	295,320	309,320
Minnesota	8,400	7,700	7,600	7,850	7,200	7,150	146	164	174	1,146,100	1,180,800	1,244,100
Mississippi	930	720	730	910	700	695	148	140	126	134,680	98,000	87,570
Missouri	3,450	2,800	3,000	3,270	2,650	2,920	140	144	153	457,800	381,600	446,760
Montana	84	78	72	38	35	26	140	136	152	5,320	4,760	3,952
Nebraska	9,400	8,800	9,150	9,200	8,550	8,850	160	163	178	1,472,000	1,393,650	1,575,300
Nevada	5	5	4	b	b	b	b	b	b	b	b	b
New Hampshire	14	15	15	b	b	b	b	b	b	b	b	b
New Jersey	95	85	80	82	74	70	124	116	143	10,168	8,540	10,010
New Mexico	135	140	130	54	55	50	180	180	185	9,720	9,900	9,250
New York	1060	1,090	1,070	550	640	595	128	144	134	70,400	92,160	79,730
North Carolina	1090	900	870	1,010	830	800	100	78	117	101,000	64,740	93,600
North Dakota	2,560	2,550	1,950	2,350	2,300	1,740	116	124	115	272,600	285,200	200,100
Ohio	3,850	3,300	3,350	3,610	3,120	3,140	150	135	174	541,500	421,200	546,360
Oklahoma	320	370	390	270	320	320	145	115	105	39,150	36,800	33,600
Oregon	60	60	60	35	33	32	200	200	215	7,000	6,600	6,880
Pennsylvania	1,430	1,350	1,350	980	880	920	124	133	143	121,520	117,040	131,560
Rhode Island	2	2	2	b	b	b	b	b	b	b	b	b
South Carolina	400	355	335	370	315	320	97	65	111	35,890	20,475	35,520
South Dakota	4,950	4,750	5,000	4,480	4,400	4,680	121	133	151	542,080	585,200	706,680
Tennessee	860	690	670	790	630	590	106	118	148	83,740	74,340	87,320
Texas	2,150	2,300	2,350	1,970	2,030	1,960	148	125	130	291,560	253,750	254,800
Utah	70	70	65	22	23	17	150	157	155	3,300	3,611	2,635
Vermont	92	94	91	b	b	b	b	b	b	b	b	b
Virginia	540	470	480	405	340	330	86	108	131	34,830	36,720	43,230
Washington	195	165	170	115	90	105	210	205	215	24,150	18,450	22,575
West Virginia	48	43	47	27	26	30	111	130	126	2,997	3,380	3,780
Wisconsin	4,050	3,800	3,850	3,280	2,880	2,930	135	137	153	442,800	394,560	448,290
Wyoming	95	95	90	60	52	45	129	134	140	7,740	6,968	6,300
US	**93,527**	**85,982**	**86,482**	**86,520**	**78,570**	**795,920**	**150.7**	**153.9**	**164.7**	**13,037,875**	**12,091,648**	**13,110,062**

Source:
U.S. Department of Agriculture, *2010 Agricultural Statistics* , Table 1-37,
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.

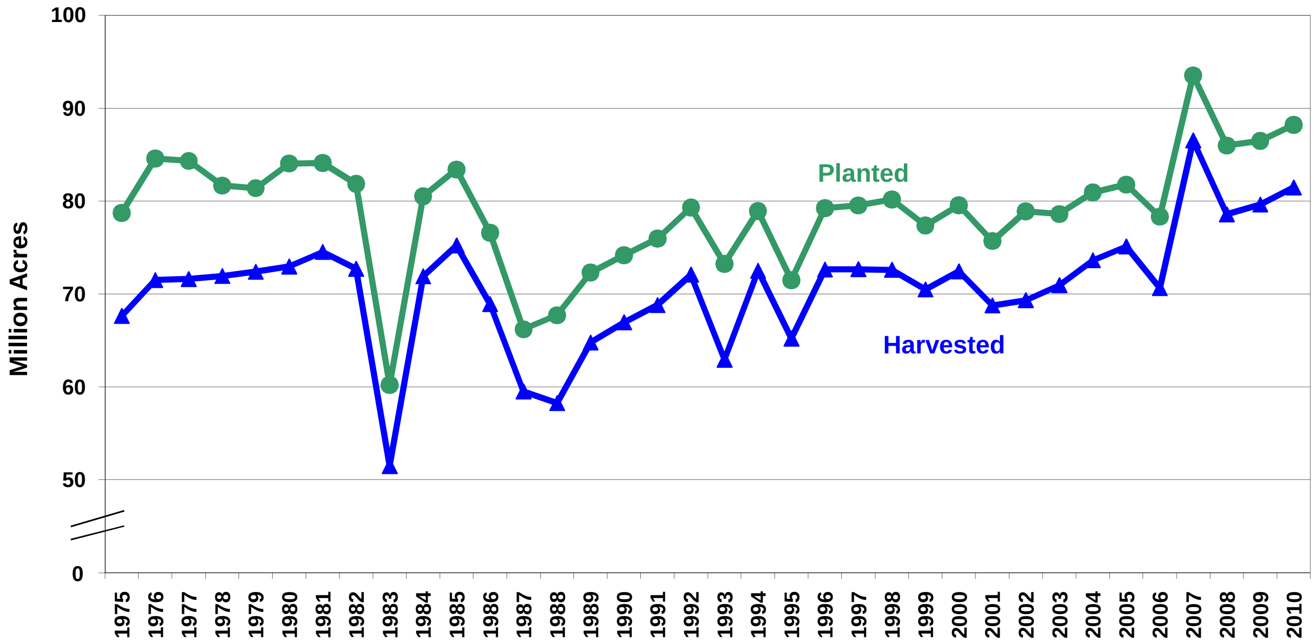
Section: FEEDSTOCKS
Corn for Grain, Harvested Acres, 2007



Source: U.S. Department of Agriculture, National Agricultural Statistics Service, The Census of Agriculture
http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/Ag_Atlas_Maps/Crops_and_Plants/

Due largely to increased ethanol demand, there was a remarkable increase in the number of corn acres planted in 2007. Acres harvested for grain are always less than planted acres due to silage and crop failure.

Section: FEEDSTOCKS
Corn Acres Planted and Harvested, 1975-2010



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

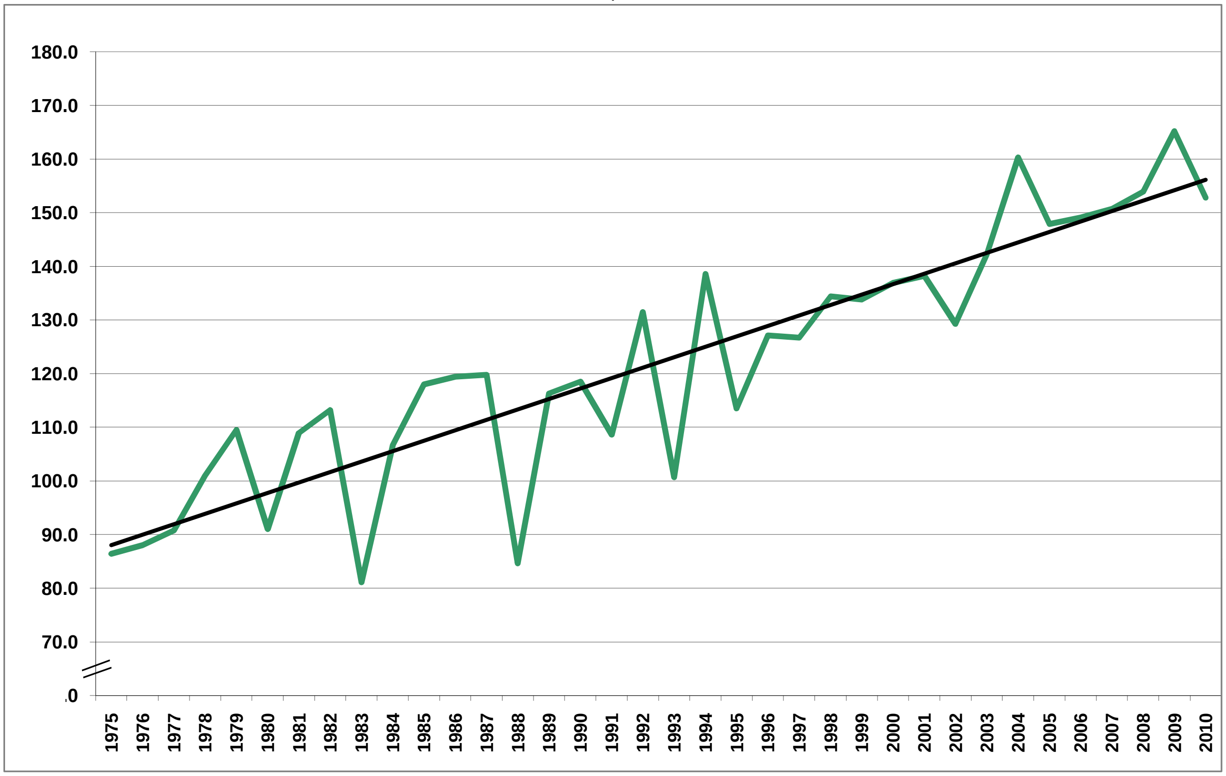
Doberman et. al., noted in 2002 that average corn yields have increased linearly at a rate of 1.7 bushels per acre (bu/ac) per year. At present that translates to a rate of 1.1% per year, but if the same average linear rate continues, the percentage rate will decline. Corn yields must continue to increase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

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 follow.

Section: FEEDSTOCKS
Corn Yield, 1975-2010



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

Additional References:

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.

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 Science. 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.

Section: FEEDSTOCKS
Corn: Supply and Disappearance, 1996-2010
(million bushels)

	Supply				Disappearance					Ending stocks August 31		
					Domestic use							
Year (beginning September 1)	**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	7,317	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	958	11,806	11	12,775	6,155	2,687	8,842	1,818	10,661	2,113	1	2,114
2005	2,114	11,112	9	13,235	6,152	2,982	9,134	2,134	11,268	1,967	0	1,967
2006	1,967	10,531	12	12,510	5,591	3,490	9,081	2,125	11,207	1,304	0	1,304
2007	1,304	13,038	20	14,362	5,858	4,442	10,300	2,437	12,737	1,624	0	1,624
2008	1,624	12,092	14	13,729	5,182	5,025	10,207	1,849	12,056	1,673	0	1,673
2009 [b]	1,673	13,110	8	14,791	5,525	5,900	11,425	1,980	13,405	1,386	0	1,386
2010 [c]	1,386	13,160	10	14,556	5,250	6,090	11,340	2,100	13,440	1,116	0	1,116

Source:
U.S. Department of Agriculture, *2010 Agricultural Statistics* , Table 1-38,
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 11, 2010, 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.

Section: FEEDSTOCKS

Corn for Grain: Marketing Year Average Price and Value, by State, Crops of 2007, 2008, and 2009

State	Marketing year average price per bushel			Value of production		
	2007	**2008**	**2009[a]**	**2007**	**2008**	**2009[a]**
	Dollars	Dollars	Dollars	1,000 Dollars	1,000 Dollars	1,000 Dollars
Alabama	4.54	5.26	4.15	99,154	128,554	112,050
Arizona	5.03	5.80	4.00	20,472	14,355	14,000
Arkansas	3.80	4.42	3.75	378,898	294,593	227,550
California	4.28	4.77	4.35	148,002	158,126	125,280
Colorado	3.96	4.14	3.85	587,664	572,852	583,160
Delaware	4.76	4.57	3.80	87,179	86,830	89,813
Florida	4.00	4.50	4.00	12,600	16,538	14,800
Georgia	4.50	4.50	3.60	257,175	195,300	186,480
Idaho	4.96	4.32	4.25	88,536	58,752	61,200
Illinois	4.09	4.01	3.65	9,340,538	8,541,701	7,537,250
Indiana	4.39	4.10	3.75	4,306,502	3,581,760	3,501,225
Iowa	4.29	4.10	3.75	10,196,901	8,974,080	9,145,500
Kansas	4.13	4.12	3.60	2,097,379	54,880	2,153,880
Kentucky	4.14	4.36	3.75	710,093	664,115	711,563
Louisiana	3.80	4.45	3.55	452,162	326,808	285,846
Maryland	4.64	4.42	4.00	217,918	213,928	246,500
Michigan	4.37	3.84	3.60	1,257,773	1,134,029	1,118,880
Minnesota	4.13	3.92	3.70	4,733,393	4,628,736	4,629,625
Mississippi	3.68	4.63	3.70	495,622	453,740	324,009
Missouri	4.17	4.11	3.65	1,909,026	1,568,376	1,630,674
Montana	4.76	3.80	4.15	25,323	18,088	16,401
Nebraska	4.14	4.05	3.70	6,094,080	5,644,283	5,828,610
New Jersey	4.65	4.15	3.40	47,281	35,624	34,034
New Mexico	5.20	5.30	4.00	50,544	52,470	37,000
New York	5.05	4.32	3.95	355,520	398,131	314,934
North Carolina	4.00	4.91	3.85	404,000	317,873	360,360
North Dakota	4.06	3.74	3.40	1,106,756	1,066,648	708,050
Ohio	4.29	4.21	3.70	2,323,035	1,773,252	2,021,532
Oklahoma	4.07	4.46	3.80	159,341	164,128	127,680
Oregon	4.36	4.15	4.10	30,520	27,390	28,208
Pennsylvania	4.56	4.16	3.85	554,131	486,886	506,506
South Carolina	3.88	4.59	3.85	139,253	93,980	136,752
South Dakota	4.17	3.78	3.40	2,260,474	2,212,056	2,444,940
Tennessee	3.80	4.53	3.65	318,212	336,760	318,718
Texas	4.35	4.82	4.05	1,268,286	1,223,075	1,031,940
Utah	4.18	4.40	4.35	13,794	15,888	11,462
Virginia	4.39	4.51	3.75	152,904	165,607	162,113
Washington	4.50	4.56	4.50	108,675	84,132	101,588
West Virginia	4.60	4.34	3.55	13,786	14,669	13,419
Wisconsin	4.11	3.89	3.70	1,819,908	1,534,838	1,658,673
Wyoming	3.12	4.25	4.20	24,149	29,614	26,460
US	**4.20**	**4.06**	**3.70**	**54,666,959**	**54,666,959**	**48,588,665**

Source: U.S. Department of Agriculture, *2010 Agricultural Statistics,* Table 1-40, http://www.nass.usda.gov/Publications/Ag_Statistics/index.asp

[a] 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.

Section: FEEDSTOCKS

Corn Production Costs and Returns per Planted Acre by Region, Excluding Government Payments, 2009-2010[a]

(dollars per planted acre)

	United States		Heartland		Northern Crescent		Northern Great Planes		Prairie Gateway		Eastern Uplands		Southern Seaboard	
Item	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**
Gross value of production														
Primary product: Corn grain	560.04	636.55	606.48	676.06	441.25	561.96	474.02	569.9	532.14	598.69	560.04	526.68	433.92	499.55
Secondary product: Corn silage	1.18	1.13	0.70	0.68	3.02	2.59	4.58	3.92	2.47	2.18	5.73	5.41	0.00	0.00
Total, gross value of production	**561.22**	**637.68**	**607.18**	**676.74**	**444.27**	**564.55**	**478.60**	**573.82**	**534.61**	**600.87**	**565.77**	**532.09**	**433.92**	**499.55**
Operating costs:														
Seed	78.92	66.15	80.61	67.61	80.61	67.61	76.91	64.51	71.04	59.58	73.52	61.66	71.43	59.91
Fertilizer [b]	132.72	100.30	139.58	105.82	150.49	114.09	88.83	67.35	92.00	69.75	168.93	128.07	141.26	107.10
Chemicals	27.68	27.39	30.35	30.08	24.49	24.27	19.42	19.25	22.88	22.67	27.34	27.09	26.38	26.14
Custom operations[c]	11.98	12.15	10.67	10.80	14.80	14.99	10.88	11.02	16.05	16.25	10.53	10.66	7.68	7.78
Fuel, lube, and electricity	29.00	35.73	22.04	26.79	27.84	34.62	28.10	35.01	66.77	81.47	19.63	22.73	24.13	28.89
Repairs	15.69	16.03	13.72	13.98	15.80	16.10	17.10	17.43	23.90	24.36	13.29	13.54	22.72	23.15
Purchased irrigation water	0.14	0.15	0.00	0.00	0.02	0.02	1.79	1.81	0.21	0.21	0.00	0.00	0.00	0.00
Interest on operating capital	0.43	0.26	0.43	0.26	0.46	0.27	0.35	0.22	0.42	0.27	0.45	0.26	0.43	0.25
Total, operating costs	**296.56**	**258.16**	**297.40**	**255.34**	**314.51**	**271.97**	**243.38**	**216.60**	**293.27**	**274.56**	**313.69**	**264.01**	**294.03**	**253.22**
Allocated overhead:														
Hired labor	2.41	2.44	1.59	1.61	3.43	3.47	3.74	3.78	4.01	4.05	1.32	1.33	6.92	6.99
Opportunity cost of unpaid labor	25.67	25.92	22.44	22.68	36.03	36.42	24.12	24.38	26.54	26.82	42.77	43.23	27.99	28.29
Capital recovery of machinery and equipmen	81.11	83.46	77.56	79.66	77.68	79.78	88.63	91.03	100.23	102.94	72.91	74.88	81.64	83.85
Opportunity cost of land (rental rate)	123.90	127.33	142.36	146.58	104.74	107.85	81.17	83.58	89.77	92.43	85.21	87.74	74.25	76.45
Taxes and insurance	8.13	8.23	7.46	7.57	11.08	11.24	5.00	5.07	9.13	9.26	6.32	6.41	9.69	9.83
General farm overhead	14.49	14.71	13.61	13.87	19.81	20.19	10.32	10.52	13.70	13.96	11.83	12.06	18.89	19.25
Total, allocated overhead	**255.71**	**262.09**	**265.02**	**271.97**	**252.77**	**258.95**	**212.98**	**218.36**	**243.38**	**249.46**	**220.36**	**225.65**	**219.38**	**224.66**
Total, costs listed	**552.27**	**520.25**	**562.42**	**527.31**	**567.28**	**530.92**	**456.36**	**434.96**	**536.65**	**524.02**	**534.05**	**489.66**	**513.41**	**477.88**
Value of production less total costs listed	8.95	117.43	44.76	149.43	-123.01	33.63	22.24	138.86	-2.04	76.85	31.72	42.43	-79.49	21.67
Value of production less operating costs	264.66	379.52	309.78	421.40	129.76	292.58	235.22	357.22	241.34	326.31	252.08	268.08	139.89	246.33
Supporting information:														
Yield (bushels per planted acre)	156	145	168	154	125	126	137	139	147	137	156	114	113	97
Price (dollars per bushel at harvest)	3.59	4.39	3.61	4.39	3.53	4.46	3.46	4.10	3.62	4.37	3.59	4.62	3.84	5.15
Enterprise size (planted acres) [a]	250	250	281	281	128	128	341	341	322	322	77	77	146	146
Production practices: [a]														
Irrigated (percent)	12	12	5	5	5	5	21	21	48	48	2	2	13	13
Dryland (percent)	88	88	95	95	95	95	79	79	52	52	98	98	87	87

Source:

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

[a] Developed from survey base year, 2005.

[b] Cost of commercial fertilizers, soil conditioners, and manure.

[c] Cost of custom operations, technical services, and commercial drying.

Oats: Area, Yield, Production, and Value, 1996-2009

Year	Area		Yield per harvested acre	Production	Marketing year average price per bushel received by farmers	Value of production
	Planted[a]	Harvested				
	1,000 Acres	1,000 Acres	Bushels	1,000 Bushels	Dollars	1,000 Dollars
1996	4,638	2,655	57.7	153,245	1.96	313,910
1997	5,068	2,813	59.5	167,246	1.60	273,284
1998	4,891	2,752	60.2	165,768	1.10	199,475
1999	4,668	2,445	59.6	145,628	1.12	174,307
2000	4,473	2,325	64.2	149,165	1.10	175,432
2001	4,401	1,911	61.5	117,602	1.59	197,181
2002	4,995	2,058	56.4	116,002	1.81	212,078
2003	4,597	2,220	65.0	144,383	1.48	224,910
2004	4,085	1,787	64.7	115,695	1.48	178,327
2005	4,246	1,823	63.0	114,859	1.63	195,166
2006	4,166	1,564	59.8	93,522	1.87	180,899
2007	3,763	1,504	60.1	90,430	2.63	247,644
2008	3,247	1,400	63.7	89,135	3.15	269,763
2009 [b]	3,404	1,379	67.5	93,081	2.10	216,566

Source: U.S. Department of Agriculture, *2010 Agricultural Statistics*, Table 1-45 and annual.
http://www.nass.usda.gov/Publications/Ag_Statistics/index.asp

[a] Oats sown for all purposes, including oats sown in the preceding fall.
[b] Preliminary

Section: FEEDSTOCKS
Oats: Area, Yield, and Production, by State, 2007-2009

	Area planted[a]			Area harvested			Yield per harvested acre			Production		
	2007	2008	2009	2007	2008	2009	2007	2008	2009	2007	2008	2009
	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	45	50	50	16	15	11	58	50	50	928	750	550
Arkansas[b]	***	***	10	***	***	8	***	***	80	***	***	640
California	215	260	250	25	20	30	99	80	105	2,475	2,000	3,150
Colorado	75	45	60	10	7	9	55	70	65	550	490	585
Georgia	70	65	60	30	25	20	56	69	56	1,680	1,725	1,120
Idaho	70	70	80	20	20	25	61	69	78	1,220	1,380	1,950
Illinois	35	45	40	24	30	25	62	70	65	1,488	2,100	1,625
Indiana	25	15	15	8	5	7	53	75	69	424	375	483
Iowa	145	150	200	67	75	95	71	65	65	4,757	4,875	6,175
Kansas	90	60	85	35	25	35	45	53	53	1,575	1,325	1,855
Maine	29	32	32	28	31	31	70	65	65	1,960	2,015	2,015
Michigan	70	75	70	55	60	55	56	66	63	3,080	3,960	3,465
Minnesota	270	250	250	180	175	170	60	68	71	10,800	11,900	12,070
Missouri	25	15	15	8	6	9	50	55	55	400	330	495
Montana	75	60	70	35	30	32	50	51	56	1,750	1,530	1,792
Nebraska	120	95	100	35	35	30	61	70	69	2,135	2,450	2,070
New York	100	80	90	60	64	60	58	66	77	3,480	4,224	4,620
North Carolina	50	60	50	15	30	15	55	80	70	825	2,400	1,050
North Dakota	460	320	350	260	130	165	59	51	68	15,340	6,630	11,220
Ohio	75	75	65	50	50	45	62	70	75	3,100	3,500	3,375
Oklahoma	80	50	50	15	10	15	31	40	34	465	400	510
Oregon	60	45	45	18	18	22	78	100	100	1,404	1,800	2,200
Pennsylvania	115	105	110	80	80	80	56	58	61	4,480	4,640	4,880
South Carolina	33	33	30	14	19	15	42	64	55	588	1,216	825
South Dakota	330	220	200	130	120	90	72	73	73	9,360	8,760	6,570
Texas	710	600	600	100	100	60	40	50	47	4,000	5,000	2,820
Utah	35	40	45	4	4	5	80	75	81	320	300	405
Virginia	16	12	12	5	4	4	60	70	54	300	280	216
Washington	30	20	20	9	5	6	50	80	80	450	400	480
Wisconsin	270	270	310	160	190	195	67	62	68	10,720	11,780	13,260
Wyoming	40	30	40	8	12	10	47	50	61	376	600	610
US	**3,763**	**3,247**	**3,404**	**1,504**	**1,400**	**1,379**	**60.1**	**63.7**	**67.5**	**90,430**	**89,135**	**93,081**

Source:
U.S. Department of Agriculture, *2010 Agricultural Statistics*, Table 1-49,
http://www.nass.usda.gov/Publications/Ag_Statistics/index.asp

[a] Relates to the total area of oats sown for all purposes, including oats sown in the preceding fall.
[b] Estimates began in 2009.

Section: FEEDSTOCKS

Oats Production Costs and Returns per Planted Acre by Region, Excluding Government Payments, 2009-2010[a]

(dollars per planted acre)

Item	United States		Northern Great Plains		Prarie Gateway		Northern Crescent		Heartland	
	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
Gross value of production										
Primary product: Oats	155.35	130.168	131.88	114.82	91.133	75.336	154.752	132.912	128.212	103.6
Secondary product: Straw	59.35	46.47	29.50	23.42	6.53	5.70	77.41	58.74	76.81	62.34
Secondary product: Hay, silage, grazing	21.05	15.77	19.10	14.57	64.03	42.09	16.88	13.23	14.92	10.32
Total, gross value of production	**235.75**	**192.41**	**180.48**	**152.81**	**161.69**	**123.13**	**249.04**	**204.88**	**219.94**	**176.26**
Operating costs:										
Seed	12.54	11.97	9.11	8.65	10.16	9.65	14.41	13.69	13.70	13.02
Fertilizer [b]	46.07	36.26	22.62	17.36	68.36	52.46	61.62	47.28	39.20	30.08
Chemicals	2.53	2.43	3.81	3.75	0.98	0.97	2.48	2.44	2.03	2.00
Custom operations	9.18	9.24	2.80	2.80	3.06	3.06	12.02	12.02	12.61	12.61
Fuel, lube, and electricity	15.53	19.31	12.19	15.13	10.79	13.39	18.93	23.49	15.44	19.17
Repairs	12.94	13.11	14.19	14.46	10.44	10.64	13.33	13.59	12.20	12.43
Purchased irrigation water	2.84	2.87	0.84	0.86	0.27	0.27	2.01	2.05	6.20	6.32
Interest on operating inputs	0.15	0.10	0.10	0.06	0.15	0.09	0.18	0.11	0.15	0.10
Total, operating costs	**101.77**	**95.28**	**65.66**	**63.07**	**104.21**	**90.53**	**124.98**	**114.67**	**101.53**	**95.73**
Allocated overhead:										
Hired labor	0.79	0.81	0.37	0.38	0.40	0.40	1.63	1.65	0.22	0.22
Opportunity cost of unpaid labor	35.29	35.96	23.06	23.31	28.74	29.05	45.68	46.17	34.32	34.68
Capital recovery of machinery and equipment	67.94	69.30	75.03	77.06	53.25	54.69	66.27	68.06	68.70	70.56
Opportunity cost of land (rental rate)	89.44	91.85	64.58	66.50	51.18	52.70	87.51	90.11	122.96	126.60
Taxes and insurance	5.55	5.67	4.46	4.53	6.13	6.22	5.78	5.86	5.96	6.05
General farm overhead	8.93	9.07	7.74	7.89	5.67	5.78	9.66	9.84	9.94	10.13
Total, allocated overhead	**207.94**	**212.67**	**175.24**	**179.67**	**145.37**	**148.84**	**216.53**	**221.69**	**242.10**	**248.24**
Total, costs listed	**309.71**	**307.96**	**240.90**	**242.74**	**249.58**	**239.37**	**341.51**	**336.36**	**343.63**	**343.97**
Value of production less total costs listed	-73.96	-115.55	-60.42	-89.94	-87.89	-116.24	-92.47	-131.48	-123.69	-167.71
Value of production less operating costs	133.98	97.12	114.82	89.73	57.48	32.60	124.06	90.21	118.41	80.53
Supporting information:										
Yield (bushels per planted acre)	65	61.4	63	60	33	34	62	57	53	52
Price (dollars per bushel at harvest)	2.39	2.12	2.10	1.92	2.77	2.19	2.48	2.34	2.41	2.00
Enterprise size (planted acres) [a]	27	27	66	66	47	47	25	25	23	23
Production practices: [a]										
Irrigated (percent of acres)	1	1	2	2	5	5	0	0	0	0
Dryland (percent of acres)	99	99	98	98	95	95	100	100	100	100
Straw (percent of acres)	71	71	47	47	18	18	79	79	82	82

Source:

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

[a] Developed from survey base year, 2005.

[b] Cost of commercial fertilizers, soil conditioners, and manure.

Rice[a]: Area, Yield, Production, and Value, 1996-2009

Year	Area		Yield per harvested acre	Production	Marketing year average price per cwt. received by farmers	Value of production
	Planted	Harvested				
	1,000 Acres	1,000 Acres	Pounds	1,000 cwt.	Dollars	1,000 Dollars
1996	2,824	2,804	6,120	171,599	9.96	1,690,270
1997	3,125	3,103	5,897	182,992	9.70	1,756,136
1998	3,285	3,257	5,663	184,443	8.89	1,654,157
1999	3,531	3,512	5,866	206,027	5.93	1,231,207
2000	3,060	3,039	6,281	190,872	5.61	1,049,961
2001	3,334	3,314	6,496	215,270	4.25	925,055
2002	3,240	3,207	6,578	210,960	4.49	979,628
2003[b]	3,022	2,997	6,670	199,897	8.08	1,628,948
2004	3,347	3,325	6,988	232,362	7.33	1,701,822
2005	3,384	3,364	6,624	222,833	7.65	1,738,598
2006	2,838	2,821	6,898	194,585	9.96	1,990,783
2007	2,761	2,748	7,219	198,388	12.80	2,600,871
2008	2,995	2,976	6,846	203,733	16.80	3,603,460
2009	3,135	3,103	7,085	219,850	14.30	3,145,521

Source: U.S. Department of Agriculture, *2010 Agricultural Statistics*, Table 1-21 and previous annual editions,
http://www.nass.usda.gov/Publications/Ag_Statistics/index.asp

[a] Rough
[b] Sweet rice yield and production included in 2003 as short grain but not in previous years.

Section: FEEDSTOCKS
Rice: Area, Yield, and Production by State, 2007-2009[a]

State	Area Planted			Area harvested			Yield per harvested acre			Production		
	2007	2008	2009[b]	2007	2008	2009[b]	2007	2008	2009[b]	2007	2008	2009[b]
	1,000 Acres	1,000 Acres	1,000 Acres	1,000 Acres	1,000 Acres	1,000 Acres	Pounds	Pounds	Pounds	1,000 cwt.	1,000 cwt.	1,000 cwt.
Arkansas	1,331.0	1,401.0	1,486.0	1,325.0	1,395.0	1,470.0	7,230	6,660	6,800	95,814	92,938	99,924
California	534.0	519.0	561.0	533.0	517.0	556.0	8,200	8,320	8,600	43,684	43,030	47,804
Louisiana	380.0	470.0	470.0	378.0	464.0	464.0	6,140	5,830	6,300	23,222	27,037	29,217
Mississippi	190.0	230.0	245.0	189.0	229.0	243.0	7,350	6,850	6,700	13,892	15,687	16,281
Missouri	180.0	200.0	202.0	178.0	199.0	200.0	6,900	6,620	6,710	12,279	13,173	13,423
Texas	146.0	175.0	171.0	145.0	172.0	170.0	6,550	6,900	7,770	9,497	11,868	13,201
US	**2,761.0**	**2,995.0**	**3,135.0**	**2,748.0**	**2,976.0**	**3,103.0**	**7,219**	**6,846**	**7,085**	**198,388**	**203,733**	**219,850**

Source: U.S. Department of Agriculture, *2010 Agricultural Statistics,* Table 1-27, http://www.nass.usda.gov/Publications/Ag_Statistics/index.asp

[a] Sweet rice acreage included with short grain.
[b] Preliminary

Section: FEEDSTOCKS

Rice Production Costs and Returns per Planted Acre by Region, Excluding Government Payments, 2009-2010[a]

(dollars per planted acre)

Item	United States 2009	United States 2010	Ark Non-Delta 2009	Ark Non-Delta 2010	California 2009	California 2010	Mississippi River Delta 2009	Mississippi River Delta 2010	Gulf Coast 2009	Gulf Coast 2010
Gross value of production										
Primary product: Rice	1072.84	795.75	927.50	681.39	1594.44	1316.00	974.16	717.10	996.04	713.30
Total, gross value of production	**1072.84**	**795.75**	**927.50**	**681.39**	**1594.44**	**1316.00**	**974.16**	**717.10**	**996.04**	**713.30**
Operating costs:										
Seed	65.48	65.65	61.20	61.58	73.72	74.17	70.05	70.48	62.45	62.84
Fertilizer [b]	105.26	79.20	89.57	67.91	119.87	90.88	102.23	77.51	129.47	98.16
Chemicals	75.39	73.65	66.05	65.45	105.77	104.82	65.29	64.70	78.42	77.71
Custom operations	49.03	48.03	31.95	32.35	93.80	94.98	38.95	39.44	55.74	56.44
Fuel, lube, and electricity	91.80	115.02	97.94	121.56	60.79	75.45	92.75	115.13	106.05	131.64
Repairs	28.50	29.09	29.95	30.52	27.56	28.08	27.00	27.52	27.78	28.31
Purchased irrigation water	12.42	11.24	0.21	0.21	49.19	49.81	0.00	0.00	18.28	18.51
Commercial drying	20.34	23.15	12.15	14.44	34.79	40.17	9.67	11.84	36.23	42.54
Interest on operating inputs	0.62	0.42	0.55	0.38	0.77	0.52	0.57	0.39	0.69	0.47
Total, operating costs	**448.84**	**445.45**	**389.57**	**394.40**	**566.26**	**558.88**	**406.51**	**407.01**	**515.11**	**516.62**
Allocated overhead:										
Hired labor	20.08	20.23	21.44	21.67	25.94	26.22	21.62	21.85	10.04	10.15
Opportunity cost of unpaid labor	45.42	44.95	38.62	39.04	71.28	72.04	31.65	31.99	50.91	51.45
Capital recovery of machinery and equipment	117.81	120.81	120.21	123.46	123.47	126.80	109.48	112.43	116.04	119.17
Opportunity cost of land (rental rate)	168.20	167.61	127.18	130.96	333.03	342.91	120.10	123.67	156.36	160.99
Taxes and insurance	18.25	18.65	18.76	19.04	15.76	15.99	22.79	23.12	14.64	14.85
General farm overhead	25.86	26.00	20.71	21.11	37.31	38.02	29.12	29.67	23.15	23.59
Total, allocated overhead	**395.62**	**398.25**	**346.92**	**355.28**	**606.79**	**621.98**	**334.76**	**342.73**	**371.14**	**380.20**
Total, costs listed	**844.46**	**843.70**	**736.49**	**749.68**	**1,173.05**	**1,180.86**	**741.27**	**749.74**	**886.25**	**896.82**
Value of production less total costs listed	228.38	-47.95	191.01	-68.29	421.39	135.14	232.89	-32.64	109.79	-183.52
Value of production less operating costs	624.00	350.30	537.93	286.99	1028.18	757.12	567.65	310.09	480.93	196.68
Supporting information:										
Price (dollars per cwt at harvest)	14.49	11.3	13	10	19	16	14	10	13	10
Yield (cwt per planted acre)	74.04	70.42	70.00	67.00	86.00	80.00	72.00	71.00	74.00	70.00
Enterprise size (planted acres) [a]	511	511	521	521	431	431	634	634	469	469

Source:

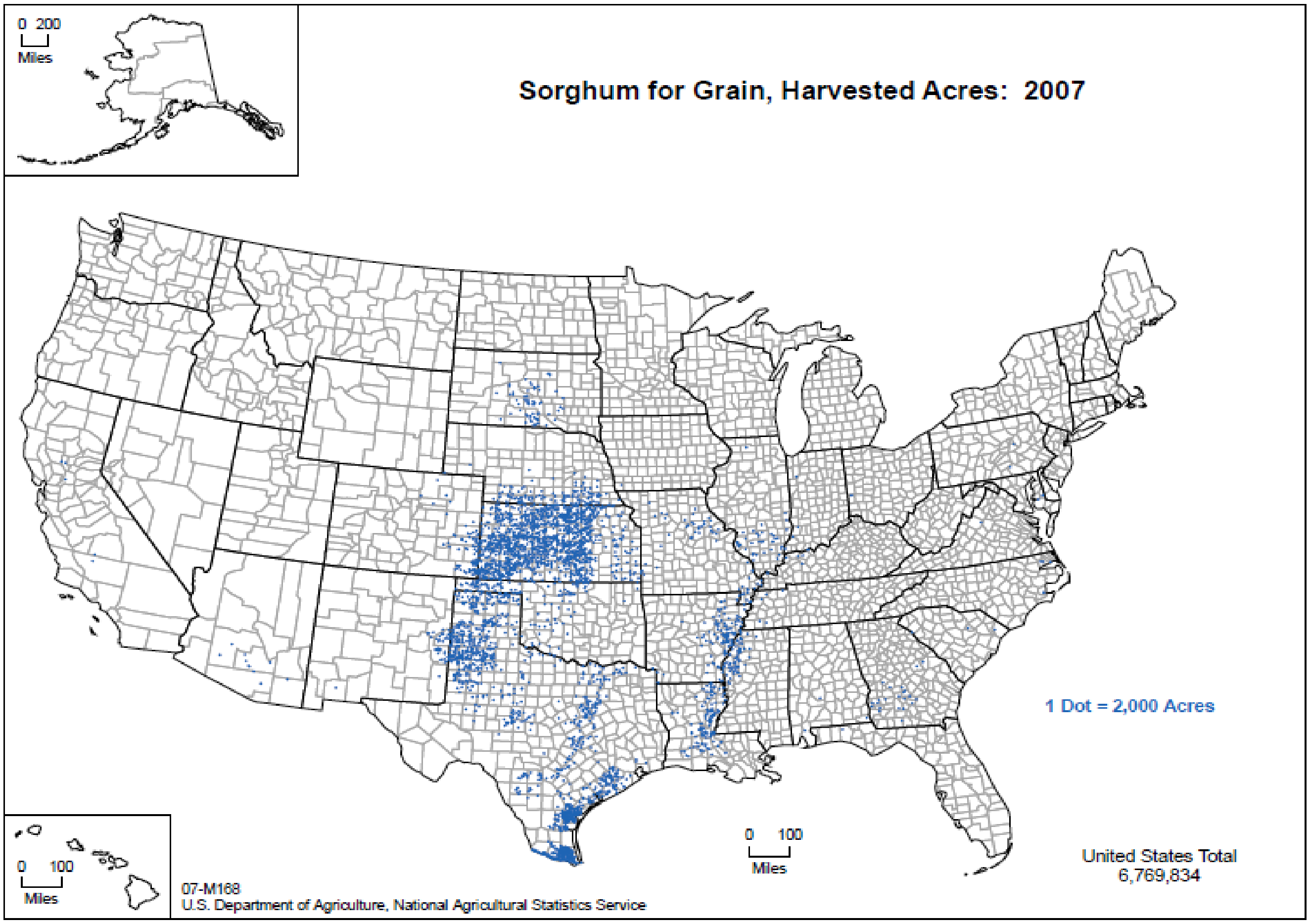
Economic Research Service, US Department of Agriculture,
http://www.ers.usda.gov/data/costsandreturns/testpick.htm

[a] Developed from survey base year, 2006.

[b] Cost of commercial fertilizers, soil conditioners, and manure.

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.

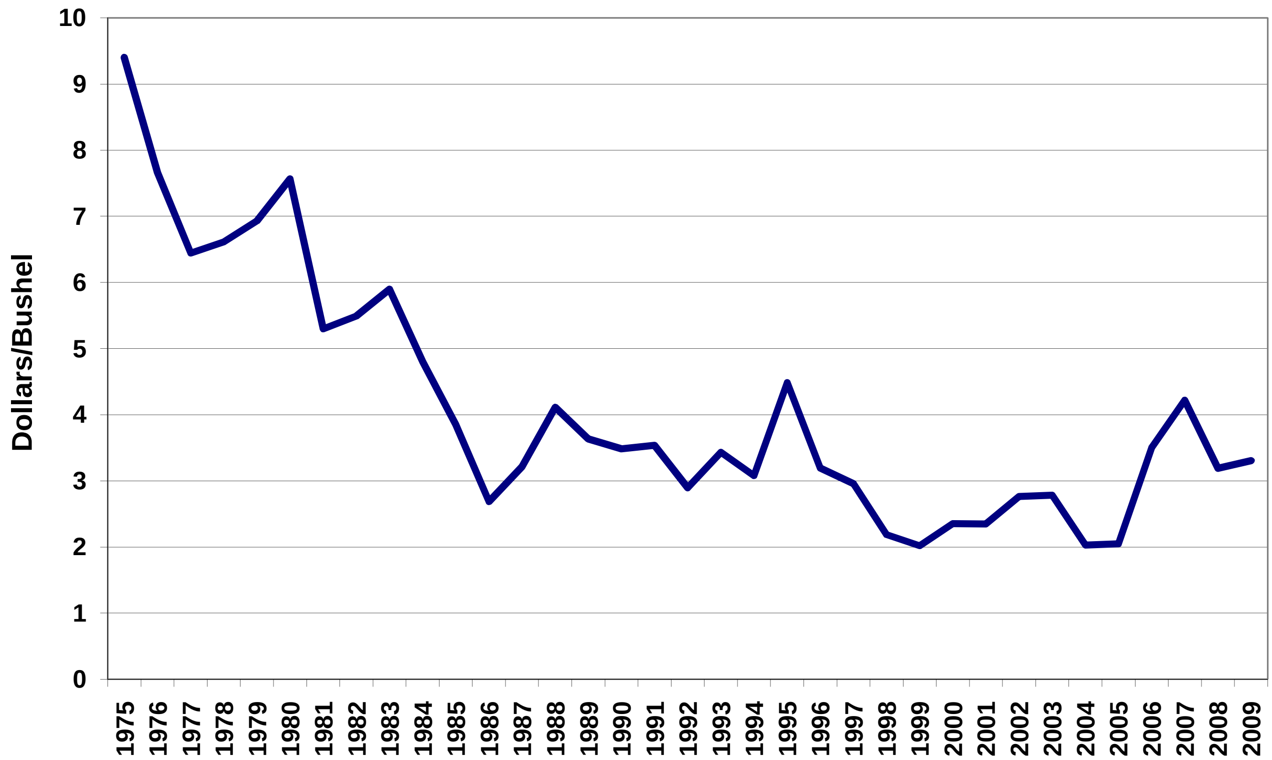
Section: FEEDSTOCKS
Sorghum for Grain, Harvested Acres, 2007



Source:
U.S. Department of Agriculture, National Agricultural Statistics Service, The Census of Agriculture
http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/Ag_Atlas_Maps/Crops_and_Plants/

The price for sorghum declined from 1975 to 1999 but has stabilized and even shown some increase in recent years. Sorghum has a different geographic distribution than corn but has similar properties, making it a viable crop for the production of ethanol. The price fluctuation for sorghum is also very similar to that of corn.

Section: FEEDSTOCKS
Sorghum: Price per Bushel, 1975-2009
(Constant 2009 dollars)



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

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%.

Section: FEEDSTOCKS
Sorghum: Area, Yield, Production, and Value, 1996-2009

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[c]	Value of production[c]	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	2.80	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	11.0	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	411,219	4.26	964,978	343	10.4	3,558
2004	7,486	6,517	69.6	453,606	3.19	843,344	352	13.6	4,782
2005	6,454	5,736	68.5	392,739	3.33	736,629	311	13.6	4,224
2006	6,522	4,937	56.1	276,824	5.88	883,204	347	13.3	4,612
2007	7,712	6,792	73.2	497,445	7.28	1,925,312	392	13.4	5,246
2008	8,284	7,271	65.0	472,342	5.72	1,631,065	408	13.8	5,646
2009[d]	6,633	5,520	69.4	382,983	5.90	1,242,196	254	14.5	3,680

Source:
USDA, *2010, Agricultural Statistics*, Table 1-62,
http://www.nass.usda.gov/Publications/Ag_Statistics/index.asp

[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 2 million acres, Kansas and Texas.

Section: FEEDSTOCKS
Sorghum: Area, Yield, and Production, by State, 2007-2009

State	Area planted for all purposes			Sorghum for grain: Area harvested			Sorghum for grain: Yield per harvested acre			Sorghum for grain: Production		
	2007	2008	2009[a]	2007	2008	2009[a]	2007	2008	2009[a]	2007	2008	2009[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[b]	12	12	***	6	6	8	40	53	85	240	318	***
Arizona	42	57	35	20	27	37	90	90	79	1800	2,430	680
Arkansas	225	125	40	215	115	***	96	88	***	20,640	10,120	2,923
California[b]	39	47	***	10	9	***	85	95	***	850	855	***
Colorado	220	230	180	150	150	150	37	30	45	5,550	4,500	6,750
Georgia	65	60	55	45	44	40	46	45	53	2,070	1,980	2,120
Illinois	80	80	40	77	76	36	81	103	82	6,237	7,828	2,952
Kansas	2,800	2,900	2,700	2,650	2,750	2,550	79	78	88	209,350	214,500	224,400
Kentucky[b]	15	13	***	12	11	***	90	90	***	1,080	990	***
Louisiana	250	120	70	245	110	65	95	87	82	23,275	9,570	5,330
Mississippi	145	85	13	115	82	11	85	71	70	9,775	5,822	770
Missouri	110	90	50	100	80	43	96	97	86	9,600	7,760	3,698
Nebraska	350	300	235	240	210	140	94	91	93	22,560	19,110	13,020
New Mexico	105	130	85	75	80	50	40	43	46	3,000	3,440	2,300
North Carolina[b]	12	16	***	8	13	***	55	56	***	440	728	***
Oklahoma	240	350	250	220	310	220	56	45	56	12,320	13,950	12,320
Pennsylvania[b]	15	11	***	3	3	***	56	37	***	168	111	***
South Carolina[b]	9	12	***	6	8	***	35	46	***	210	368	***
South Dakota	210	170	180	130	115	120	60	64	61	7,800	7,360	7,320
Tennessee[b]	18	26	***	15	22	***	82	91	***	1,230	2,002	***
Texas	2,750	3,450	2,700	2,450	3,050	2,050	65	52	48	159,250	158,600	98,400
US	**7,712**	**8,284**	**6,633**	**6,792**	**7,271**	**5,520**	**73**	**65**	**69.4**	**497,445**	**472,342**	**382,983**

Source:
USDA, *2010 Agricultural Statistics*, Table 1-65,
http://www.nass.usda.gov/Publications/Ag_Statistics/index.asp

[a] Preliminary.
[b] Estimates discontinued in 2009

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.

Section: FEEDSTOCKS

Sorghum Production Costs and Returns per Planted Acre by Region, Excluding Government Payments, 2009-2010[a]

(dollars per planted acre)

Item	United States		Heartland		Prairie Gateway		Fruitful Rim		Northern Great Plains	
	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
Gross value of production:										
Primary product: Sorghum	183.6	292.79	248.80	338.92	202.34	300.56	125.02	269.75	151.90	204.45
Secondary product: Sorgum silage	9.32	9.46	0.00	0.00	12.3	12.03	0.00	0.00	5.46	5.05
Total, gross value of production	**192.92**	**302.25**	**248.80**	**338.92**	**214.64**	**312.59**	**125.02**	**269.75**	**157.36**	**209.5**
Operating costs:										
Seed	7.47	7.58	12.31	12.62	6.88	7.05	8.96	9.18	9.61	9.85
Fertilizer[b]	43.41	33.22	85.94	65.9	42.45	32.55	46.42	35.59	37.01	28.38
Chemicals	21.18	21.34	24.48	24.15	24.83	24.5	9.06	8.94	17.46	17.23
Custom operations	11.37	10.37	6.73	6.14	11.3	10.31	12.25	11.17	8.83	8.05
Fuel, lube, and electricity	36.76	47.61	15.16	18.46	42.60	53.07	22.67	33.14	7.18	8.82
Repairs	19.27	19.79	17.28	17.61	20.4	20.79	17.3	17.63	9.06	9.23
Purchased irrigation water	0.15	0.12	0.00	0.00	0.00	0.00	0.69	0.63	0.19	0.17
Interest on operating inputs	0.21	1.4	0.23	1.45	0.22	1.48	0.17	1.16	0.13	0.82
Total, operating costs	**139.82**	**141.43**	**162.13**	**146.33**	**148.68**	**149.75**	**117.52**	**117.44**	**89.47**	**82.55**
Allocated overhead:										
Hired labor	6.11	5.89	2.61	2.64	3.8	3.84	15.26	15.42	0.65	0.66
Opportunity cost of unpaid labor	29.87	30.42	28.04	28.34	31.7	32.04	25.84	26.12	17.44	17.63
Capital recovery of machinery and equipment	78.96	81.13	69.67	71.23	81.99	83.83	73.59	75.24	52.73	53.91
Opportunity cost of land	44.7	48.39	86.55	93.89	43.75	47.46	45.91	49.8	47.970	52.04
Taxes and insurance	5.42	4.74	29.44	25.61	5.52	4.8	3.820	3.32	7.72	6.710
General farm overhead	8.58	8.6	29.27	29.83	7.39	7.53	11.33	11.55	12.12	12.35
Total, allocated overhead	173.64	179.17	245.58	251.54	174.15	179.5	175.75	181.45	138.63	143.3
Total costs listed	**313.46**	**320.6**	**407.71**	**397.87**	**322.83**	**329.25**	**293.27**	**298.89**	**228.1**	**225.85**
Value of production less total costs listed	-120.54	-18.35	-158.91	-58.95	-108.19	-16.66	-168.25	-29.14	-70.74	-16.35
Value of production less operating costs	53.10	160.82	86.67	192.59	65.96	162.84	7.5	152.310	67.89	126.95
Supporting information:										
Sorghum Yield: bushels per planted acre	60	67	80	74	67	68	38	65	49	47
Price: dollars per bushel	3.06	4.37	3.11	4.58	3.02	4.42	3.29	4.15	3.1	4.35
Enterprise size (planted acres)[a]	297	297	125	125	269	269	785	785	272	272
Production practices:[a]	100	100	1	1	72	72	23	23	3	3
Irrigated (percent)	11	11	6	6	13	13	13	13	13	13
Dryland (percent)	89	89	94	94	87	87	87	87	87	87

Source:

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

[a] Developed from survey base year, 2003.

[b] Commercial fertilizer and soil conditioners.

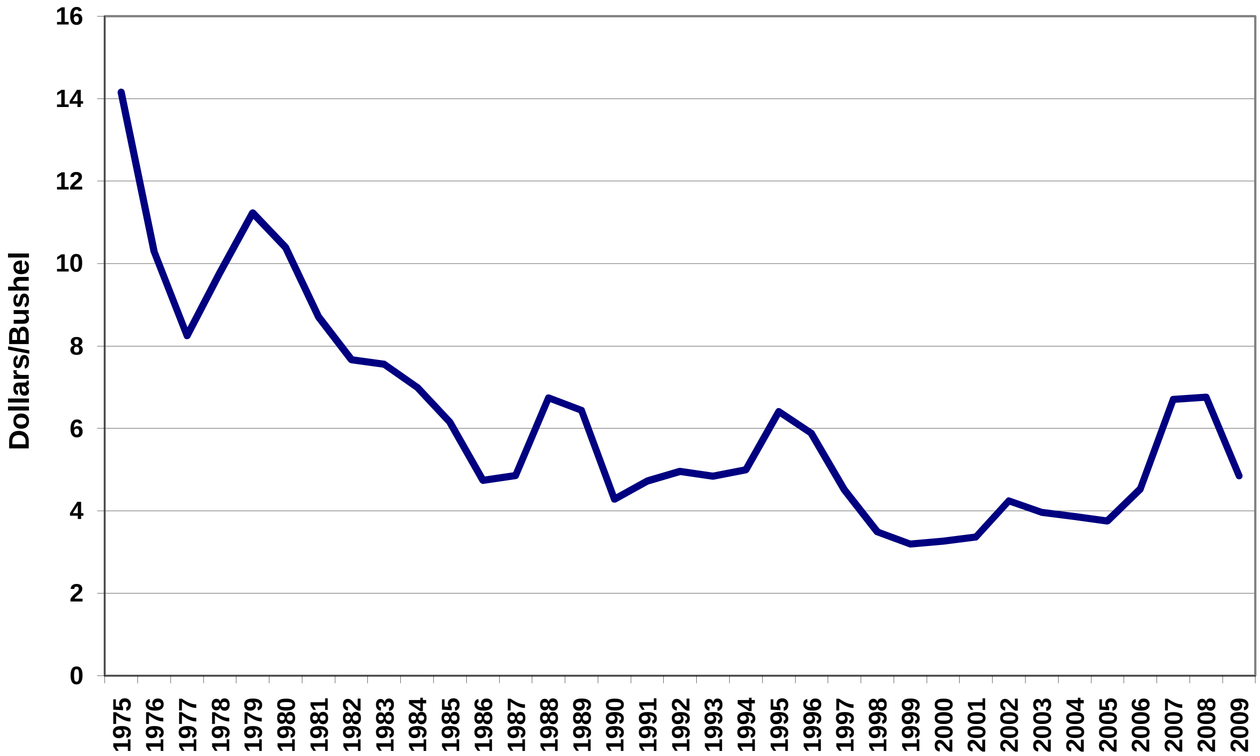
Section: FEEDSTOCKS
Wheat Baseline Projections, 2009 - 2021

Item	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21
Area (million acres):												
Planted acres	59.2	53.6	57.0	55.5	54.0	53.0	52.0	51.5	51.5	51.5	51.0	51.0
Harvested acres	49.9	47.6	48.5	47.2	45.9	45.1	44.2	43.8	43.8	43.8	43.4	43.4
Yields (bushels per acre):												
Yield/harvested acre	44.5	46.4	43.8	44.2	44.5	44.8	45.2	45.5	45.8	46.1	46.5	46.8
Supply and use (million bushels):												
Beginning stocks	657	976	848	718	706	746	759	743	718	694	682	661
Production	2,218	2,208	2,125	2,085	2,045	2,020	2,000	1,995	2,005	2,020	2,020	2,030
Imports	119	110	110	110	110	115	115	120	120	125	125	130
Supply	2,993	3,294	3,083	2,913	2,861	2,881	2,874	2,858	2,843	2,839	2,827	2,821
Food	917	940	950	959	968	977	986	995	1,004	1,013	1,022	1,031
Seed	69	76	75	73	72	70	70	70	70	69	69	69
Feed and Residual	150	180	190	175	175	175	175	175	175	175	175	175
Domestic Use	1,137	1,196	1,215	1,207	1,215	1,222	1,231	1,240	1,249	1,257	1,266	1,275
Exports	881	1,250	1,150	1,000	900	900	900	900	900	900	900	900
Total use	2,018	2,446	2,365	2,207	2,115	2,122	2,131	2,140	2,149	2,157	2,166	2,175
Ending stocks	976	848	718	706	746	759	743	718	694	682	661	646
Stocks/use ratio, percent	48.4	34.7	30.4	32.0	35.3	35.8	34.9	33.6	32.3	31.6	30.5	29.7
Prices (dollars per bushel):												
Farm price	4.87	5.50	6.50	5.90	5.55	5.45	5.45	5.50	5.50	5.55	5.55	5.60
Variable costs of production (dollars):												
Per acre	128.51	125.24	132.70	135.57	137.68	139.84	142.32	145.16	147.90	150.66	153.60	156.59
Per bushel	2.89	2.70	3.03	3.07	3.09	3.12	3.15	3.19	3.23	3.27	3.30	3.35
Returns over variable costs (dollars per acre):												
Net returns	88	130	152	125	109	104	104	105	104	105	104	105

Source:
USDA Long-Term Agricultural, Projection Tables to 2020 , February 2011, Table 23 - "U.S. Wheat Long-Term Projections",
http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1192

Overall, the price for wheat has been declining due to improvements in farming techniques.

Section: FEEDSTOCKS
Wheat: Price per Bushel, 1975-2009
(constant 2009 dollars)



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

Wheat: Area, Yield, Production, and Value, 1996-2009

Year	Area		Yield per harvested acre	Production	Marketing year average price per bushel received by farmers[b]	Value of production[b]
	Planted[a]	harvested				
	1,000 Acres	1,000 Acres	Bushels	1,000 Bushels	Dollars	1,000 Dollars
1996	75,105	62,819	36.3	2,277,388	4.30	9,782,238
1997	70,412	62,840	39.5	2,481,466	3.38	8,286,741
1998	65,821	59,002	43.2	2,547,321	2.65	6,780,623
1999	62,664	53,773	42.7	2,295,560	2.48	5,586,675
2000	62,549	53,063	42.0	2,228,160	2.62	5,771,786
2001	59,432	48,473	40.2	1,947,453	2.78	5,412,834
2002	60,318	45,824	35.0	1,605,878	3.56	5,637,416
2003	62,141	53,063	44.2	2,344,415	3.40	7,927,981
2004	59,644	49,969	43.2	2,156,790	3.40	7,277,932
2005	57,214	50,104	42.0	2,103,325	3.42	7,167,166
2006	57,344	46,800	38.6	1,808,416	4.26	7,694,734
2007	60,460	50,999	40.2	2,051,088	6.48	13,289,326
2008	63,193	55,699	44.9	2,499,164	6.78	16,625,759
2009	59,133	49,868	44.4	2,216,171	4.85	10,626,176

Source: U.S. Department of Agriculture, *2010 Agricultural Statistics*, Table 1-2 and previous annual editions, http://www.nass.usda.gov/Publications/Ag_Statistics/index.asp

[a] Includes area seeded in preceding fall for winter wheat.

[b] Includes allowance for loans outstanding and purchases by the Government valued at the average loan and purchase rate, by States, where applicable.

Section: FEEDSTOCKS
Wheat: Area, Yield, and Production, by State, 2007-2009

State	Area planted[a]			Area harvested			Yield per harvested acre			Production		
	2007	2008	2009	2007	2008	2009	2007	2008	2009	2007	2008	2009
	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	120	240	220	76	200	180	42.0	71.0	55.0	3,192	14,200	9,900
Arizona	89	159	132	86	155	129	101.4	97.9	99.4	8,724	15,172	12,825
Arkansas	820	1070	430	700	980	390	41.0	57.0	44.0	28,700	55,860	17,160
California	640	840	770	345	545	485	85.4	90.3	87.0	29,465	49,225	42,200
Colorado	2,520	2,190	2,630	2,369	1,936	2,479	39.2	30.8	40.6	92,980	59,700	100,610
Delaware	57	80	70	55	79	67	68.0	77.0	62.0	3,740	6	4,154
Florida	13	25	17	9	23	14	55.0	55.0	43.0	495	1,265	602
Georgia	360	480	340	230	400	250	40.0	56.0	42.0	9,200	22,400	10,500
Idaho	1,235	1,400	1,310	1,175	1,330	1,250	71.2	73.8	79.3	83,645	98,170	99,130
Illinois	1,000	1,200	850	890	1,150	820	55.0	64.0	56.0	48,950	73,600	45,920
Indiana	420	580	470	370	560	450	56.0	69.0	67.0	20,720	38,640	30,150
Iowa	35	40	28	28	35	22	48.0	48.0	45.0	1,344	1,680	990
Kansas	10,400	9,600	9,300	8,600	8,900	8,800	33.0	40.0	42.0	283,800	356,000	369,600
Kentucky	440	580	510	250	460	390	48.0	71.0	57.0	12,000	32,660	22,230
Louisiana	235	400	185	220	385	175	54.0	57.0	56.0	11,880	21,945	9,800
Maryland	220	255	230	160	180	195	66.0	73.0	60.0	10,560	13,140	11,700
Michigan	550	730	620	530	710	560	65.0	69.0	69.0	34,450	48,990	38,640
Minnesota	1,765	1,925	1,655	1,710	1,870	1,595	47.9	55.9	52.8	81,900	104,440	84,175
Mississippi	370	520	180	330	485	165	56.0	62.0	50.0	18,480	30,070	8,250
Missouri	1,050	1,250	780	880	1,160	730	43.0	48.0	47.0	37,840	55,680	34,310
Montana	5,170	5,740	5,520	5,065	5,470	5,305	29.6	30.1	33.3	149,820	164,730	176,625
Nebraska	2,050	1,750	1,700	1,960	1,670	1,600	43.0	44.0	48.0	84,280	73,480	76,800
Nevada	23	21	20	13	11	13	99.2	100.1	97.8	1,290	1,101	1,272
New Jersey	31	35	34	28	33	29	51.0	61.0	51.0	1,428	2,013	1,479
New Mexico	490	430	450	300	140	140	28.0	30.0	25.0	8,400	4	3,500
New York	100	130	115	85	122	105	53.0	63.0	65.0	4,505	7,686	6,825
North Carolina	630	820	700	500	720	600	40.0	60.0	49.0	20,000	43,200	29,400
North Dakota	8,595	9,230	8,680	8,405	8,640	8,415	35.6	36.0	44.8	298,875	311,200	377,190
Ohio	820	1,120	1,010	730	1,090	980	61.0	68.0	72.0	44,530	74	70,560
Oklahoma	5,900	5,600	5,700	3,500	4,500	3,500	28.0	37.0	22.0	98,000	166,500	77,000
Oregon	855	960	890	835	945	877	52.3	55.7	55.7	43,680	52,600	48,858
Pennsylvania	170	195	190	155	185	175	58.0	64.0	56.0	8,990	11,840	9,800
South Carolina	160	220	165	135	205	150	30.0	54.0	47.0	4,050	11,070	7,050
South Dakota	3,508	3,661	3,209	3,327	3,420	3,009	43.1	50.5	42.9	143,515	172,540	129,147
Tennessee	420	620	430	260	520	340	41.0	63.0	51.0	10,660	32,760	17,340
Texas	6,200	5,800	6,400	3,800	3,300	2,450	37.0	30.0	25.0	140,600	99,000	61,250
Utah	146	150	154	132	139	147	42.8	41.4	49.5	5,656	5,756	7,278
Virginia	230	310	250	205	280	210	64.0	71.0	58.0	13,120	19,880	12,180
Washington	2,170	2,290	2,290	2,137	2,255	2,225	58.7	52.7	55.3	125,342	118,790	123,085
West Virginia	8	11	9	6	8	5	57.0	60.0	50.0	342	480	250
Wisconsin	299	373	335	278	357	315	67.1	64.5	68.0	18,640	23,012	21,420
Wyoming	146	163	155	130	146	132	25.4	29.4	38.0	3,300	4,286	5,016
US	**60,460**	**63,193**	**59,133**	**50,999**	**55,699**	**49,868**	**40.2**	**44.9**	**44.4**	**2,051,088**	**2,499,164**	**2,216,171**

Source:
U.S. Department of Agriculture, *2010 Agricultural Statistics*, Table 1-6,
http://www.nass.usda.gov/Publications/Ag_Statistics/index.asp

[a] Includes area planted preceding fall.

Section: FEEDSTOCKS
Wheat: Supply and Disappearance, 1996-2009
(million bushels)

Year (beginning September 1)	Supply				Disappearance						Ending stocks May 31
					Domestic use						
	Beginning stocks	Production	Imports[a]	Total	Food	Seed	Feed[b]	Total	Exports[a]	Total disappearance	
1996	376	2,277	92	2,746	891	102	308	1,301	1,002	2302	444
1997	444	2,481	95	3,020	914	92	251	1,257	1,040	2,298	722
1998	722	2,547	103	3,373	909	81	391	1,381	1,046	2,427	946
1999	946	2,296	95	3,336	929	92	279	1,300	1,086	2,386	950
2000	950	2,228	90	3,268	950	79	300	1,330	1,062	2,392	876
2001	876	1,947	108	2,931	926	83	182	1,192	962	2,154	777
2002	777	1,606	77	2,460	919	84	116	1,119	850	1,969	491
2003	491	2,344	63	2,899	912	80	203	1,194	1,158	2,353	546
2004	546	2,157	71	2,774	910	78	181	1,168	1,066	2,234	540
2005	540	2,103	81	2,725	917	77	157	1,151	1,003	2,154	571
2006	571	1,808	122	2,501	938	82	117	1,137	908	2,045	456
2007	456	2,051	113	2,620	947	88	115	1,050	1,264	2,314	306
2008	306	2,499	127	2,932	927	78	255	1,260	1,015	2,275	657
2009 [c]	657	2,216	119	2,991	917	70	149	1,137	881	2,018	973

Source:
U.S. Department of Agriculture, *2010 Agricultural Statistics* , Table 1-7, and previous annual editions,
http://www.nass.usda.gov/Publications/Ag_Statistics/index.asp

[a] Imports and exports include flour and other products expressed in wheat equivalent.
[b] Approximates feed and residual use and includes negligible quantities used for distilled spirits.
[c] Preliminary. Totals may not add due to independent rounding.

Wheat: Marketing Year Average Price and Value, by State, Crop of 2007, 2008, and 2009

State[a]	Marketing year average price per bushel 2007	2008	2009[b]	Value of production 2007	2008	2009[b]
	Dollars	Dollars	Dollars	1,000 Dollars	1,000 Dollars	1,000 Dollars
Alabama	5.30	5.95	4.60	16,918	84,490	45,540
Arizona	7.03	8.27	8.85	61,329	125,993	112,970
Arkansas	4.72	5.88	4.85	135,464	328,457	83,226
California	5.41	7.08	5.70	159,583	352,644	240,600
Colorado	6.01	6.62	4.50	561,326	397,140	451,962
Delaware	5.56	5.96	3.50	20,794	36,255	14,539
Florida	4.00	5.50	4.30	1,980	6,958	2,589
Georgia	6.50	5.95	4.30	59,800	133,280	45,150
Idaho	6.56	6.38	4.75	549,000	626,694	469,179
Illinois	5.37	5.89	3.85	262,862	433,504	176,792
Indiana	5.20	5.91	4.20	107,744	228,362	126,630
Iowa	5.25	5.90	3.95	7,056	9,912	3,911
Kansas	5.93	6.94	4.85	1,682,934	2,470,640	1,792,560
Kentucky	5.28	5.60	4.60	63,360	182,896	102,258
Louisiana	5.20	5.50	4.70	61,776	120,698	46,060
Maryland	5.97	5.89	3.60	63,043	77,395	42,120
Michigan	5.01	5.63	4.25	172,595	275,814	164,220
Minnesota	7.28	7.06	4.80	595,467	739,133	402,825
Mississippi	4.30	5.36	4.50	79,464	161,175	37,125
Missouri	5.17	5.35	4.30	195,633	297,888	147,533
Montana	7.14	6.84	5.15	1,075,754	1,138,548	906,149
Nebraska	5.82	6.68	4.90	490,510	490,846	376,320
Nevada	6.50	6.79	4.65	8,363	7,478	5,934
New Jersey	5.80	6.15	3.75	8,282	12,380	5,546
New Mexico	5.50	7.70	4.70	46,200	32,340	16,450
New York	6.92	6.16	4.70	31,175	47,346	32,078
North Carolina	4.90	5.80	4.35	98,000	251,424	127,890
North Dakota	7.74	7.31	4.85	2,339,614	2,296,523	1,822,071
Ohio	5.37	5.82	4.35	239,126	431,378	306,936
Oklahoma	6.22	6.93	4.80	609,560	1,153,845	369,600
Oregon	8.23	6.56	4.60	358,968	343,104	223,633
Pennsylvania	6.60	5.42	4.10	59,334	64,173	40,180
South Carolina	4.55	5.95	4.85	18,428	65,867	34,193
South Dakota	6.42	6.92	5.10	899,263	1,199,255	661,874
Tennessee	5.05	5.71	4.65	53,833	187,060	80,631
Texas	6.40	7.58	5.25	899,840	750,420	321,563
Utah	8.30	7.97	6.30	46,822	45,855	40,090
Virginia	5.78	5.88	4.05	75,834	116,894	49,329
Washington	7.58	6.26	4.80	949,132	745,163	585,473
West Virginia	6.17	5.85	4.20	2,110	2,808	1,050
Wisconsin	5.30	5.47	4.10	99,002	125,803	87,822
Wyoming	6.68	6.51	4.70	22,048	27,921	23,575
US	**6.48**	**6.78**	**4.85**	**13,289,326**	**16,625,759**	**10,626,176**

Source: U.S. Department of Agriculture, *2010 Agricultural Statistics,* Table 1-10, http://www.nass.usda.gov/Publications/Ag_Statistics/index.asp

[a] States with no data are not listed.

[b] Preliminary

Wheat Production Costs and Returns per Planted Acre by Region, Excluding Government Payments, 2009-2010[a]
(dollars per planted acre)

Item	United States		Northern Great Plains		Prarie Gateway		Basin and Range		Fruitful Rim		Northern Crescent		Heartland	
	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
Gross value of production														
Primary product: Wheat grain	218.97	207.93	239.26	241.50	167.04	146.86	282.49	328.72	300.78	347.05	321.18	357.57	274.39	272.27
Secondary product: Silage, straw, grazing	7.98	7.31	3.34	3.06	9.44	8.65	3.64	3.33	11.17	10.23	26.91	24.64	16.13	14.77
Total, gross value of production	**226.95**	**215.24**	**242.60**	**244.56**	**176.48**	**155.51**	**286.13**	**332.05**	**311.95**	**357.28**	**348.09**	**382.21**	**290.52**	**287.04**
Operating costs:														
Seed	15.82	11.76	16.47	12.45	11.08	8.37	22.11	16.72	18.88	14.28	41.03	31.02	32.55	24.61
Fertilizer[b]	53.45	41.23	45.96	36.12	46.97	36.92	74.20	58.32	60.63	47.66	110.99	87.24	106.73	83.89
Chemicals	10.25	10.37	17.56	17.29	4.62	4.55	17.20	16.94	10.82	10.66	6.62	6.52	5.92	5.83
Custom operations	7.90	7.92	8.22	8.22	7.54	7.54	7.56	7.56	8.23	8.23	12.91	12.91	7.11	7.11
Fuel, lube, and electricity	17.13	21.57	8.68	10.77	21.08	26.17	12.96	16.09	52.90	65.66	10.43	12.95	8.28	10.28
Repairs	13.72	14.06	11.59	11.81	14.84	15.13	14.73	15.01	21.10	21.50	12.49	12.73	10.42	10.61
Purchased irrigation water and straw baling	0.38	0.40	0.12	0.13	0.09	0.09	0.94	0.95	3.37	3.41	0.94	0.95	0.65	0.66
Interest on operating inputs	0.17	0.11	0.16	0.10	0.15	0.10	0.22	0.13	0.26	0.17	0.28	0.16	0.25	0.14
Total, operating costs	**118.82**	**107.42**	**108.76**	**96.89**	**106.37**	**98.87**	**149.92**	**131.72**	**176.19**	**171.57**	**195.69**	**164.48**	**171.91**	**143.13**
Allocated overhead:														
Hired labor	2.74	2.85	2.10	2.13	2.65	2.68	4.60	4.65	8.24	8.33	1.36	1.37	1.19	1.20
Opportunity cost of unpaid labor	23.82	24.15	16.29	16.47	27.58	27.88	30.91	31.24	38.48	38.89	28.45	28.75	19.14	19.35
Capital recovery of machinery and equipmen	62.64	64.63	58.17	59.74	60.23	61.86	75.75	77.80	99.58	102.28	69.64	71.52	60.97	62.62
Opportunity cost of land (rental rate)	57.34	58.59	54.76	56.38	43.27	44.55	73.79	75.98	110.41	113.69	95.42	98.25	105.58	108.71
Taxes and insurance	8.62	8.83	10.97	11.13	6.22	6.31	11.00	11.16	10.97	11.13	12.40	12.58	7.95	8.07
General farm overhead	9.21	9.43	10.54	10.75	7.28	7.41	9.85	10.04	13.09	13.34	16.50	16.81	9.70	9.89
Total, allocated overhead	**164.37**	**168.48**	**152.83**	**156.60**	**147.23**	**150.69**	**205.90**	**210.87**	**280.77**	**287.66**	**223.77**	**229.28**	**204.53**	**209.84**
Total, costs listed	**283.19**	**275.90**	**261.59**	**253.49**	**253.60**	**249.56**	**355.82**	**342.59**	**456.96**	**459.23**	**419.46**	**393.76**	**376.44**	**352.97**
Value of production less total costs listed	-56.24	-60.66	-18.99	-8.93	-77.12	-94.05	-69.69	-10.54	-145.01	-101.95	-71.37	-11.55	-85.92	-65.93
Value of production less operating costs	108.13	107.82	133.84	147.67	70.11	56.64	136.21	200.33	135.76	185.71	152.40	217.73	118.61	143.91
Supporting information:														
Yield (bushels per planted acre)	40.4	45.4	46.1	48.3	28.9	36.9	53.3	61.1	55.7	63.1	70.9	68.5	61.8	57.2
Price (dollars per bushel at harvest)	5.42	4.58	5.19	5.00	5.78	3.98	5.30	5.38	5.40	5.50	4.53	5.22	4.44	4.76
Enterprise size (planted acres)[a]	412	412	618	618	443	443	858	858	584	584	87	87	104	104
Production practices:[a]														
Winter wheat (percent of acres)	67	67	27	27	100	100	75	75	72	72	93	93	83	83
Spring wheat (percent of acres)	28	28	61	61	0	0	25	25	27	27	7	7	17	17
Durum wheat (percent of acres)	c	c	12	12	0	0	0	0	c	c	0	0	0	0
Irrigated (percent of acres)	5	5	c	c	7	7	8	8	23	23	0	0	0	0
Dryland (percent of acres)	95	95	99	99	93	93	92	92	67	67	100	100	100	100
Straw (percent of acres)	7	7	5	5	c	c	6	6	13	13	42	42	23	23

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

[a] Developed from survey base year, 2004.
[b] Cost of commercial fertilizers, soil conditioners, and manure.
[c] 0.1 to less than 5 percent.

Section: FEEDSTOCKS
Oil per Acre Production for Various Crops

Plant	Latin Name	Oil/ Acre (gallons)	Plant	Latin Name	Oil/ Acre (gallons)
Oil Palm	Elaeis guineensis	610	Rice	Oriza sativa L.	85
Macauba Palm	Acrocomia aculeata	461	Buffalo Gourd	Cucurbita foetidissima	81
Pequi	Caryocar brasiliense	383	Safflower	Carthamus tinctorius	80
Buriti Palm	Mauritia flexuosa	335	Crambe	Crambe abyssinica	72
Oiticia	Licania rigida	307	Sesame	Sesamum indicum	71
Coconut	Cocos nucifera	276	Camelina	Camelina sativa	60
Avocado	Persea americana	270	Mustard	Brassica alba	59
Brazil Nut	Bertholletia excelsa	245	Coriander	Coriandrum sativum	55
Macadamia Nut	Macadamia terniflora	230	Pumpkin Seed	Cucurbita pepo	55
Jatropa	Jatropha curcas	194	Euphorbia	Euphorbia lagascae	54
Babassu Palm	Orbignya martiana	188	Hazelnut	Corylus avellana	49
Jojoba	Simmondsia chinensis	186	Linseed	Linum usitatissimum	49
Pecan	Carya illinoensis	183	Coffee	Coffea arabica	47
Bacuri	Platonia insignis	146	Soybean	Glycine max	46
Castor Bean	Ricinus communis	145	Hemp	Cannabis sativa	37
Gopher Plant	Euphorbia lathyris	137	Cotton	Gossypium hirsutum	33
Piassava	Attalea funifera	136	Calendula	Calendula officinalis	31
Olive Tree	Olea europaea	124	Kenaf	Hibiscus cannabinus L.	28
Rapeseed	Brassica napus	122	Rubber Seed	Hevea brasiliensis	26
Opium Poppy	Papaver somniferum	119	Lupine	Lupinus albus	24
Peanut	Ariachis hypogaea	109	Palm	Erythea salvadorensis	23
Cocoa	Theobroma cacao	105	Oat	Avena sativa	22
Sunflower	Helianthus annuus	98	Cashew Nut	Anacardium occidentale	18
Tung Oil Tree	Aleurites fordii	96	Corn	Zea mays	18

Source:
Amanda Hill, Al Kurki, and Mike Morris. 2010. "Biodiesel: The Sustainability Dimensions." ATTRA Publication. Butte, MT: National Center for Appropriate Technology. Pages 4-5.
http://www.attra.org/attra-pub/biodiesel_sustainable.html

Camelina can be grown under marginal conditions with little moisture. It is an excellect rotational crop that is generally grown in the summer. Because camelina is high in omega-3 fatty acids, it is often used for edible oil applications, but can also be used for fuel purposes.

Section: FEEDSTOCKS

Camelina: Area, Yield, and Value in Montana

Year	Acreage		Production		Value	
	Planted	Harvested	Yield Per Acre (Pounds)	Total (Thousand Pounds)	Price Per CWT (Dollars)	Value of Production (Thousand Dollars)
2007	22,500	20,400	598	12,197	9.18	1,112
2008	12,200	9,100	569	5,182	n/a	n/a
2009	20,800	19,500	615	11,998	n/a	n/a
2010	9,900	9,400	1,010	9,465	n/a	n/a

Source:

U.S. Department of Agriculture, website accessed Sept 2011.
http://www.nass.usda.gov/Statistics_by_State/Montana/Publications/crops/camelayp.htm

Section: FEEDSTOCKS
Cotton: Area, Yield, Production, and Value, 1996-2009

Year	Area		Yield per harvested acre	Production	Marketing year average price per pound received by farmers	Value of production
	Planted	Harvested				
	1,000 Acres	1,000 Acres	Pounds	1,000 bales[a]	Cents	1,000 Dollars
1996	14,652.5	12,888.1	705	18,942.0	70.50	6,408,144
1997	13,898.0	13,406.0	673	18,793.0	66.20	5,975,585
1998	13,392.5	10,683.6	625	13,918.2	61.70	4,119,911
1999	14,873.5	13,424.9	607	16,968.0	46.80	3,809,560
2000	15,517.2	13,053.0	632	17,188.3	51.60	4,260,417
2001	15,768.5	13,827.7	705	20,302.8	32.00	3,121,848
2002	13,957.9	12,416.6	665	17,208.6	45.70	3,777,132
2003	13,479.6	12,003.4	730	18,255.2	63.00	5,516,761
2004	13,658.6	13,057.0	855	23,250.7	44.70	4,993,565
2005	14,245.4	13,802.6	831	23,890.2	49.70	5,695,217
2006	15,274.0	12,731.5	814	21,587.8	48.40	5,013,238
2007	10,827.2	10,489.1	879	19,206.9	61.30	5,652,907
2008	9,471.0	7,568.7	813	12,815.3	49.10	3,021,485
2009[b]	9,149.2	7,690.5	774	12,401.3	62.80	3,735,564

Source: U.S. Department of Agriculture, *2010 Agricultural Statistics*, Table 2-1 and previous annual editions,
http://www.nass.usda.gov/Publications/Ag_Statistics/index.asp

[a]480 pound net weight bales
[b] Preliminary.

Section: FEEDSTOCKS

Cotton: Area, Yield, and Production by State, Crop of 2007, 2008, and 2009

State and cotton classification	Area Planted			Area Harvested			Yield per Harvested Acre			Production[a]		
	2007	2008	2009[b]	2007	2008	2009[b]	2007	2008	2009[b]	2007	2008	2009[b]
Upland:	1,000 Acres	1,000 Acres	1,000 Acres	1,000 Acres	1,000 Acres	1,000 Acres	Pounds	Pounds	Pounds	1,000 bales[c]	1,000 bales[c]	1,000 bales[c]
Alabama	400.0	290.0	255.0	385.0	286.0	250.0	519	787	691	416.0	469.0	360.0
Arizona	170.0	135.0	145.0	168.0	133.0	144.0	1,469	1,462	1,467	514.0	405.0	440.0
Arkansas	860.0	620.0	520.0	850.0	615.0	500.0	1,071	1,012	797	1,896.0	1,296.0	830.0
California	195.0	120.0	71.0	194.0	117.0	70.0	1,608	1,506	1,714	650.0	367.0	250.0
Florida	85.0	67.0	82.0	81.0	65.0	78.0	687	916	646	116.0	124.0	105.0
Georgia	1,030.0	940.0	1,000.0	995.0	920.0	990.0	801	835	882	1,660.0	1,600.0	1,820.0
Kansas	47.0	35.0	38.0	43.0	25.0	34.0	639	653	720	57.2	34.0	51.0
Louisiana	335.0	300.0	230.0	330.0	234.0	225.0	1,017	576	725	699.0	281.0	340.0
Mississippi	660.0	365.0	305.0	655.0	360.0	295.0	966	911	692	1,318.0	683.0	425.0
Missouri	380.0	306.0	272.0	379.0	303.0	260.0	968	1,106	960	764.0	698.0	520.0
New Mexico	43.0	38.0	30.5	39.0	35.0	29.0	1,095	974	828	89.0	71.0	50.0
North Carolina	500.0	430.0	375.0	490.0	428.0	370.0	767	847	986	783.0	755.0	760.0
Oklahoma	175.0	170.0	205.0	165.0	155.0	200.0	817	811	792	281.0	262.0	330.0
South Carolina	180.0	135.0	115.0	158.0	134.0	114.0	486	881	842	160.0	246.0	200.0
Tennessee	515.0	285.0	300.0	510.0	280.0	280.0	565	909	857	600.0	530.0	500.0
Texas	4,900.0	5,000.0	5,000.0	4,700.0	3,250.0	3,650.0	843	657	644	8,250.0	4,450.0	4,900.0
Virginia	60.0	61.0	64.0	59.0	60.0	63.0	829	908	990	101.9	113.5	130.0
Total	**10,535.0**	**9,297.0**	**9,007.5**	**10,201.0**	**7,400.0**	**7,552.0**	**864**	**803**	**763**	**18,355.1**	**12,384.5**	**12,011.0**
American-Pima:												
Arizona	2.5	0.8	1.7	2.5	0.8	1.7	883	480	1,129	4.6	0.8	4.0
California	260.0	155.0	119.0	257.0	151.0	116.0	1,481	1,281	1,448	793.0	403.0	350.0
New Mexico	4.7	2.6	3.0	4.6	1.9	3.0	856	758	688	8.2	3.0	4.3
Texas	25.0	15.6	18.0	24.0	15.0	17.8	920	768	863	46.0	24.0	32.0
Total	292.2	174.0	141.7	288.1	168.7	138.5	1,419	1,226	1,353	851.8	430.8	390.3
U.S. Total	**10,827.2**	**9,471.0**	**9,149.2**	**10,489.1**	**7,568.7**	**7,690.5**	**879**	**813**	**774**	**19,206.9**	**12,401.3**	**12,401.3**

Source: U.S. Department of Agriculture, *2010 Agricultural Statistics,* Table 2-2,
http://www.nass.usda.gov/Publications/Ag_Statistics/index.asp

Notes:

[a] Production ginned and to be ginned.

[b] Preliminary

[c] 480-pound net weight bale.

Cotton Production Costs and Returns per Planted Acre by Region, Excluding Government Payments, 2009-2010[a]

(dollars per planted acre)

Item	United States		Heartland		Prarie Gateway		Southern Seaboard		Fruitful Rim		Mississippi Portal	
	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
Gross value of production												
Primary product: Cotton	365.58	620.65	478.44	795.75	268.80	550.63	495.60	603.20	604.35	1058.81	410.85	715.92
Secondary product: Cottonseed	80.20	99.15	114.64	154.44	62.16	90.16	80.16	85.40	123.80	166.76	96.64	121.92
Total, gross value of production	**445.78**	**719.80**	**593.08**	**950.19**	**330.96**	**640.79**	**575.76**	**688.60**	**728.15**	**1225.57**	**507.49**	**837.84**
Operating costs:												
Seed	73.52	81.38	121.43	132.85	56.91	62.27	82.56	90.32	76.16	83.32	103.56	113.30
Fertilizer [b]	92.29	73.54	116.96	89.98	53.70	41.32	145.23	111.73	121.56	93.52	124.15	95.51
Chemicals	67.97	68.35	90.29	88.65	42.68	41.90	91.42	89.76	98.98	97.17	105.66	103.74
Custom operations	22.11	22.86	14.18	14.36	13.97	14.15	22.97	23.26	62.71	63.50	29.18	29.54
Fuel, lube, and electricity	40.15	50.81	40.72	51.85	41.47	53.49	34.17	41.83	75.05	95.31	30.66	39.25
Repairs	33.74	34.42	43.35	44.18	31.58	32.18	33.94	34.59	36.57	37.27	39.57	40.32
Ginning	101.64	127.64	135.53	164.34	79.38	116.72	113.81	105.19	188.63	225.62	119.63	152.76
Purchased irrigation water	2.86	3.03	0.00	0.00	0.00	0.00	0.00	0.00	36.58	37.04	0.00	0.00
Interest on operating capital	0.63	0.46	0.82	0.59	0.46	0.36	0.76	0.50	1.01	0.73	0.80	0.57
Total, operating costs	434.91	462.49	563.28	586.80	320.15	362.39	524.86	497.18	697.25	733.48	553.21	574.99
Allocated overhead:												
Hired labor	14.26	14.50	17.54	17.73	11.94	12.07	13.46	13.60	27.43	27.72	16.63	16.81
Opportunity cost of unpaid labor	26.11	26.10	27.44	27.73	29.20	29.51	20.70	20.92	32.81	33.17	20.41	20.63
Capital recovery of machinery and equipment	128.49	132.32	176.89	181.67	117.18	120.35	129.34	132.84	149.18	153.21	149.51	153.55
Opportunity cost of land (rental rate)	67.18	70.79	101.85	104.87	40.50	41.71	82.48	84.93	115.32	118.74	103.80	106.88
Taxes and insurance	7.43	7.60	6.82	6.92	6.30	6.40	7.78	7.90	10.20	10.35	9.50	9.64
General farm overhead	15.62	16.16	13.80	14.07	12.12	12.35	18.24	18.59	27.04	27.55	19.20	19.57
Total, allocated overhead	259.09	267.47	344.34	352.99	217.24	222.39	272.00	278.78	361.98	370.74	319.05	327.08
Total costs listed	**694.00**	**729.96**	**907.62**	**939.79**	**537.39**	**584.78**	**796.86**	**775.96**	**1,059.23**	**1,104.22**	**872.26**	**902.07**
Value of production less total costs listed	-248.22	-10.16	-314.54	10.40	-206.43	56.01	-221.10	-87.36	-331.08	121.35	-364.77	-64.23
Value of production less operating costs	10.87	257.31	29.80	363.39	10.81	278.40	50.90	191.42	30.90	492.09	-45.72	262.85
Supporting information:												
Cotton Yield (pounds per planted acre)	620	766	886	1061	480	697	826	754	765	937	747	942
Price (dollars per pound)	0.59	0.81	0.54	0.75	0.56	0.79	0.6	0.8	0.79	1.13	0.55	0.76
Cottonseed Yield (pounds per planted acre)	1,003	1,239	1,433	1,716	777	1,127	1,336	1,220	1,238	1,516	1,208	1,524
Price (dollars per pound)	0.08	0.08	0.08	0.09	0.08	0.08	0.06	0.07	0.10	0.11	0.08	0.08
Enterprise size (planted acres)[a]	687	687	861	861	770	770	453	453	507	507	954	954
Production practices:[a]												
Irrigated (percent)	43	43	61	61	46	46	28	28	57	57	45	45
Dryland (percent)	57	57	39	39	54	54	72	72	43	43	55	55

Source:

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

[a]Developed from survey base year, 2007.

[b]Commercial fertilizer, soil conditioners, and manure.

USDA's 2008 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.

Section: FEEDSTOCKS

Soybeans and Products Baseline Projections, 2008-2021

Item	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21
Area (million acres):													
Planted	75.7	77.5	77.7	78.0	78.3	78.5	79.0	79.0	79.5	79.5	79.5	79.5	79.5
Harvested	74.7	76.4	76.8	77.1	77.3	77.6	78.1	78.1	78.5	78.5	78.5	78.5	78.5
Yield/harvested acre (bushels)	39.7	44.0	43.9	43.5	44.0	44.4	44.9	45.3	45.8	46.2	46.7	47.1	47.6
Supply (million bushels)													
Beginning stocks, Sept 1	205	138	151	185	190	195	194	197	199	196	197	198	199
Production	2,967	3,359	3,375	3,355	3,395	3,445	3,505	3,540	3,590	3,625	3,660	3,695	3,735
Imports	13	15	10	10	10	10	10	10	10	10	10	10	10
Total supply	3,185	3,512	3,536	3,550	3,595	3,650	3,709	3,747	3,799	3,831	3,867	3,903	3,945
Disposition (million bushels)													
Crush	1,662	1,752	1,665	1,660	1,670	1,695	1,715	1,735	1,770	1,790	1,810	1,830	1,850
Seed and residual	101	108	117	125	125	126	127	128	128	129	129	129	130
Exports	1,283	1,501	1,570	1,575	1,605	1,635	1,670	1,685	1,705	1,715	1,730	1,745	1,765
Total disposition	3,047	3,361	3,351	3,360	3,400	3,456	3,512	3,548	3,603	3,634	3,669	3,704	3,745
Carryover stocks, August 31													
Total ending stocks	138	151	185	190	195	194	197	199	196	197	198	199	200
Stocks/use ratio, percent	4.5	4.5	5.5	5.7	5.7	5.6	5.6	5.6	5.4	5.4	5.4	5.4	5.3
Prices (dollars per bushel)													
Soybean price, farm	9.97	9.59	11.45	11.20	10.55	10.25	10.20	10.25	10.25	10.30	10.30	10.35	10.35
Variable costs of production (dollars):													
Per acre	127.06	132	131	136	139	140	142	144	146	148	150	152	154
Per bushel	3.20	3.01	2.98	3.13	3.15	3.16	3.17	3.18	3.19	3.20	3.22	3.23	3.24
Returns over variable costs (dollars per acre):													
Net returns	269	290	372	351	325	315	315	320	323	328	330	335	338
Soybean oil (million pounds)													
Beginning stocks, Oct. 1	2,485	2,861	3,358	2,653	2,368	2,073	2,093	2,143	2,123	2,208	2,223	2,198	2,128
Production	18,753	19,615	18,980	18,940	19,070	19,375	19,620	19,865	20,285	20,530	20,780	21,025	21,275
Imports	90	105	115	125	135	145	155	165	175	185	195	205	215
Total supply	21,328	22,581	22,453	21,718	21,573	21,593	21,868	22,173	22,583	22,923	23,198	23,428	23,618
Domestic disappearance	16,339	15,822	17,100	17,400	18,000	18,200	18,425	18,650	18,875	19,125	19,375	19,625	19,875
For methyl ester [a]	1,904	1,682	2,900	3,100	3,500	3,500	3,500	3,500	3,500	3,525	3,550	3,575	3,600
Exports	2,250	3,400	2,700	1,950	1,500	1,300	1,300	1,400	1,500	1,575	1,625	1,675	1,700
Total demand	18,589	19,222	19,800	19,350	19,500	19,500	19,725	20,050	20,375	20,700	21,000	21,300	21,575
Ending stocks, Sept. 30	2,739	3,358	2,653	2,368	2,073	2,093	2,143	2,123	2,208	2,223	2,198	2,128	2,043
Soybean oil price ($/lb)	0.3216	0.3567	0.445	0.455	0.455	0.455	0.460	0.460	0.460	0.463	0.465	0.468	0.470
Soybean meal (thousand short tons)													
Beginning stocks, Oct. 1	294	235	303	300	300	300	300	300	300	300	300	300	300
Production	39,112	41,702	39,532	39,435	39,685	40,235	40,685	41,235	41,985	42,485	42,985	43,485	43,985
Imports	90	150	165	165	165	165	165	165	165	165	165	165	165
Total supply	39,496	42,087	40,000	39,900	40,150	40,700	41,150	41,700	42,450	42,950	43,450	43,950	44,450
Domestic disappearance	30,757	30,634	30,600	31,000	31,250	31,700	32,150	32,650	33,150	33,650	34,150	34,650	35,150
Exports	8,500	11,150	9,100	8,600	8,600	8,700	8,700	8,750	9,000	9,000	9,000	9,000	9,000
Total demand	39,257	41,784	39,700	39,600	39,850	40,400	40,850	41,400	42,150	42,650	43,150	43,650	44,150
Ending stocks, Sept. 30	239	303	300	300	300	300	300	300	300	300	300	300	300
Soybean meal price ($/ton)	331.17	311.27	330.00	312.50	286.00	275.00	271.00	273.50	273.50	275.00	274.00	275.00	275.00
Crushing yields (pounds per bushel)													
Soybean oil	11.28	11.20	11.40	11.41	11.42	11.43	11.44	11.45	11.46	11.47	11.48	11.49	11.50
Soybean meal	47.08	47.60	47.50	47.50	47.50	47.50	47.50	47.50	47.50	47.50	47.50	47.50	47.50
Crush margin ($ per bushel)	1.45	1.81	1.46	1.41	1.44	1.48	1.50	1.51	1.52	1.54	1.55	1.55	1.59

Source:

U.S.Department of Agriculture, *USDA Agricultural Projections to 2020* , February 2011, Table 24 - U.S. soybean and products, long term projections
http://usda.mannlib.cornell.edu/MannUsda/viewStaticPage.do?url=http://usda.mannlib.cornell.edu/usda/ers/94005/./2011/index.html

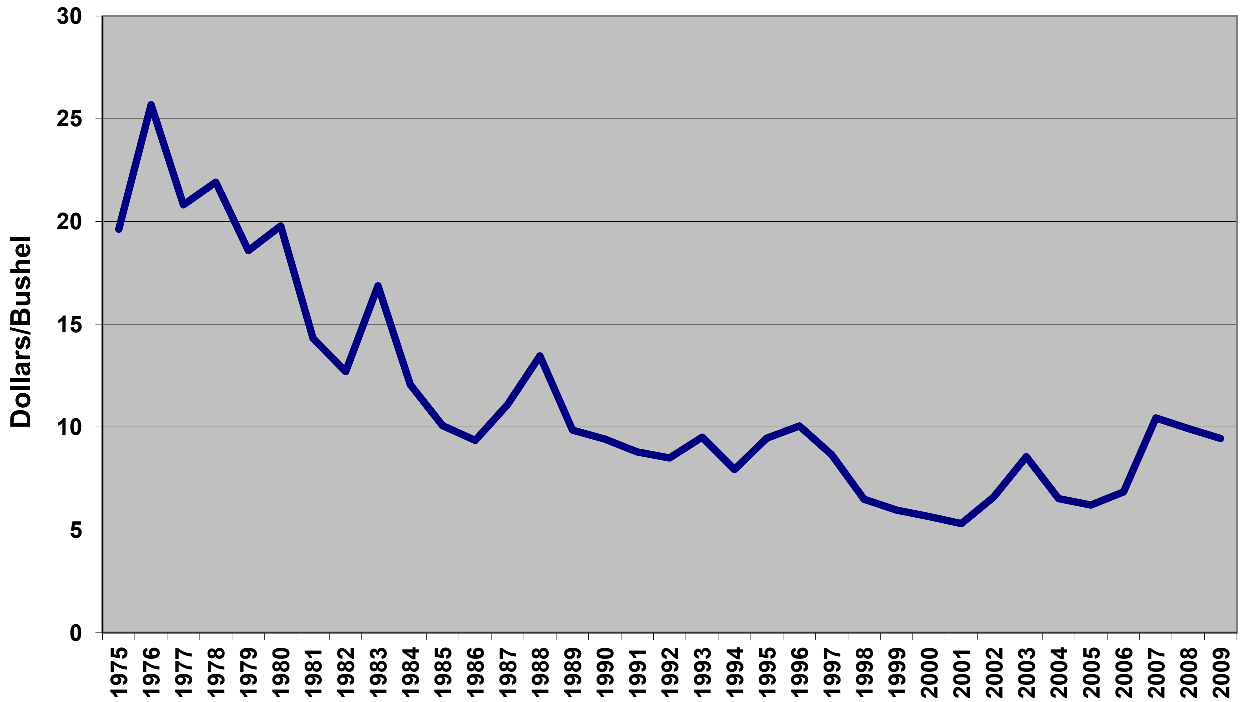
[a] Soybean oil used for methyl ester for production of biodiesel, history from the U.S. Department of Commerce.

Note:

Marketing year beginning September 1 for soybeans; October 1 for soybean oil and soybean meal.

The price for soybeans has declined since the mid 70s but has shown a modest increase since reaching a low of about five dollars a bushel in 2001.

Section: FEEDSTOCKS
Soybeans: Price per Bushel, 1975-2009
(constant 2009 dollars)



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

Soybeans: Area, Yield, Production, and Value, 1996-2009

Year	Area Planted	Soybeans for beans				
		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	2,453,845	7.34	18,015,097
2004	75,208	73,958	42.2	3,123,790	5.74	17,895,510
2005	72,032	71,251	43.1	3,068,342	5.66	17,297,137
2006	75,522	74,602	42.9	3,196,726	6.43	20,468,267
2007	64,741	64,146	41.7	2,677,117	10.10	26,974,406
2008	75,718	74,681	39.7	2,967,007	9.97	29,458,225
2009	77,451	76,372	44.0	3,359,011	9.45	31,760,452

Source:
U.S. Department of Agriculture, 2*010 Agricultural Statistics*, Table 3-31,
http://www.nass.usda.gov/Publications/Ag_Statistics/index.asp

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.

Section: FEEDSTOCKS
Soybeans: Area, Yield, and Production, by State, 2007-2009

State	Area planted			Soybeans for beans								
				Area harvested			Yield per harvested acre			Production		
	2007	2008	2009	2007	2008	2009	2007	2008	2009	2007	2008	2009
	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	190	360	440	185	350	430	21.0	35.0	40.0	3,885	12,250	17,200
Arizona	2,850	3,300	3,420	2,820	3,250	3,270	36.0	38.0	37.5	101,520	123,500	122,625
Delaware	160	195	185	155	193	183	26.0	27.5	42.0	4,030	5,308	7,686
Florida	14	32	37	12	29	34	24.0	38.0	38.0	288	1,102	1,292
Georgia	295	430	470	285	415	440	30.0	31.0	36.0	8,550	12,865	15,840
Illinois	8,300	9,200	9,400	8,280	9,120	9,350	43.5	47.0	46.0	360,180	428,640	430,100
Indiana	4,800	5,450	5,450	4,790	5,430	5,440	46.0	45.0	49.0	220,340	244,350	266,560
Iowa	8,650	9,750	9,600	8,630	9,670	9,530	52.0	46.5	51.0	448,760	449,655	486,030
Kansas	2,650	3,300	3,700	2,610	3,250	3,650	33.0	37.0	44.0	86,130	120,250	160,600
Kentucky	1,120	1,390	1,430	1,100	1,380	1,420	27.5	34.5	48.0	30,250	47,610	68,160
Louisiana	615	1,050	1,020	600	950	940	43.0	33.0	39.0	25,800	31,350	36,660
Maryland	405	495	485	390	485	475	27.5	30.0	42.0	10,725	14,550	19,950
Michigan	1,800	1,900	2,000	1,790	1,890	1,990	40.0	37.0	40.0	71,600	69,930	79,600
Minnesota	6,350	7,050	7,200	6,290	6,970	7,120	42.5	38.0	40.0	267,325	264,860	284,800
Mississippi	1,460	2,000	2,160	1,440	1,960	2,030	40.5	40.0	38.0	58,320	78,400	77,140
Missouri	4,700	5,200	5,350	4,670	5,030	5,300	37.5	38.0	43.5	175,125	191,140	230,550
Nebraska	3,870	4,900	4,800	3,850	4,860	4,760	51.0	46.5	54.5	196,350	225,990	259,420
New Jersey	82	92	89	80	90	87	31.0	30.0	42.0	2,480	2,700	3,654
New York	205	230	255	203	226	254	39.0	46.0	43.0	7,917	10,396	10,922
North Carolina	1,440	1,690	1,800	1,380	1,670	1,750	22.0	33.0	34.0	30,360	55,110	59,500
North Dakota	3,100	3,800	3,900	3,060	3,760	3,870	35.5	28.0	30.0	108,630	105,280	116,100
Ohio	4,250	4,500	4,550	4,240	4,480	4,530	47.0	36.0	49.0	199,280	161,280	221,970
Oklahoma	190	400	405	180	360	390	26.0	25.0	31.0	4,680	9,000	12,090
Pennsylvania	435	435	450	430	430	445	41.0	40.0	46.0	17,630	17,200	20,470
South Carolina	460	540	590	440	530	565	18.5	32.0	24.5	8,140	16,960	13,843
South Dakota	3,250	4,100	4,250	3,240	4,060	4,190	42.0	34.0	42.0	136,080	138,040	175,980
Tennessee	1,080	1,490	1,570	1,010	1,460	1,530	19.0	34.0	45.0	19,190	49,640	68,850
Texas	95	230	215	92	205	190	37.5	24.5	25.0	3,450	5,023	4,750
Virginia	510	580	580	500	570	570	27.5	32.0	37.0	13,750	18,240	21,090
West Virginia	15	19	20	14	18	19	33.0	41.0	41.0	462	738	779
Wisconsin	1,400	1,610	1,630	1,380	1,590	1,620	40.5	35.0	40.0	55,890	55,650	64,800
US	**64,741**	**75,718**	**77,451**	**64,146**	**74,681**	**76,372**	**41.7**	**39.7**	**44.0**	**2,677,117**	**2,967,007**	**3,359,011**

Source:
U.S.Department of Agriculture, *2010 Agricultural Statistics*, Table 3-36, and previous annual editions,
http://www.nass.usda.gov/Publications/Ag_Statistics/index.asp

In 2006, soybean stocks and production reached its greatest level during the period 1995-2008.

Section: FEEDSTOCKS
Soybeans: Supply and Disappearance, 1995-2008
(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	2,637,773
2004	29,400	83,014	112,414	3,123,686	3,241,782
2005	99,700	156,038	255,738	3,063,237	3,327,452
2006	176,300	273,026	449,326	3,188,247	3,655,086
2007	143,000	430,810	573,810	2,677,117	3,260,798
2008[b]	47,000	158,034	205,034	2,967,007	3,185,314

Table continued

Year beginning September	Disappearance			
	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	1,596,980	154,476	874,334	2,625,790
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	1,614,787	131,380	1,044,372	2,790,540
2003	1,529,699	109,072	886,551	2,525,322
2004	1,696,081	192,806	1,097,156	2,986,044
2005	1,738,852	199,396	939,879	2,878,126
2006	1,807,706	157,074	1,116,496	3,081,276
2007	1,803,407	93,445	1,158,829	3,055,764
2008[b]	1,661,987	101,849	1,283,269	3,047,106

Source:
U.S. Department of Agriculture, *2010 Agricultural Statistics*, Table 3-34, and previous annual editions, http://www.nass.usda.gov/Publications/Ag_Statistics/index.asp

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

Prices for soybeans used for biodiesel production may vary for each mill depending on whether the mills are owned by farmers cooperatives or whether the soybeans are purchased on the open market. The average price per bushel rose sharply by nearly 4 dollars between 2006 and 2007 but then declined by 65 cents between 2007 and 2009.

Section: FEEDSTOCKS

Soybeans for Beans: Marketing Year Average Price and Value, by State, Crop of 2007, 2008, and 2009

State[a]	Marketing year average price per bushel 2007	2008	2009[b]	Value of production 2007	2008	2009[b]
	Dollars	Dollars	Dollars	1,000 Dollars	1,000 Dollars	1,000 Dollars
Alabama	11.40	10.30	10.40	44,289	126,175	178,880
Arkansas	9.02	9.64	9.60	915,710	1,190,540	1,177,200
Delaware	11.50	9.40	9.60	46,345	49,895	73,786
Florida	8.90	8.50	9.50	2,563	9,367	12,274
Georgia	11.90	9.50	9.50	101,745	122,218	153,900
Illinois	10.40	10.20	9.70	3,745,872	4,372,128	4,171,970
Indiana	10.20	10.20	9.55	2,247,468	2,492,370	2,545,648
Iowa	10.50	10.20	9.40	4,711,980	4,586,481	4,568,682
Kansas	10.10	9.39	9.25	869,913	1,129,148	1,485,550
Kentucky	10.10	10.00	9.65	305,525	476,100	657,744
Louisiana	8.43	9.52	9.60	217,494	298,452	351,936
Maryland	11.20	9.20	9.70	120,120	133,860	193,515
Michigan	9.69	9.82	9.40	693,804	686,713	748,240
Minnesota	10.20	10.10	9.30	2,726,715	2,675,086	2,648,640
Mississippi	8.36	9.29	9.15	487,555	728,336	705,831
Missouri	10.10	9.74	9.40	1,768,763	1,861,704	2,167,170
Nebraska	9.92	9.79	9.40	1,947,792	2,212,442	2,438,548
New Jersey	10.10	9.75	9.45	25,048	26,325	34,530
New York	11.20	10.30	8.95	88,670	107,079	97,752
North Carolina	10.10	9.33	9.50	306,636	514,176	571,710
North Dakota	9.63	9.71	9.25	1,046,107	1,022,269	1,073,925
Ohio	9.93	10.30	9.60	1,978,850	1,661,184	2,130,912
Oklahoma	10.00	9.10	9.35	46,800	81,900	113,042
Pennsylvania	10.70	10.20	9.35	188,641	175,440	191,395
South Carolina	10.90	9.00	9.75	88,726	152,640	138,938
South Dakota	9.60	9.65	9.05	1,306,368	1,332,086	1,592,619
Tennessee	10.30	9.45	9.65	197,657	469,098	664,403
Texas	10.40	9.25	9.25	35,880	46,463	43,938
Virginia	11.40	9.10	9.60	156,750	165,984	207,936
West Virginia	11.30	9.75	9.60	5,221	7,196	7,478
Wisconsin	9.83	9.80	9.45	549,399	545,370	612,360
US	**10.10**	**9.97**	**9.45**	**26,974,406**	**29,458,225**	**31,760,452**

Source: U.S. Department of Agriculture, *2010 Agricultural Statistics,* Table 3-38, http://www.nass.usda.gov/Publications/Ag_Statistics/index.asp

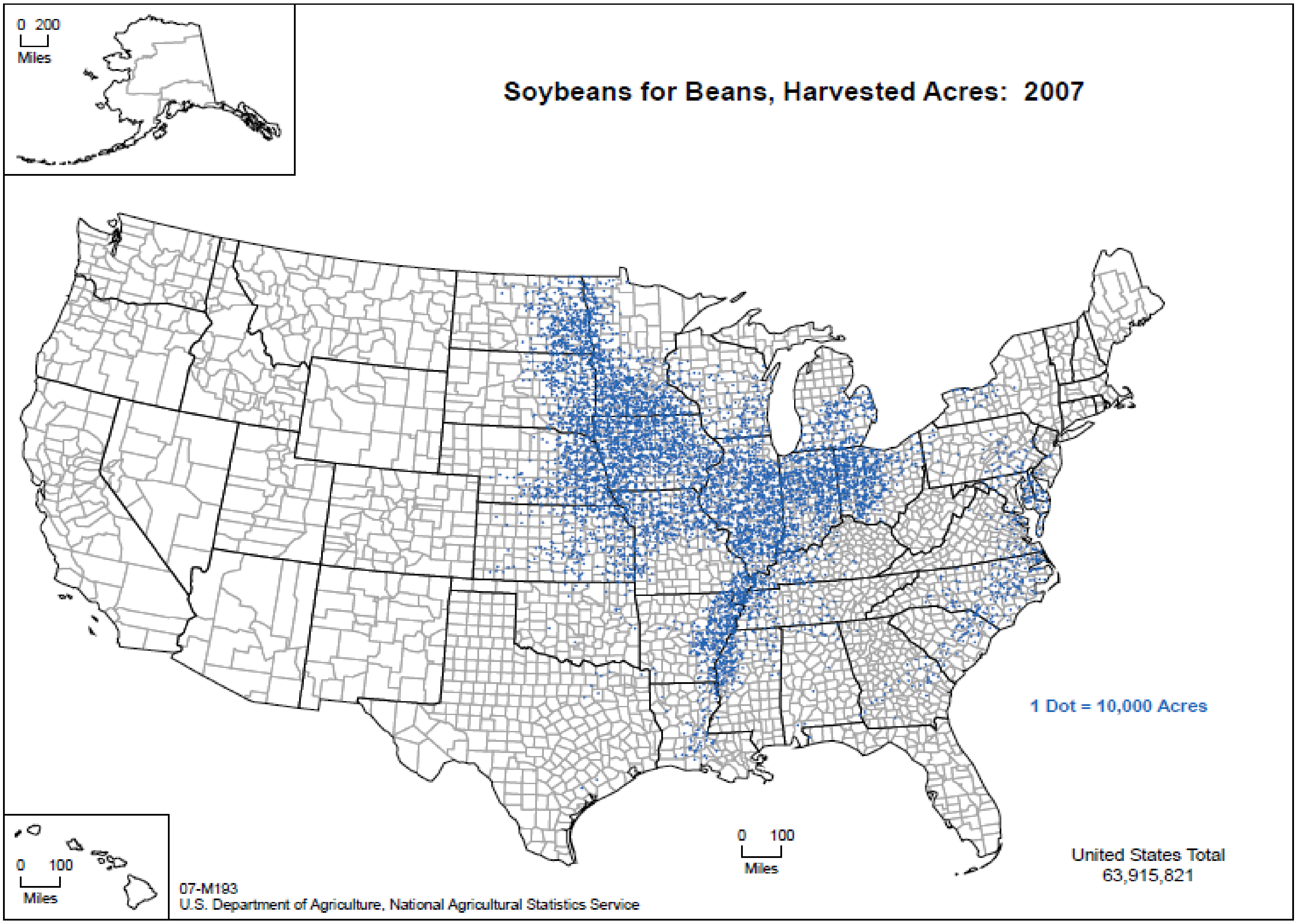
Notes:

[a] States with no data are not listed.

[b] Preliminary

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.

Section: FEEDSTOCKS
Soybeans for Beans, Harvested Acres in the United States, 2007



Source:
U.S. Department of Agriculture, National Agricultural Statistics Service, The Census of Agriculture
http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/Ag_Atlas_Maps/Crops_and_Plants/

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.

Section: FEEDSTOCKS

Soybean Production Costs and Returns per Planted Acre by Region, Excluding Government Payments, 2009-2010[a]

(dollars per planted acre)

Item	United States		Heartland		Northern Crescent		Northern Great Plains		Prarie Gateway		Eastern Uplands		Southern Seaboard		Mississippi Portal	
	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
Gross value of production																
Primary product: Soybeans	437.10	449.32	502.86	505.41	415.80	468.00	323.40	352.98	482.46	410.34	393.60	327.67	373.92	310.30	341.60	332.64
Total, gross value of production	**437.10**	**449.32**	**502.86**	**505.41**	**415.80**	**468.00**	**323.40**	**352.98**	**482.46**	**410.34**	**393.60**	**327.67**	**373.92**	**310.30**	**341.60**	**332.64**
Operating costs:																
Seed	55.26	59.20	53.50	57.49	57.94	62.26	57.43	61.71	51.29	55.11	52.55	56.46	50.52	54.29	54.47	58.53
Fertilizer [b]	23.65	17.87	22.01	16.88	33.93	26.02	10.64	8.15	13.19	10.12	36.51	27.99	60.11	46.09	22.48	17.24
Chemicals	17.38	17.04	16.87	16.64	16.33	16.11	14.63	14.43	15.18	14.98	13.48	13.30	18.48	18.23	21.79	21.49
Custom operations	7.17	6.52	6.03	5.50	9.35	8.52	5.78	5.27	8.80	8.02	8.28	7.55	6.11	5.57	10.47	9.54
Fuel, lube, and electricity	13.48	16.75	10.48	13.01	11.88	14.74	9.65	11.98	25.13	31.19	11.12	13.81	9.52	11.82	25.43	31.57
Repairs	13.22	13.46	11.47	11.69	11.40	11.62	13.29	13.54	18.24	18.59	11.37	11.59	10.42	10.62	19.37	19.74
Purchased irrigation water	0.14	0.14	0.00	0.00	0.00	0.00	0.00	0.00	1.76	1.61	0.00	0.00	0.00	0.00	0.00	0.00
Interest on operating capital	0.19	1.31	0.17	1.21	0.20	1.39	0.16	1.15	0.19	1.40	0.19	1.31	0.22	1.47	0.22	1.58
Total, operating costs	**130.49**	**132.29**	**120.53**	**122.42**	**141.03**	**140.66**	**111.58**	**116.23**	**133.78**	**141.02**	**133.50**	**132.01**	**155.38**	**148.09**	**154.23**	**159.69**
Allocated overhead:																
Hired labor	2.14	2.11	1.26	1.27	1.28	1.29	1.64	1.66	2.08	2.10	2.95	2.98	2.90	2.93	7.31	7.38
Opportunity cost of unpaid labor	17.19	17.33	15.67	15.84	18.27	18.47	14.45	14.60	20.81	21.03	18.19	18.38	19.06	19.26	19.83	20.04
Capital recovery of machinery and equipment	75.54	77.51	71.33	73.26	64.62	66.37	80.29	82.46	88.58	90.97	66.81	68.61	62.51	64.20	84.10	86.38
Opportunity cost of land (rental rate)	108.98	148.34	127.92	174.63	89.62	122.34	58.89	80.40	76.55	104.51	71.47	97.56	49.46	67.52	81.22	110.88
Taxes and insurance	10.84	9.41	10.68	9.29	13.43	11.68	9.26	8.06	10.77	9.37	8.28	7.20	9.18	7.99	10.08	8.77
General farm overhead	14.57	14.86	14.62	14.90	18.80	19.16	11.64	11.86	15.94	16.24	14.23	14.50	10.87	11.08	10.51	10.71
Total, allocated overhead	229.26	269.56	241.48	289.19	206.02	239.31	176.17	199.04	214.73	244.22	181.93	209.23	153.98	172.98	213.05	244.16
Total costs listed	**359.75**	**401.85**	**362.01**	**411.61**	**347.05**	**379.97**	**287.75**	**315.27**	**348.51**	**385.24**	**315.43**	**341.24**	**309.36**	**321.07**	**367.28**	**403.85**
Value of production less total costs listed	77.35	47.47	140.85	93.80	68.75	88.03	35.65	37.71	133.95	25.10	78.17	-13.57	64.56	-10.77	-25.68	-71.21
Value of production less operating costs	306.61	317.03	382.33	382.99	274.77	327.34	211.82	236.75	348.68	269.32	260.10	195.66	218.54	162.21	187.37	172.95
Supporting information:																
Yield (bushels per planted acre)	47	47	51	51	42	48	35	37	51	42	40	31	38	29	35	33
Price (dollars per bushel at harvest)	9.30	9.56	9.86	9.91	9.90	9.75	9.24	9.54	9.46	9.77	9.84	10.57	9.84	10.70	9.76	10.08
Enterprise size (planted acres) [a]	303	303	299	299	164	164	164	164	254	254	321	321	240	240	676	676
Production practices: [a]																
Irrigated (percent)	9	9	4	4	2	2	2	2	32	32	6	6	0	0	38	38
Dryland (percent)	91	91	96	96	98	98	98	98	68	68	94	94	100	100	62	62

Source:

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

[a] Developed from survey base year, 2006.

[b] Commercial fertilizer, soil conditioners, and manure.

Using algae as a feedstock for biofuels has several advantages, according to the U.S. Department of Energy's National Algal Biofuels Technology Roadmap. One of those advantages is that algal production offers high yields per acre of cultivation compared to other feedstocks. Originating from several different sources of data, an estimated oil content of different algal species is shown below.

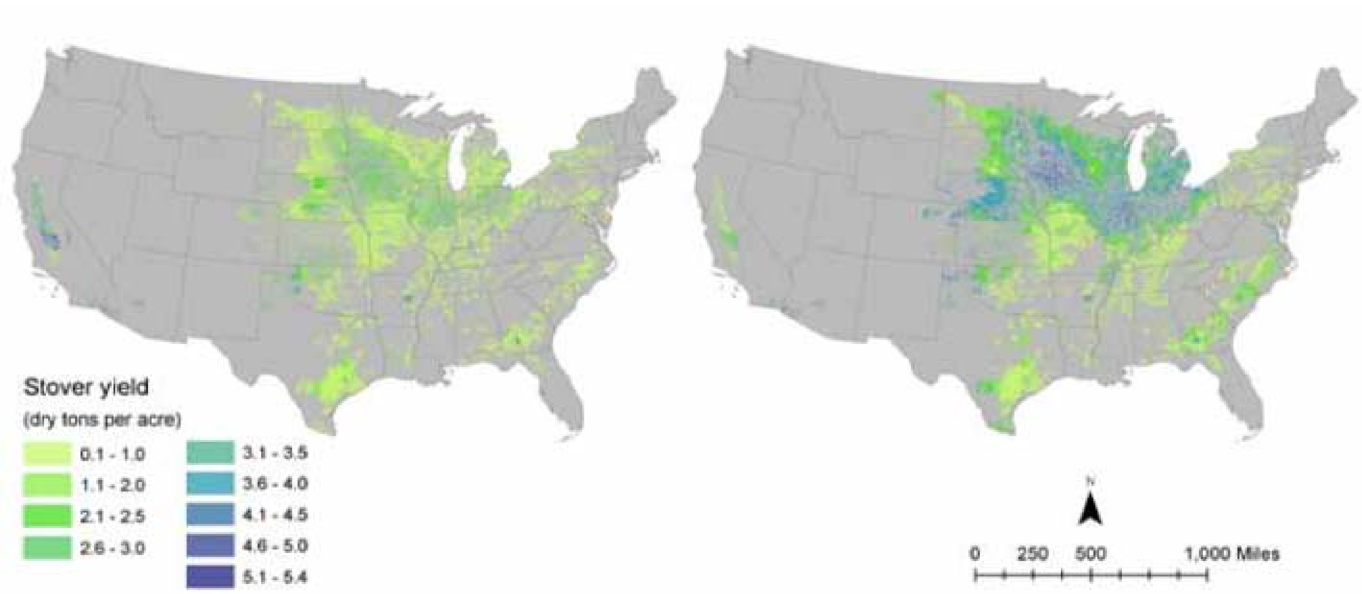
Section: FEEDSTOCKS
Oil Content in Selected Algal Species

Species	Oil Content (% dry weight)	Reference (cited after Carisson et al., 2007)
Ankistrodesmus TR-87	28-40	Ben-Amotz and Tornabene (1985)
Botryococcus braunii	29-75	Sheehan et al. (1998); Banerjee et al. (2002); Metzger & Largeau (2005)
Chlorella sp.	29	Sheehan et al. (1998)
Chlorella protothecoides (autotrophic/heterothrophic)	15-55	Xu et al. (2006)
Cyclotella DI-35	42	Sheehan et al. (1998)
Dunaliella tertiolecta	36-42	Kishimoto et al. (1994); Tsukahara & Sawayama (2005)
Hantzschia DI-160	66	Sheehan et al. (1998)
Isochrysis sp.	7-33	Sheehan et al. (1998); Valenzuela-Espinoza et al. (2002)
Nannochloris	31 (6-63)	Ben-Amotz & Tornabene (1985); Negoro et al. (1991); Sheehan et al. (1998)
Nannochloropsis	46 (31-68)	Sheehan et al. (1998); Hu et al. (2006)
Nitzschia TR-114	28-50	Kyle DJ, Gladue RM (1991) Patent Application, PCT WO 91/1447, 3 Oct 1991
Phaeodactylum tricornutum	31	Sheehan et al. (1998)
Scenedesmus TR-84	45	Sheehan et al. (1998)
Stichococcus	33 (9-59)	Sheehan et al. (1998)
Tetraselmis suecica	15-32	Sheehan et al. (1998); Zittelli et al. (2006); Christi (2007)
Thalassiosira pseudonana	(21-31)	Brown et al. (1996)
Crpythecodinium cohnii	20	www.oilgae.com
Neochloris oleoabundans	35-54	www.oilgae.com
Schisochytrium	50-77	www.oilgae.com

Source:
Oak Ridge National Laboratory, Reality of Algal Fuels, presentation by Tanya Kuritz, September 1, 2011.
http://www.ornl.gov/sci/ees/cbes/forums/Tanya%20Kuritz%20slides_Sep_1_11.pdf

Corn stover residue consists of the stalks, leaves, husks, and cobs left in the field after corn is harvested.

Section: FEEDSTOCKS
Corn Stover Residue Yield for Reduced Tillage and No-till Production, 2012

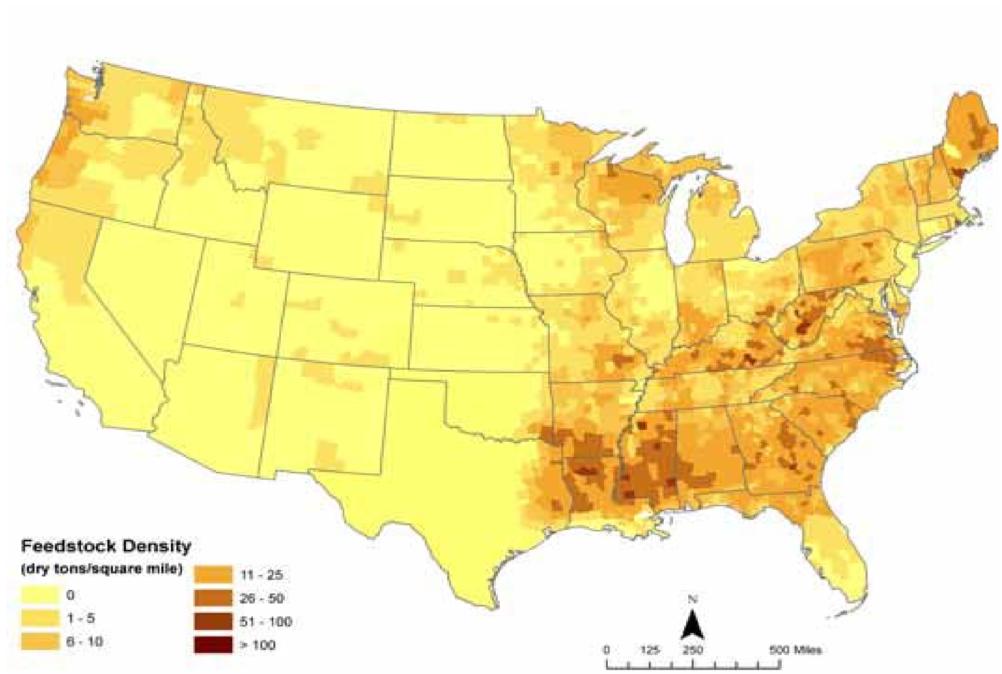


Source:
U.S. Department of Energy. 2011. *U.S. Billion-Ton Update*: *Biomass Supply for a Bioenergy and Bioproducts Industry*. R.D. Perlack and B.J. Stokes (Leads), ORNL/TM-2011/224. Oak Ridge National Laboratory, Oak Ridge, TN. 227p. http://www1.eere.energy.gov/biomass/pdfs/billion_ton_update.pdf

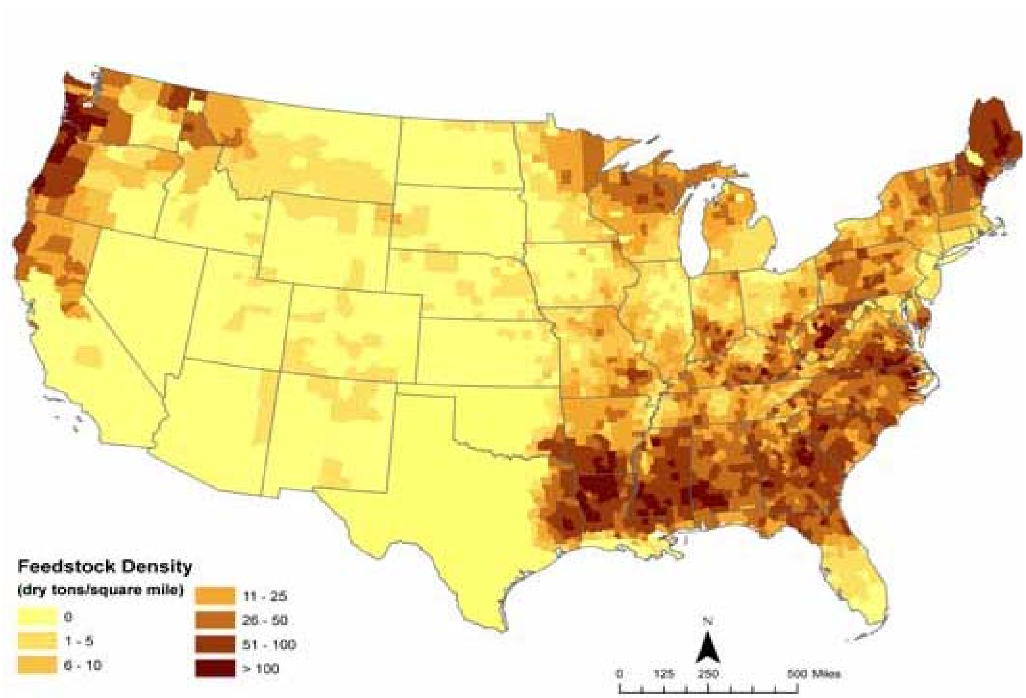
Logging residues are the unused portions of growing-stock and non-growing-stock trees cut or killed by logging and left in the woods.

Section: FEEDSTOCKS

Spatial Distribution of Logging Residues at $20 and $40 per Dry Ton Delivered to Roadside



$20 per dry ton



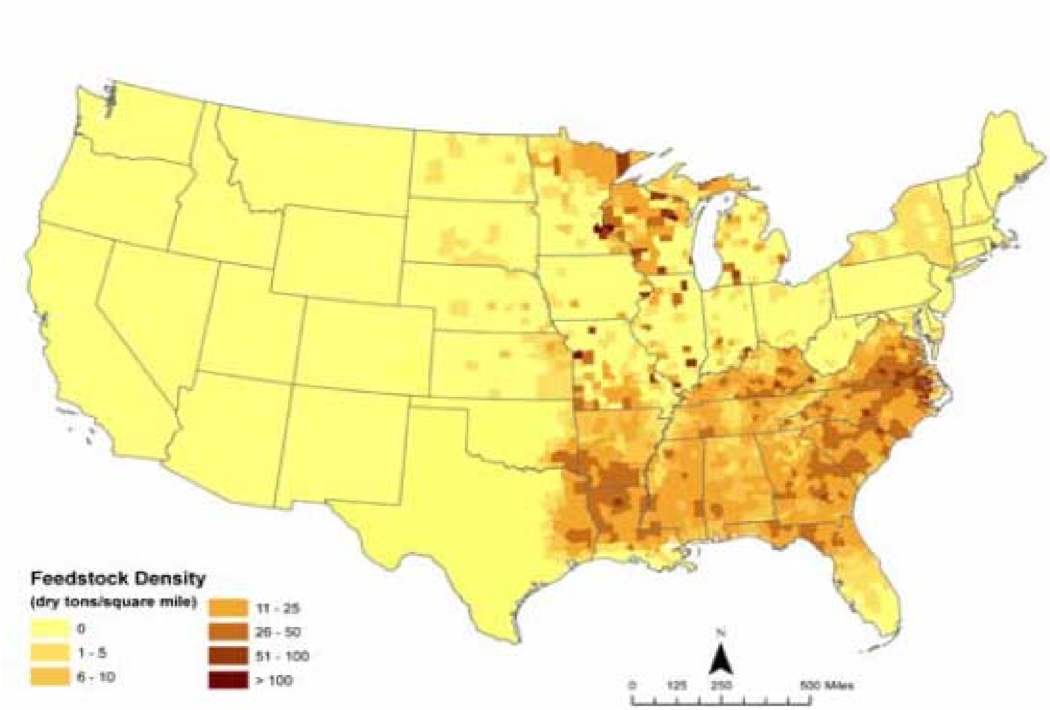
$40 per dry ton

Source:

U.S. Department of Energy. 2011. *U.S. Billion-Ton Update*: *Biomass Supply for a Bioenergy and Bioproducts Industry*. R.D. Perlack and B.J. Stokes (Leads), ORNL/TM-2011/224. Oak Ridge National Laboratory, Oak Ridge, TN. 227p. http://www1.eere.energy.gov/biomass/pdfs/billion_ton_update.pdf

Other removal residues are the unutilized wood volume cut or otherwise killed from timberland clearing or precommercial thinning operations. It does not include volume removed from inventory through reclassification of timberland to productive reserved forest land.

Section: FEEDSTOCKS
Spatial Availability of Other Removal Residues at $40 per Dry Ton (Delivered to Roadside)



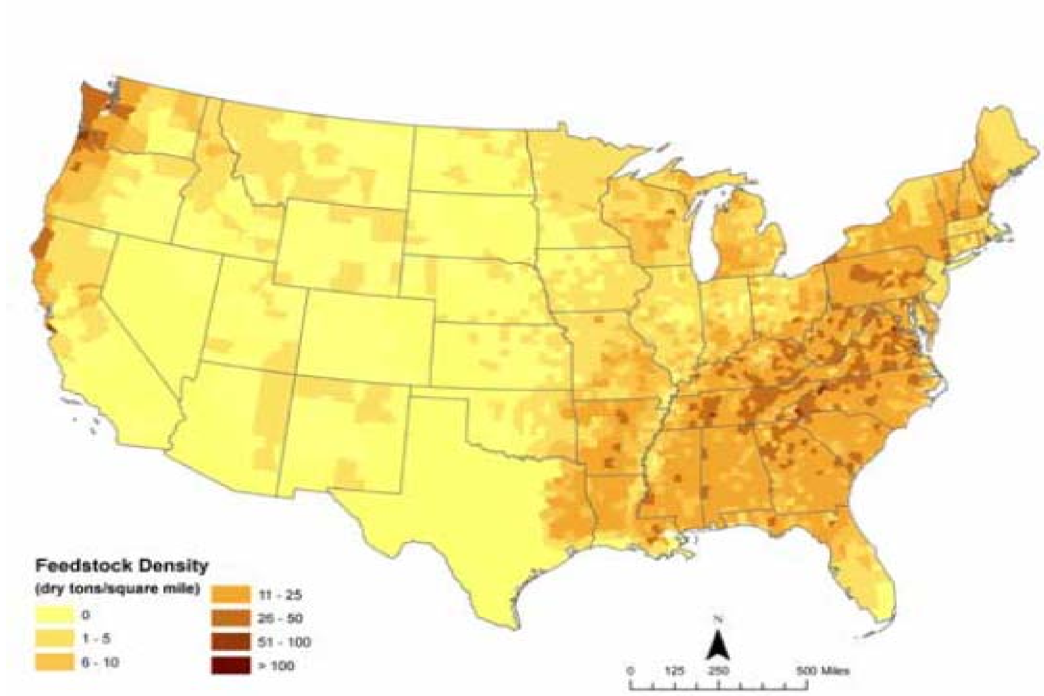
$40 per dry ton

Source:
U.S. Department of Energy. 2011. *U.S. Billion-Ton Update*: *Biomass Supply for a Bioenergy and Bioproducts Industry*. R.D. Perlack and B.J. Stokes (Leads), ORNL/TM-2011/224. Oak Ridge National Laboratory, Oak Ridge, TN. 227p. http://www1.eere.energy.gov/biomass/pdfs/billion_ton_update.pdf

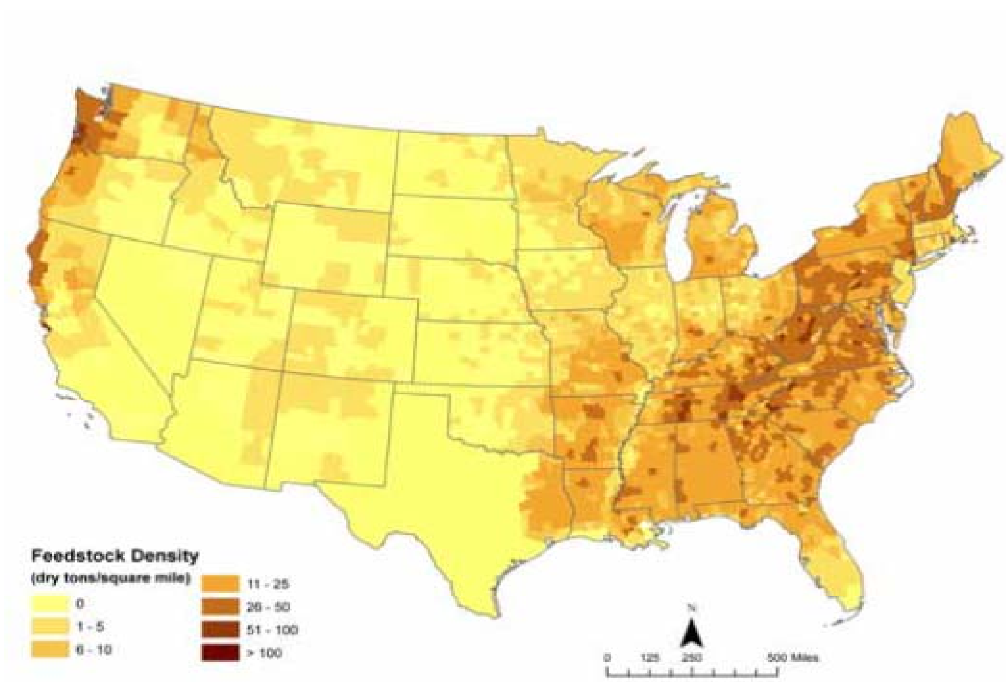
Forest residue thinnings are the material generated from thinnings designed to reduce the risk of loss to wildfire on timberlands. Timberland is forestland that is capable of producing in excess of 20 cubic feet per acre per year of industrial products in natural stands and is not withdrawn from timber utilization by statute or administrative regulation. These lands are distributed throughout the United States. As with logging residues, economics, site-specific characteristics and costs affect the recoverability of this material.

Section: FEEDSTOCKS

Spatial Distribution of Simulated Forest Residue Thinnings at $30 and $60 per Dry Ton (Roadside)



$30 per dry ton



$60 per dry ton

Source:

U.S. Department of Energy. 2011. *U.S. Billion-Ton Update*: *Biomass Supply for a Bioenergy and Bioproducts Industry*. R.D. Perlack and B.J. Stokes (Leads), ORNL/TM-2011/224. Oak Ridge National Laboratory, Oak Ridge, TN. 227p. http://www1.eere.energy.gov/biomass/pdfs/billion_ton_update.pdf

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 Data Book 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/default.asp. 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.

The Forest Service's State and Private Forestry, Technology Marketing Unit, has awarded grants to stimulate utilization of woody biomass, especially of wood from areas needing hazardous fuels reduction. The projects are small and often support the purchase of equipment by small companies. The primary objective of the Forest Service is to increase the removal and use of small diameter wood from forests. Only 2009 and 2010 projects are shown in this summary.

Section: FEEDSTOCKS

U.S. Forest Service - Woody Biomass Utilization Grantees 2009 & 2010

Company Name	Location	Award (Dollars)
	2010 Grant Summary	
Headrick Logging	Anderson, CA	350,000
Sierra Resource Management	Jamestown, CA	329,000
Del Logging, Inc.	Bieber, CA	350,000
Cooley Forest Products	Phoenix, AZ	350,000
J. W. Bamford, Inc.	Oroville, CA	300,000
West Range Reclamation	Crawford, CO	350,000
Arizona Log and TimberWorks	Eagar, AZ	350,000
JL Shavings	Tularosa, NM	350,000
San Carlos Apache Timber Products	San Carlos, AZ	272,770
Warner Enterprises	Redding, CA	350,000
Foothills Firewood	Lyons, OR	325,014
Restoration Solutions	Corona, NM	350,000
ABCO Wood Recycling	Post Falls, ID	200,000

Table Continued on Next Page

Section: FEEDSTOCKS

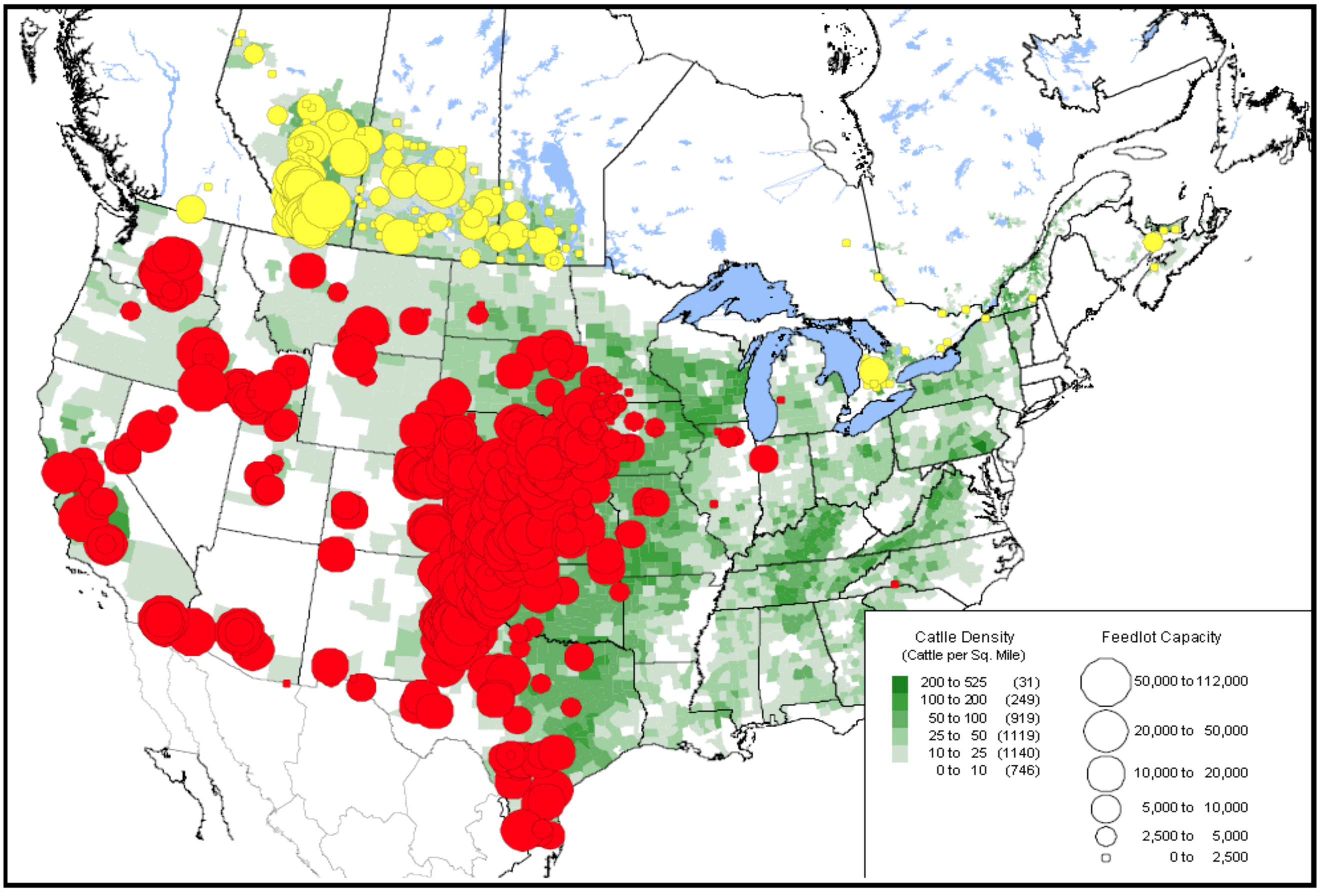
U.S. Forest Service - Woody Biomass Utilization Grantees 2009 & 2010 - Continued

Company Name	Location	Award (Dollars)
	2009 Grant Summary	
Rover Shavings & Post, Inc.	Rover, AR	250,000
Pure Wood Products, LLC	Pinetop, AZ	250,000
California Wood Shavings, Inc.	Jamestown, CA	249,550
CLT Logging, Inc.	Grenada, CA	250,000
Franklin Logging, Inc.	Bella Vista,CA	250,000
Scott Dunn Logging	Fortuna, CA	250,000
Trinity River Lumber Company	Weaverville, CA	250,000
Independent Log Company	Alamosa, CO	250,000
Intermountain Resources, LLC	Montrose, CO	250,000
Rogue Resources, Inc./More Lumber	Milner, CO	250,000
Idaho Forest Group, LLC	Athol, ID	250,000
Eagle Stud Mill, Inc.	Missoula, MT	250,000
Eureka Pellet Mills, Inc.	Missoula, MT	250,000
Southwest Piñon, Inc.	Datil, NM	250,000
Community Smallwood Solutions	Wallowa, OR	249,819
Marubeni Sustainable Energy	Lakeview, OR	250,000
Olson Brothers Enterprises, LLC	Crivitz, WI	250,000

Source: U.S. Forest Service State & Private Forestry Technology Marketing Unit website.
http://www.usda.gov/wps/portal/usda/usdahome?contentidonly=true&contentid=2010/06/0340.xml
http://www.wbi.wisc.edu/research/agriculture-secretary-vilsack-awards-more-than-42-million-for-woody-biomass-utilization-projects/

The map below showing feedlot capacity and distribution throughout the United States is important as an indication of manure availability.

Section: FEEDSTOCKS
Feedlot Capacity and Distribution, 2004



Source:
United States Department of Agriculture, U.S. Biobased Products Market Potential and Projections Through 2025. Page 224. OCE-2008-1, February 2008.
http://www.usda.gov/oce/energy/index.htm

The Forest Service classifies primary mill residues into three categories: bark, coarse residues (chunks and slabs) and fine residues (shavings and sawdust). These mill residues are excellent sources of biomass for cellulosic ethanol because they tend to be clean, uniform, concentrated, have low moisture content, and are already located at a processing facility. These traits make mill residues excellent feedstocks for energy and biomass needs as well.

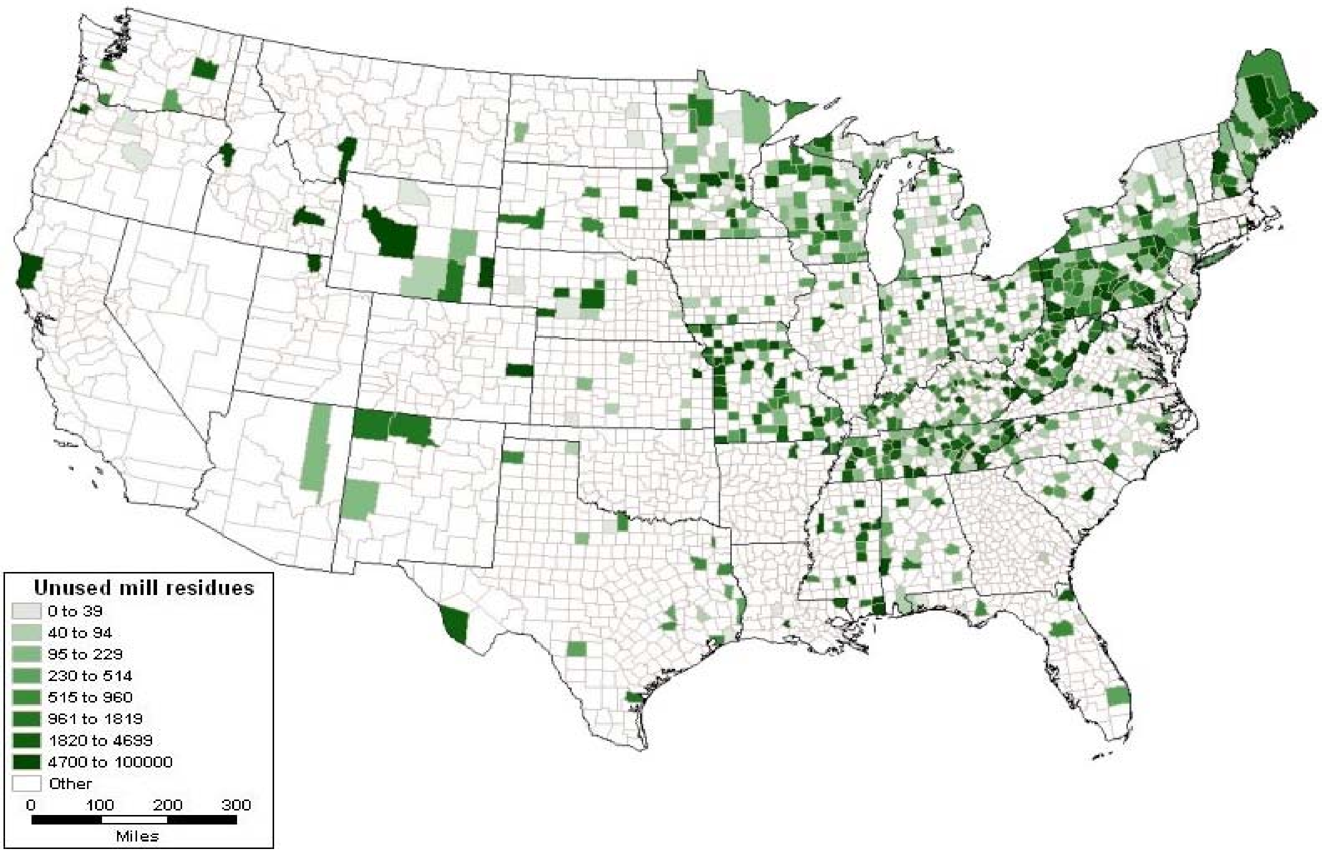
Section: FEEDSTOCKS
Primary Mill Residue Production and Use by State, 2007
(Dry tons)

State	Total residue produced	Fiber byproducts	Fuel byproducts	Miscellaneous byproducts	Unused mill residues
Alabama	6,770,270	2,319,180	3,990,970	453,010	7,120
Arizona	97,190	31,920	520	63,400	1,350
Arkansas	5,372,030	2,456,840	2,710,020	192,280	12,890
California	3,629,030	1,476,540	1,665,350	422,040	65,090
Colorado 113,930		31,680	21,990	57,960	2,300
Connecticut	45,860	3,440	5,080	33,390	3,950
Delaware	21,500	0	2,560	18,940	0
Florida	2,513,390	847,310	1,171,030	492,860	2,200
Georgia	6,994,830	2,972,760	2,889,040	1,087,890	45,140
Idaho	2,219,550	1,265,060	825,880	122,610	6,010
Illinois	282,420	61,060	97,910	104,920	18,520
Indiana	766,650	243,420	150,360	362,240	10,630
Iowa	181,810	3,280	28,460	149,910	160
Kansas	27,500	5,530	3,000	10,250	8,720
Kentucky	1,550,470	432,260	463,290	599,730	55,200
Louisiana	4,611,930	1,756,760	2,677,480	147,610	30,080
Maine	506,010	190,440	166,820	106,270	42,480
Maryland	222,510	40,070	12,330	153,030	17,070
Massachusetts	126,770	23,340	41,200	62,230	0
Michigan	1,850,630	517,590	946,470	372,800	13,760
Minnesota	1,232,550	133,450	996,530	75,700	26,880
Mississippi	6,542,100	2,423,340	3,284,510	739,120	95,140
Missouri	1,146,430	206,690	148,650	711,310	79,790
Montana	1,510,080	1,075,350	286,000	139,600	9,140
Nebraska	46,710	0	7,800	33,930	4,970
Nevada	0	0	0	0	0
New Hampshire	335,450	82,920	125,670	119,850	7,020
New Jersey	8,720	0	1,340	5,950	1,440
New Mexico	114,000	58,000	8,710	42,390	4,900
New York	1,236,310	210,720	453,000	545,200	27,390
North Carolina	5,249,660	2,229,160	1,772,510	1,235,180	12,810
North Dakota	430	0	80	90	260
Ohio	352,880	40,670	140,010	149,600	22,600
Oklahoma	826,190	282,710	466,650	76,340	500
Oregon	7,577,270	5,439,820	1,559,250	561,870	16,320
Pennsylvania	1,628,140	351,080	419,530	686,560	170,970
Rhode Island	15,310	0	290	14,640	390
South Carolina	2,808,670	1,140,530	1,454,330	212,760	1,050
South Dakota	230,500	148,030	31,730	48,440	2,290
Tennessee	2,009,600	622,210	844,040	355,770	187,580
Texas	4,843,870	1,686,570	2,728,800	425,480	3,020
Utah	41,110	360	5,240	31,070	4,440
Vermont	104,440	59,940	44,500	0	0
Virginia	2,897,960	1,130,530	1,211,790	516,280	39,370
Washington	5,278,350	2,682,220	1,593,360	981,320	21,450
West Virginia	843,300	272,170	281,230	171,120	118,780
Wisconsin	1,708,220	357,640	947,400	342,770	60,410
Wyoming	219,840	96,940	44,910	43,980	34,010
Total	**86,712,401**	**35,409,538**	**36,727,621**	**13,279,682**	**1,295,560**

Source:
USDA-FS (U.S. Department of Agriculture - Forest Service). 2007. “Timber Products Output Mapmaker Version 1.0”

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.

Section: FEEDSTOCKS
Unused Mill Residues in the U.S. by County



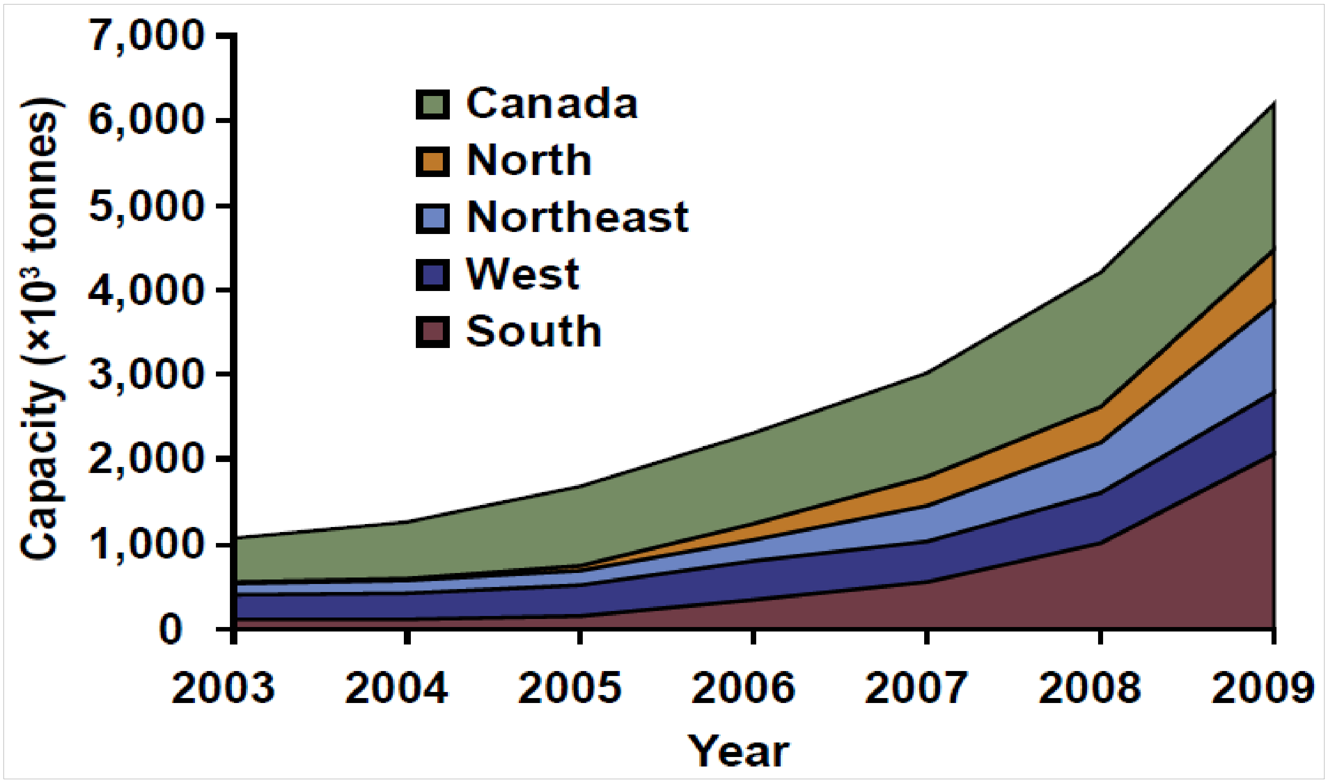
Source:
USDA-FS (U.S. Department of Agriculture - Forest Service). 2007. "Timber Products Output Mapmaker Version 1.0"

Note: Map created by Bioenergy Resource and Engineering Systems Program, Oak Ridge National Laboratory.

Wood pellet capacity increased sharply from 2005 to 2009. In 2008 U.S. production was 66% of capacity while Canadian production was about 81% of capacity that year. About 80% of U.S. pellet production is used domestically while the remaining 20% is exported, largely to Europe where there is growing demand for pellet fuel.

Section: FEEDSTOCKS

North American Pellet Capacity, 2003-2009



Source:

United States Department of Agriculture, *North America's Wood Pellet Sector* , Henry Spelter, Daniel Toth, Research Paper FPL–RP–656, August 2009, Corrected September 2009.

Shipments of cordwood appliances have been declining over the last 10 years while shipments of pellet appliances rose sharply at times during this period. Cordwood appliances are by far the largest share of wood burning appliances.

Section: FEEDSTOCKS
Pellet and Cordwood Appliance Shipments from Manufacturers, 1998-2010

	Pellet Appliances	% Change	Cordwood Appliances	% Change
1998	34,000	a	652,500	a
1999	18,360	-46%	795,767	22%
2000	30,970	69%	609,332	-23%
2001	53,473	73%	637,856	5%
2002	33,978	-36%	534,406	-16%
2003	48,669	43%	503,699	-6%
2004	67,467	39%	498,630	-1%
2005	118,746	76%	561,696	13%
2006	133,105	12%	518,439	-8%
2007	54,032	-59%	362,243	-30%
2008	141,208	161%	345,658	-5%
2009	46,133	-67%	236,743	-32%
2010	44,269	-4%	230,787	-3%

Source:
Hearth, Patio & Barbecue Association,
http://www.hpba.org/index.php?id=238

[a] Data not available

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.

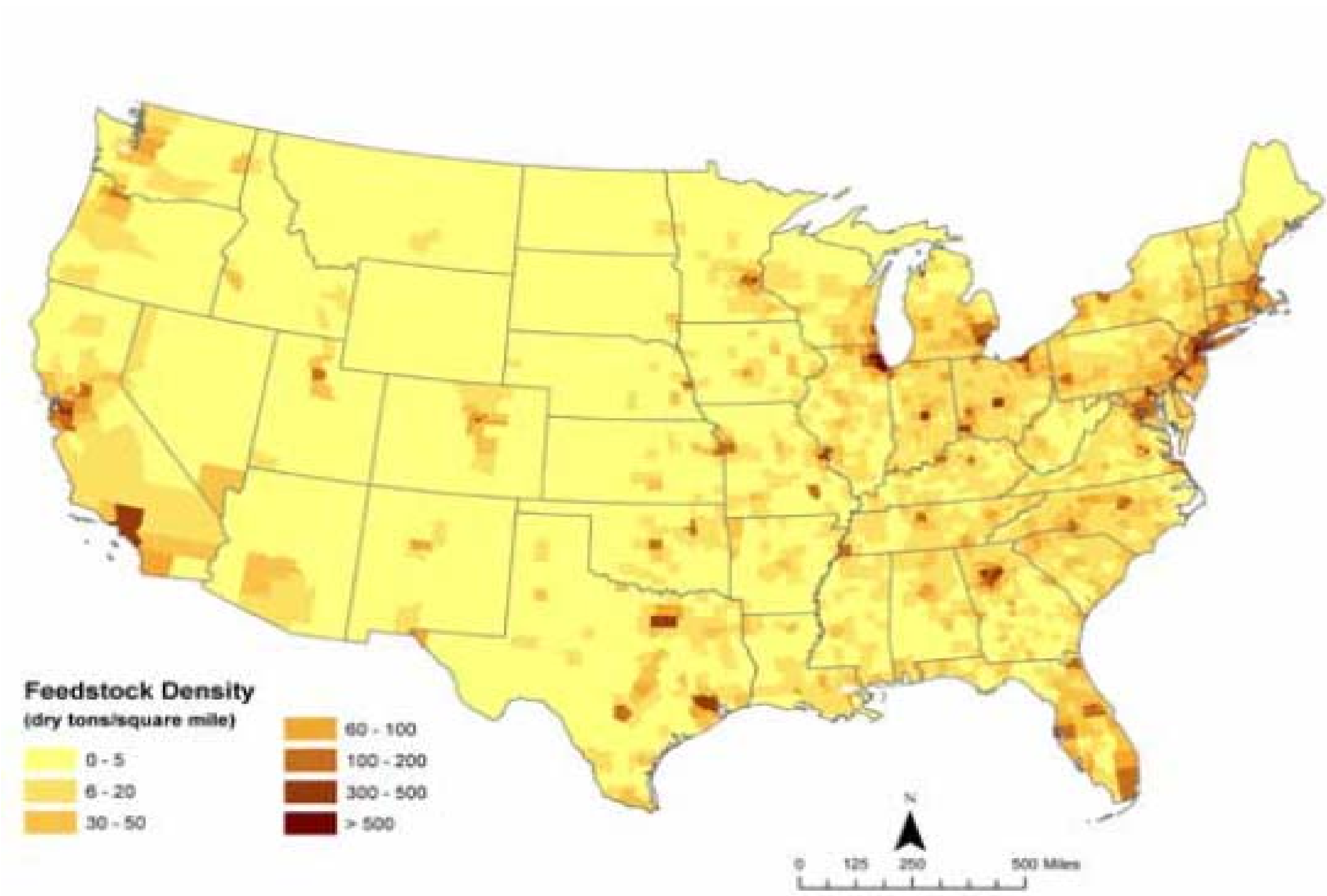
The category “other wood waste from the urban environment” could include trimmings from urban trees, which technically fits the definition of primary biomass. However, because this material is normally handled as a waste stream along with other post-consumer wastes from urban environments (and included 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.

Section: FEEDSTOCKS
Spatial Availability of Urban Wood Waste (Municipal Solid Waste) and Construction and Demolition Wood Residues



Source:

U.S. Department of Energy. 2011. *U.S. Billion-Ton Update*: *Biomass Supply for a Bioenergy and Bioproducts Industry*. R.D. Perlack and B.J. Stokes (Leads), ORNL/TM-2011/224. Oak Ridge National Laboratory, Oak Ridge, TN. 227p. http://www1.eere.energy.gov/biomass/pdfs/billion_ton_update.pdf

Landfill gas is becoming a more prominent source of energy; all but four 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.

Section: FEEDSTOCKS

Landfill Gas Projects and Candidate Landfills by State, April 2011

State	Operational Projects	Candidate Landfills
Alabama	4	18
Alaska	0	2
Arizona	3	14
Arkansas	4	7
California	77	37
Colorado	1	12
Connecticut	3	3
Delaware	3	a
Florida	16	16
Georgia	13	24
Hawaii	0	8
Idaho	2	3
Illinois	32	23
Indiana	22	12
Iowa	4	14
Kansas	6	8
Kentucky	7	18
Louisiana	6	7
Maine	2	2
Maryland	10	11
Massachusetts	20	2
Michigan	35	5
Minnesota	7	6
Mississippi	2	13
Missouri	11	15
Montana	1	3
Nebraska	2	4
Nevada	0	3
New Hampshire	7	3
New Jersey	18	3
New Mexico	2	3
New York	28	6
North Carolina	17	33
North Dakota	2	1
Ohio	19	21
Oklahoma	3	12
Oregon	7	3
Pennsylvania	38	11
Puerto Rico	0	12
Rhode Island	2	a
South Carolina	12	8
South Dakota	1	1
Tennessee	6	11
Texas	27	50
Utah	4	5
Vermont	5	a
Virginia	26	12
Virgin Islands	0	2
Washington	6	8
West Virginia	2	9
Wisconsin	26	6
Wyoming	0	2
U.S. Total	**551**	**~510**

Source:
EPA's Landfill Methane Outreach Program, April 12, 2011
http://www.epa.gov/lmop/

[a] No data available.

Appendix A - Conversions

Contents	Data Type	Updated
Lower and Higher Heating Values of Gas, Liquid and Solid Fuels	Table	09/30/2011
Heat Content Ranges for Various Biomass Fuels	Table	09/30/2011
Average Heat Content for Selected Waste Fuels	Table	09/30/2011
The Effect of Moisture on Heating Values	Table	09/30/2011
Forestry Volume Unit to Biomass Weight Considerations	Table	09/30/2011
Estimation of Biomass Weights from Forestry Volume Data	Table	09/30/2011
Forestry Volume Unit to Biomass Weight Examples	Table	09/30/2011
Stand Level Biomass Estimation	Table	09/30/2011
Number of Trees per Acre and Hectare by Tree Spacing Combination	Table	09/30/2011
Wood and Log Volume to Volume Conversion Factors	Table	09/30/2011
Estimating Tons of Wood Residues Per Thousand Board Feet of Lumber Produced by Sawmills	Table	09/30/2011
Estimating Tons of Wood Residue Per Thousand Board Feet of Wood Used for Selected Products	Table	09/30/2011
Area and Length Conversions	Table	09/30/2011
Mass Units and Mass per Unit Area Conversions	Table	09/30/2011
Distance and Velocity Conversions	Table	09/30/2011
Capacity, Volume and Specific Volume Conversions	Table	09/30/2011
Power Unit Conversions	Table	09/30/2011
Small and Large Energy Units and Energy per Unit Weight Conversions	Table	09/30/2011
Most Commonly Used Biomass Conversion Factors	Table	09/30/2011
Alternative Measures of Greenhouse Gases	Table	09/30/2011
Fuel Efficiency Conversions	Table	09/30/2011
SI Prefixes and Their Values	Table	09/30/2011
Metric Units and Abbreviations	Table	09/30/2011
Cost per Unit Conversions	Table	09/30/2011

Lower and Higher Heating Values of Gas, Liquid and Solid Fuels

Fuels	Lower Heating Value (LHV) [1]			Higher Heating Value (HHV) [1]			Density
Gaseous Fuels @ 32 F and 1 atm	**Btu/ft3 [2]**	**Btu/lb [3]**	**MJ/kg [4]**	**Btu/ft3 [2]**	**Btu/lb [3]**	**MJ/kg [4]**	**grams/ft3**
Natural gas	983	20,267	47.141	1089	22,453	52.225	22.0
Hydrogen	290	51,682	120.21	343	61,127	142.18	2.55
Still gas (in refineries)	1458	20,163	46.898	1,584	21,905	50.951	32.8
Liquid Fuels	**Btu/gal [2]**	**Btu/lb [3]**	**MJ/kg [4]**	**Btu/gal [2]**	**Btu/lb [3]**	**MJ/kg [4]**	**grams/gal**
Crude oil	129,670	18,352	42.686	138,350	19,580	45.543	3,205
Conventional gasoline	116,090	18,679	43.448	124,340	20,007	46.536	2,819
Reformulated or low-sulfur gasoline	113,602	18,211	42.358	121,848	19,533	45.433	2,830
CA reformulated gasoline	113,927	18,272	42.500	122,174	19,595	45.577	2,828
U.S. conventional diesel	128,450	18,397	42.791	137,380	19,676	45.766	3,167
Low-sulfur diesel	129,488	18,320	42.612	138,490	19,594	45.575	3,206
Petroleum naphtha	116,920	19,320	44.938	125,080	20,669	48.075	2,745
NG-based FT naphtha	111,520	19,081	44.383	119,740	20,488	47.654	2,651
Residual oil	140,353	16,968	39.466	150,110	18,147	42.210	3,752
Methanol	57,250	8,639	20.094	65,200	9,838	22.884	3,006
Ethanol	76,330	11,587	26.952	84,530	12,832	29.847	2,988
Butanol	99,837	14,775	34.366	108,458	16,051	37.334	3,065
Acetone	83,127	12,721	29.589	89,511	13,698	31.862	2,964
E-Diesel Additives	116,090	18,679	43.448	124,340	20,007	46.536	2,819
Liquefied petroleum gas (LPG)	84,950	20,038	46.607	91,410	21,561	50.152	1,923
Liquefied natural gas (LNG)	74,720	20,908	48.632	84,820	23,734	55.206	1,621
Dimethyl ether (DME)	68,930	12,417	28.882	75,610	13,620	31.681	2,518
Dimethoxy methane (DMM)	72,200	10,061	23.402	79,197	11,036	25.670	3,255
Methyl ester (biodiesel, BD)	119,550	16,134	37.528	127,960	17,269	40.168	3,361
Fischer-Tropsch diesel (FTD)	123,670	18,593	43.247	130,030	19,549	45.471	3,017
Renewable Diesel I (SuperCetane)	117,059	18,729	43.563	125,294	20,047	46.628	2,835
Renewable Diesel II (UOP-HDO)	122,887	18,908	43.979	130,817	20,128	46.817	2,948
Renewable Gasoline	115,983	18,590	43.239	124,230	19,911	46.314	2,830
Liquid Hydrogen	30,500	51,621	120.07	36,020	60,964	141.80	268
Methyl tertiary butyl ether (MTBE)	93,540	15,094	35.108	101,130	16,319	37.957	2,811
Ethyl tertiary butyl ether (ETBE)	96,720	15,613	36.315	104,530	16,873	39.247	2,810
Tertiary amyl methyl ether (TAME)	100,480	15,646	36.392	108,570	16,906	39.322	2,913
Butane	94,970	19,466	45.277	103,220	21,157	49.210	2,213
Isobutane	90,060	19,287	44.862	98,560	21,108	49.096	2,118
Isobutylene	95,720	19,271	44.824	103,010	20,739	48.238	2,253
Propane	84,250	19,904	46.296	91,420	21,597	50.235	1,920
Solid Fuels	**Btu/ton [2]**	**Btu/lb [5]**	**MJ/kg [4]**	**Btu/ton [2]**	**Btu/lb [5]**	**MJ/kg [4]**	
Coal (wet basis) [6]	19,546,300	9,773	22.732	20,608,570	10,304	23.968	
Bituminous coal (wet basis) [7]	22,460,600	11,230	26.122	23,445,900	11,723	27.267	
Coking coal (wet basis)	24,600,497	12,300	28.610	25,679,670	12,840	29.865	
Farmed trees (dry basis)	16,811,000	8,406	19.551	17,703,170	8,852	20.589	
Herbaceous biomass (dry basis)	14,797,555	7,399	17.209	15,582,870	7,791	18.123	
Corn stover (dry basis)	14,075,990	7,038	16.370	14,974,460	7,487	17.415	
Forest residue (dry basis)	13,243,490	6,622	15.402	14,164,160	7,082	16.473	
Sugar cane bagasse	12,947,318	6,474	15.058	14,062,678	7,031	16.355	
Petroleum coke	25,370,000	12,685	29.505	26,920,000	13,460	31.308	

Source:

GREET, The Greenhouse Gases, Regulated Emissions, and Energy Use In Transportation Model, GREET 1.8d.1, developed by Argonne National Laboratory, Argonne, IL, released August 26, 2010.
http://greet.es.anl.gov/

Notes:

[1] The **lower heating value** (also known as net calorific value) of a fuel is defined as the amount of heat released by combusting a specified quantity (initially at 25°C) and returning the temperature of the combustion products to 150°C, which assumes the latent heat of vaporization of water in the reaction products is not recovered. The LHV are the useful calorific values in boiler combustion plants and are frequently used in Europe.

The **higher heating value** (also known as gross calorific value or gross energy) of a fuel is defined as the amount of heat released by a specified quantity (initially at 25°C) once it is combusted and the products have returned to a temperature of 25°C, which takes into account the latent heat of vaporization of water in the combustion products. The HHV are derived only under laboratory conditions, and are frequently used in the US for solid fuels.

[2] Btu = British thermal unit.

[3] The heating values for gaseous fuels in units of Btu/lb are calculated based on the heating values in units of Btu/ft3 and the corresponding

[4] The heating values in units of MJ/kg, are converted from the heating values in units of Btu/lb.

[5] For solid fuels, the heating values in units of Btu/lb are converted from the heating values in units of Btu/ton.

[6] Coal characteristics assumed by GREET for electric power production.

[7] Coal characteristics assumed by GREET for hydrogen and Fischer-Tropsch diesel production.

Section: Appendix A

Heat Content Ranges for Various Biomass Fuels (dry weight basis[a]) with English and Metric Units

Fuel type & source	English			Metric[b]			
		Higher Heating Value		Higher Heating Value		Lower Heating Value	
	Btu/lb[c]	Btu/lb	MBtu/ton	kJ/kg	MJ/kg	kJ/kg	MJ/kg
Agricultural Residues							
Corn stalks/stover (1,2,6)	7,487	7,587 - 7,967	15.2 - 15.9	*17,636 - 18,519*	*17.6 - 18.5*	16,849 - 17,690	16.8 - 18.1
Sugarcane bagasse (1,2,6)	7,031	7,450 - 8,349	14.9 - 16.7	*17,317 - 19,407*	*17.3 - 19.4*	17,713 - 17,860	17.7 - 17.9
Wheat straw (1,2,6)		*6,964 - 8,148*	13.9 - 16.3	16,188 - 18,940	16.1 - 18.9	15,082 - 17,659	15.1 - 17.7
Hulls, shells, prunings (2,3)		6,811 - 8,838	13.6 - 17.7	*15,831 - 20,543*	*15.8 - 20.5*		
Fruit pits (2-3)		8,950 - 10,000	17.9 - 20.0				
Herbaceous Crops	7,791						
Miscanthus (6)				18,100 - 19,580	18.1 - 19.6	17,818 - 18,097	17.8 - 18.1
switchgrass (1,3,6)		7,754 - 8,233	15.5 - 16.5	*18,024 - 19,137*	*18.0 - 19.1*	16,767 - 17,294	16.8 - 18.6
Other grasses (6)				18,185 - 18,570	18.2 - 18.6	16,909 - 17,348	16.9 - 17.3
Bamboo (6)				19,000 - 19,750	19.0 - 19.8		
Woody Crops	8,852						
Black locust (1,6)		8,409 - 8,582	16.8 - 17.2	*19,546 - 19,948*	*19.5 - 19.9*	18,464	18.5
Eucalyptus (1,2,6)		*8,174* - 8,432	16.3 - 16.9	19,000 - *19,599*	*19.0 - 19.6*	17,963	18.0
Hybrid poplar (1,3,6)		*8,183* - 8,491	*16.4* - 17.0	19,022 - *19,737*	*19.0 - 19.7*	17,700	17.7
Willow (2,3,6)		7,983 - 8,497	16.0 - 17.0	18,556 - 19,750	18.6 - 19.7	16,734 - 18,419	16.7 - 18.4
Forest Residues	7,082						
Hardwood wood (2,6)		8,017 - 8,920	16.0 - 17.5	*18,635 - 20,734*	*18.6 - 20.7*		
Softwood wood (1,2,3,4,5,6)		8,000 - 9,120	16.0 - 18.24	*18,595 - 21,119*	*18.6 - 21.1*	17,514 - 20,768	17.5 - 20.8
Urban Residues							
MSW (2,6)		5,644 - 8,542	11.2 - 17.0	*13,119 - 19,855*	*13.1 - 19.9*	11,990 - 18,561	12.0 - 18.6
RDF (2,6)		*6,683 - 8,563*	*13.4 - 17.1*	15,535 - 19,904	15.5 - 19.9	14,274 - 18,609	14.3 - 18.6
Newspaper (2,6)		8,477 - 9,550	17 - 19.1	*19,704 - 22,199*	19.7 - 22.2	18,389 - 20,702	18.4 - 20.7
Corrugated paper (2,6)		7,428 -7,939	14.9 - 15.9	17,265 - 18,453	17.3 - 18.5	17,012	
Waxed cartons (2)		11,727 - 11,736	23.5 - 23.5	*27,258 - 27,280*	*27.3*	25,261	

Sources:

1 http://www1.eere.energy.gov/biomass/feedstock_databases.html

2 Jenkins, B., *Properties of Biomass*, Appendix to *Biomass Energy Fundamentals*, EPRI Report TR-102107, January, 1993.

3 Jenkins, B., Baxter, L., Miles, T. Jr., and Miles, T., *Combustion Properties of Biomass*, Fuel Processing Technology 54, pg. 17-46, 1998.

4 Tillman, David, *Wood as an Energy Resource*, Academic Press, New York, 1978

5 Bushnell, D., *Biomass Fuel Characterization: Testing and Evaluating the Combustion Characteristics of Selected Biomass Fuels*, BPA report, 1989

6 http://www.ecn.nl/phyllis

Original references are provided in the Phyllis database for biomass and waste of the Energy Research Centre of the Netherlands.

[a] This table attempts to capture the variation in reported heat content values (on a dry weight basis) in the US and European literature based on values in the Phyllis database, the US DOE/EERE feedstock database, and selected literature sources. Table A.3 of this document provides information on heat contents of materials "as received" with varying moisture contents.

[b] Metric values include both HHV and LHV since Europeans normally report the LHV (or net calorific values) of biomass fuels.

[c] HHV assumed by GREET model given in Table A.1 of this document

Section: Appendix A
Average Heat Content of Selected Waste Fuels

Fuel Type	Heat Content[a]	Units
Agricultural Byproducts	8.248	Million Btu/Short Ton
Black Liquor	11.758	Million Btu/Short Ton
Digester Gas	0.619	Million Btu/Thousand Cubic Feet
Landfill Gas	0.490	Million Btu/Thousand Cubic Feet
MSW Biogenic	9.696	Million Btu/Short Ton
Methane	0.841	Million Btu/Thousand Cubic Feet
Paper Pellets	13.029	Million Btu/Short Ton
Peat	8.000	Million Btu/Short Ton
Railroad Ties	12.618	Million Btu/Short Ton
Sludge Waste	7.512	Million Btu/Short Ton
Sludge Wood	10.071	Million Btu/Short Ton
Solid Byproducts	25.830	Million Btu/Short Ton
Spent Sulfite Liquor	12.720	Million Btu/Short Ton
Utility Poles	12.500	Million Btu/Short Ton
Waste Alcohol	3.800	Million Btu/Barrel

Source:
U.S. Energy Information Administration, Renewable Energy Trends in Consumption and Electricity, 2008 Edition, Table 1.10, Average Heat Content of Selected Biomass Fuels. August 2010.
http://www.eia.doe.gov/cneaf/solar.renewables/page/trends/rentrends.html

[a] Higher heating value
MSW = Municipal Solid Waste

The Effect of Moisture on Heating Values

Definitions for heating value of a biomass

The heating value of any fuel is the energy released per unit mass or per unit volume of the fuel when the fuel is completely burned (ANSI/ASABE S593.1 2011). The term calorific value is synonymous to the heating value. Typical units for expressing calorific or heating value are MJ/kg in SI units or Btu/lb in English units. The heating value of a fuel depends on the assumption made on the condition of water molecules in the final combustion products. The higher heating value (*HHV*) refers to a condition in which the water is condensed out of the combustion products. Because of this condensation all of the heating value of the fuel including sensible heat and latent heat are accounted for. The lower heating value (*LHV*), on the other hand refers to the condition in which water in the final combustion products remains as vapor (or steam); i.e. the steam is not condensed into liquid water and thus the latent heat is not accounted for. The term net heating value (*NHV*) refers to *LHV* (ANSI/ASABE S593.1 2011). The term gross heating value (*GHV*) refers to *HHV*.

Determination of heating value of a biomass

Heating value of a biomass is measured experimentally in terms of the high heating value (HHV). The standard method uses a device called bomb calorimeter. The device burns a small mass of biomass in the presence of oxygen inside a sealed container (or bomb). The heat released from combustion is transferred to a mass of fluid (air or water) that surrounds the container. The heating value is calculated from the product of mass of fluid x specific heat of fluid x net temperature increase. The calculated heating value must be corrected for heat losses to the mass of container, heat conduction through the container wall, and heat losses to the surrounding of the device. In modern calorimeters the corrections are made automatically using sensors and controllers. The resulting measured heating value is considered gross heating value (high heating value) at constant volume because the biomass combustion in the container has taken place inside the fixed volume of the container. The resulting gross heating value can be expressed based on dry mass content of the sample biomass,

$$HHV_d = \frac{HHV}{1-M} \quad \text{(Eq. 1)}$$

where HHV_d is the gross heating value of the biomass in MJ/kg of bone dry biomass, *HHV* is the gross heating value determined by the calorimeter. *M* is the moisture content of the biomass in decimal wet mass fraction.

The high heating value can be estimated from the composition of the fuel (Gaur and Reed 1995),

$$HHV_d = 0.35X_C + 1.18X_H + 0.10X_S - 0.02X_N - 0.10X_O - 0.02X_{ash} \quad \text{(Eq. 2)}$$

where *X* is the mass fractions (percent mass dry basis) for Carbon (C), Hydrogen (H), Sulfur (S), Nitrogen (N), Oxygen (O), and ash content (ash). The unit of *HHV* in Equation 2 is in

MJ/kg dry mass. Equation 2 shows that the elements Carbon, Hydrogen, Sulfur increase the heating value whereas the elements Nitrogen, Oxygen, and ash suppress the heating value.

Net heating value of biomass

The *HHV* or *GHV* for woody biomass (including bark) that is determined experimentally is around 20 MJ/kg (8600 Btu/ lb) dry mass basis and for herbaceous biomass it is around 18.8 MJ/kg (8080 Btu/ lb) dry mass basis (Oberberger and Thek 2010). For a moist fuel, the heating value decreases because a portion of the combustion heat is used up to evaporate moisture in the biomass and this evaporated moisture has not been condensed to return the heat back to the system. An estimate of the *LHV* or net heating value (*NHV*) is obtained from the measured *HHV* by subtracting the heat of vaporization of water in the products.

$$LHV = HHV(1 - M) - 2.447M \qquad \text{(Eq. 3)}$$

where *LHV* is the gross (or lower) heating value MJ/kg, M is the wet basis moisture content (mass fraction decimal). The constant 2.447 is the latent heat of vaporization of water in MJ/kg at 25^{o}C. A more accurate estimate of the net heating value from equation 3 can be obtained by including the heat released by the combustion of the hydrogen content of the biomass.

High and low heating value at constant pressure

In practice, the gases evolving from combustion of a biomass are expanded without much constraints. In other words during combustion the volume expands but the pressure in the combustion zone does not change much. This situation is often present in a boiler combustion chamber with unrestricted exhaust system. For these cases equation 3 developed from constant volume measurement is converted to heating value at constant pressure according to equation 4,

$$HHV_p = HHV - 0.212X_H - 0.0008(X_O + X_N) \qquad \text{(Eq. 4)}$$

where HHV_p is the high heating value at constant pressure for dry biomass. X_H, X_O, *and* X_N are the mass fraction (percent dry mass) of the biomass. For wet biomass, the net heating value at constant pressure is calculated from

$$LHV_{p,w} = HHV_p(1.0 - M) - 2.443M \qquad \text{(Eq. 5)}$$

M is the wet basis moisture content (mass fraction decimal). $LHV_{p,w}$ is the net heating value of biomass at constant pressure per unit of wet biomass.

Example of using equations 1-5

The high heating values of two biomass species poplar and stover along with their ultimate analysis were measured. The moisture content of the samples was 35% wet mass basis. The table below lists the measured data.

Measured Moisture, Elements, and High Heating Value of Biomass								
	M (%)	Ash (%)	C (%)	H (%)	O (%)	N (%)	S (%)	HHV_d (MJ/kg)
Poplar	35	0.65	51.64	6.26	41.45	0.00	0.00	20.75
Stover	35	11.27	44.80	5.35	39.55	0.38	0.01	17.33

Estimation of HHV_d (constant volume)

Equation 2 is used to calculate high heating value

$$HHV_d = 0.35X_C + 1.18X_H + 0.10X_S - 0.02X_N - 0.10X_O - 0.02X_{ash}$$

Substituting from compositions listed in the table above

for poplar

$$HHV_d = 0.35(51.64) + 1.18(6.26) + 0.10(0.00) - 0.02(0.00) - 0.10(41.45) - 0.02(0.65)$$
$$= 21.3\ MJ/kg$$

and for stover,

$$HHV_d = 0.35(44.80) + 1.18(5.35) + 0.10(0.01) - 0.02(0.38) - 0.10(39.55) - 0.02(11.27)$$
$$= 17.8\ MJ/kg$$

The calculated HHV_d for both species are slightly higher than measured HHV_d in the table above.

Estimation of *LHV* (constant volume)

Equation 3 is used to calculate low heating value

$$LHV = HHV_d(1 - M) - 2.447M$$

Substituting for *HHV* and moisture content,

for poplar,

$$LHV = (20.8)(1 - 0.35) - 2.447(0.35)$$
$$= 12.7\ MJ/kg$$

and for stover,

$$LHV = (17.3)(1 - 0.35) - 2.447(0.35)$$
$$= 10.4\ MJ/kg$$

Calculations for of HHV_p (constant pressure)

Equation 3 is used to calculate low heating value (or net calorific value) at constant pressure

$$HHV_p = HHV_d - 0.212X_H - 0.0008(X_O + X_N)$$

Substituting from the table above for HHV_d (for constant volume) and concentrations,

for poplar,

$$HHV_p = (20.8) - 0.212(6.26) - 0.0008(41.45 + 0.00)$$
$$= 19.4\ MJ/kg$$

and for stover,

$$HHV_p = (17.3) - 0.212(5.35) - 0.0008(39.55 + 0.38)$$
$$= 16.1\ MJ/kg$$

Calculations for of *LHV_p* (constant pressure)

Equation 5 is used to calculate low heating value,

$$LHV_p = HHV_p(1.0 - M) - 2.443M$$

Substituting for HHV_p and moisture content,
for poplar,

$$LHV = (19.4)(1 - 0.35) - 2.443(0.35)$$
$$= 11.8\ MJ/kg$$

and for stover,

$$LHV = (16.1)(1 - 0.35) - 2.443(0.35)$$
$$= 9.6\ MJ/kg$$

The table below shows the application of equation 5 to calculate the net heating value of biomass at various levels of moisture content. Increasing moisture content diminished the net heat value of biomass to the point that at slightly higher than 80% moisture content, much of the heat content of the biomass is used up to evaporate its moisture.

Effect of Moisture Content on the Net Heating Value of Biomass at Constant Pressure

Biomass	Moisture content percent wet mass basis								
	0	10	20	30	40	50	60	70	80
Poplar	19.4	17.3	15.1	12.9	10.7	8.5	6.3	4.1	1.9
Stover	16.1	14.3	12.4	10.6	8.7	6.8	5.0	3.1	1.3

List and Definition of Symbols

Symbol	Definition
LHV	Lower heating value
HHV	Higher heating value
GHV	Gross heating value
NHV	Net heating value
HHV_p	High heating value at constant pressure
HHV_d	Bone dry gross heating value of the biomass
M	Moisture content wet mass basis
X	Mass fraction percent dry mass basis
Subscripts	
ash	Ash
C	Carbon
d	Dry mass basis
H	Hydrogen
N	Nitrogen
O	Oxygen
p	Constant pressure
w	Moist biomass
Units	
Btu	British thermal unit
°C	Degrees Celsius
MJ	Mega (10^6) Joule (SI unit)
kg	Kilogram
lb	Pound mass

References

ASABE Standards. 2011. American Society for Agricultural & Biological Engineers, St. Joseph, MI: ASABE.

ASTM E870 - 82(2006) Standard Test Methods for Analysis of Wood Fuels. http://www.astm.org/Standards/E870.htm

Gaur, S., T. Reed. 1995. An atlas of thermal data for biomass and other fuels. NREL/TB-433-7965, UC Category: 1310, DE95009212, National Renewable laboratory, Golden Colorado, USA.

Obenberger, I. and G. Thek. 2010. The Pellet Handbook. IEA Bioenergy. Earthscan LLC, Washington, DC.

SIS-CENéTS14918:2005. Solid biofuels. Method of determination of calorific value. http://www.biomassenergycentre.org.uk/portal/page?_pageid=77,19836&_dad=portal&_schema=PORTAL

Sjaak, Van Loo, Jaap Koppejan. 2008. The handbook of biomass combustion and co-firing. Earthsacn, Washington, DC.

TAPPI Gross heating value of black liquor, Test Method T 684 om-11http://www.tappi.org/Bookstore/Standards--TIPs/Standards.aspx

Written by Shahab Sokhansanj, Oak Ridge National Laboratory, September 2011.

Forestry Volume Unit to Biomass Weight Considerations

Biomass is frequently estimated from forestry inventory merchantable volume data, particularly for purposes of comparing regional and national estimates of aboveground biomass and carbon levels. Making such estimations can be done several ways but always involves the use of either conversion factors or biomass expansion factors (or both combined) as described by figure 1 below. Figure 2 clarifys the issue further by defining what is included in each catagory of volume or biomass units.

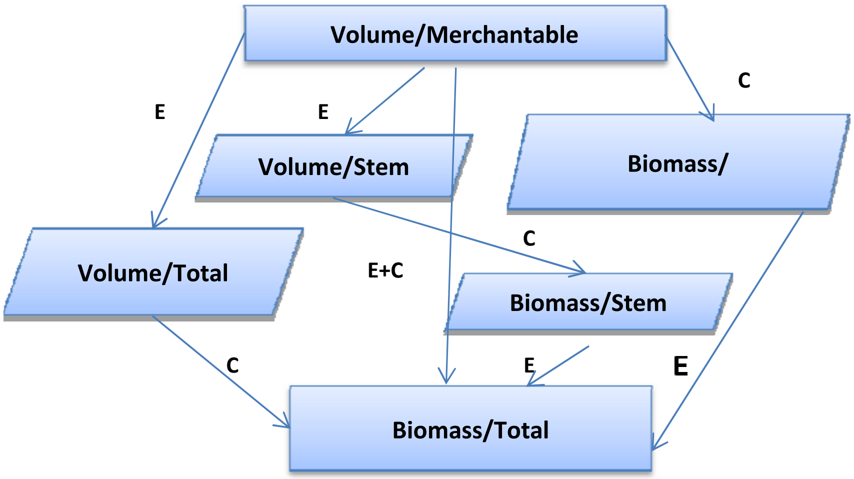


Figure 1 Source: Somogyi Z. et al. Indirect methods of large-scale biomass estimation. Eur J Forest Res (2006) DOI 10.1007/s10342-006-0125-7

Unfortunately definitions used in figure 1 are not standardized worldwide, but figure 2 below demonstrates definitions used in the United States for forest inventory data. The <u>merchantable volume</u> provided by forest inventory reports commonly refers only to the underbark volume or biomass of the main stem above the stump up to a 4 inch (10 cm) top. Merchantable stem volume can be converted (symbolized by C in Fig. 1) to merchantable biomass. Both merchantable volume and biomass must be expanded (symbolized by E in Figure 1) to include the bark for stem volume or biomass. Further expansion is needed to obtain the <u>total volume or biomass</u> which includes stem, bark, stump, branches and foliage, especially if evergreen trees are being measured. When estimating biomass available for bioenergy, the foliage is not included and the above-ground portion of the stump may or may not be included depending on whether harvest occurs at ground level or higher.

Both conversion and expansion factors can be used together to translate directly between merchantable volumes per unit area and total biomass per unit area (see table A5, Appendix A) .

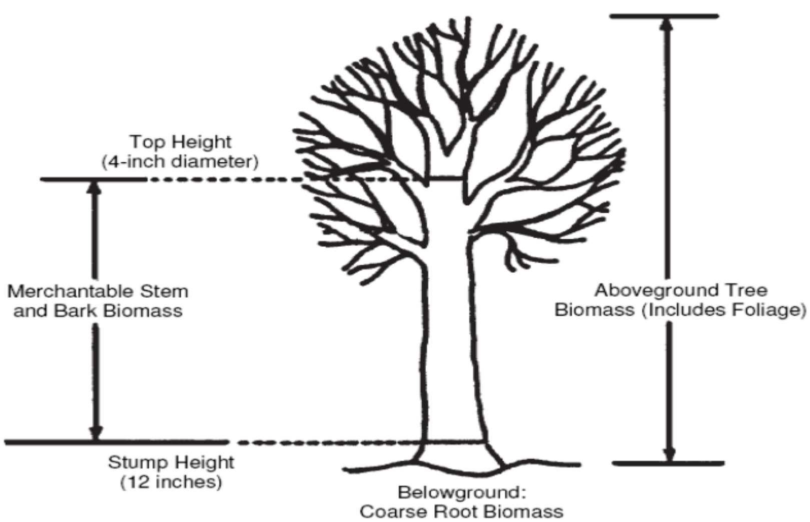


Figure 2 Source: Jenkins, JC, Chojnacky DC, Heath LS, Birdsey RA. Comprehensive Database of Diameter-based Biomass Regressions for North American Tree Species. United States Department of Agriculture, Forest Service General Technical Report NE-319, pp 1-45 (2004)

Section: Appendix A
Estimation of Biomass Weights from Forestry Volume Data

Simple volume to weight conversion

An equation for estimation of merchantable biomass from merchantable volume assuming the specific gravity and moisture content are known and the specific gravity basis corresponds to the moisture content of the volume involved.

Weight = (volume) * (specific gravity) * (density of H_2O) * (1+MC^{od}/100)

where volume is expressed in cubic feet or cubic meters,

where the density of water is 62.4 lb/ft^3 or 1000 kg/m^3,

where MC^{od} equals oven dry moisture content.

for example the weight of fiber in an oven dry log of 44 ft^3 with a specific gravity of 0.40 =

40 ft^3*0.40 * 62.4 lb ft^3 * (1+0/100) equals 1,098 lb or 0.549 dry ton

Source: Briggs D. 1994. Forest Products Measurements and Conversion Factors, Chapter 1. College of Forest Resources University of Washington. http://www.ruraltech.org/projects/conversions/briggs_conversions/briggs_book.asp

Specific gravity (SG) is a critical element of the volume to biomass estimation equation. The SG content should correspond to the moisture content of the volume involved. SG varies considerably from species to species, differs for wood and bark, and is closely related to the moisture content as explained in graphs and tables in Briggs (1994). The wood specific gravity of species can be found in several references though the moisture content basis is not generally given. Briggs (1994) suggests that a moisture content of 12% is the standard upon which many wood properties measurements are based.

Biomass expansion factors for estimating total aboveground biomass Mg ha^{-1} from growing stock volume data (m^3 ha^{-1})

Methods for estimating total aboveground dry biomass per unit area from growing stock volume data in the USDA ForestService FIA database were described by Schroeder et. al (1997). The growing stock volume was by definition limited to trees > than or equal to 12.7 cm diameter. It is highly recommended that the paper be studied for details of how the biomass expansion factors (BEF) for oak-hickory and beech-birch were developed.

The BEFs for the two forest types were combined and reported as:

BEF = EXP (1.912 - 0.344*lnGSV) **GSV = growing stock volume m^3 ha^{-1}**

R2 = 0.85, n = 208 forest units , std. error of estimate = 0.109.

The result is curvilinear with BEF values ranging from 3.5 to 1.5 for stands with very low growing stock volume and approaching the value of 1 at high growing stock volumes. Minimum BEFs for the forest types evaluated are estimated to be about 0.61 to 0.75.

Source: Schroeder P, Brown S, Mo J, Birdsey R, Cieszewski C. 1997. Biomass estimation for temperate broadleaf forests of the US using forest inventlry data. Forest Science 43, 424-434.

Section: Appendix A
Forestry Volume Unit to Biomass Weight Examples

(selected examples from the north central region)

Species Group	Specific gravity wood[a]	Specific gravity bark[a]	Green MC wood & bark (%)	Green weight wood & bark lb/ft^3	Dry weight wood & bark lb/ft^3	Green weight of solid cord[b] (lbs)	Green weight of solid cord[b] (tons)[c]	Air-dry tons per solid cord[b] 15% MC[c]	Oven-dry tons per solid cord 0% MC[c]
Softwood									
Southern Pine	0.47	0.32	50	64	32	5,056	2.5	1.5	1.3
Jack Pine	0.40	0.34	47	54	29	4,266	2.1	1.3	1.1
Red Pine	0.41	0.24	47	54	29	4,266	2.1	1.3	1.1
White Pine	0.37	0.49	47	53	28	4,187	2.1	1.3	1.1
Hardwood									
Red Oak	0.56	0.65	44	73	41	5,767	2.9	1.9	1.6
Beech	0.56	0.56	41	64	38	5,056	2.5	1.7	1.5
Sycamore	0.46	0.45	55	62	28	4,898	2.4	1.3	1.1
Cottonwood	0.37	0.43	55	59	27	4,661	2.3	1.2	1.0
Willow	0.34	0.43	55	56	25	4,424	2.2	1.1	1.0

Source:

Smith, B. Factors and Equations to Estimate Forest Biomass in the North Central Region. 1985. USDA Forest Service, North Central Experimental Station. Research Paper NC-268 (This paper quotes many original literature sources for the equations and estimates.)

Note: *A caution:* In extensive online research for reference sources that could provide guidance on estimating biomass per unit area from volume data (eg m^3, ft^3 or board ft), several sources of conversion factors and "rules of thumb" were found that provided insufficient information to discern whether the reference was applicable to estimation of biomass availibility. For instance moisture contents were not associated with either the volume or the weight information provided. These "rule of thumb" guides can be useful when fully understood by the user, but they can be easily misinterpreted by someone not understanding the guide's intent. For this reason, most simple "rules of thumb guides" are not useful for converting forest volume data to biomass estimates.

---

[a] The SG numbers are based on weight oven-dry and volume when green (Smith, 1985; table 1) of wood and bark respectively. Wood and bark are combined for other columns (Smith, 1985, table 2).

[b] A standard solid cord for the north central region was determined by Smith, 1985 to be 79 ft^3 rather than the national average of 80 ft^3 as used in table A9 in appendix A..

[c] The green weight values in lbs provided by the Smith (1985) paper were converted to green tons, air-dry tons and oven-dry tons for convenience of the user.

Section: Appendix A
Stand Level Biomass Estimation

Biomass estimation at the individual field or stand level is relatively straight forward, especially if being done for plantation grown trees that are relatively uniform in size and other characteristics. The procedure involves first developing a biomass equation that predicts individual tree biomass as a function of diameter at breast height (dbh) , or of dbh plus height. Secondly, the equation parameters (dbh and height) need to be measured on a sufficiently large sample size to minimize variation around the mean values, and thirdly, the mean individual tree weight results are scaled to the area of interest based on percent survival or density information (trees per acre or hectare). Regression estimates are developed by directly sampling and weighing enough trees to cover the range of sizes being included in the estimation. They often take the form of:

ln Y (weight in kg) = -factor 1 + factor 2 x ln X (where X is dbh or dbh^2 +height/100) Regression equations can be found for many species in a wide range of literature. Examples for trees common to the Pacific Northwest are provided in reference 1 below. The equations will differ depending on whether foliage or live branches are included, so care must be taken in interpreting the biomass data. For plantation trees grown on cropland or marginal cropland it is usually assumed that tops and branches are included in the equations but that foliage is not. For trees harvested from forests on lower quality land, it is usually recommended that tops and branches should not be removed (see reference 2 below) in order to maintain nutrient status and reduce erosion potential, thus biomass equations should assume regressions based on the stem weight only.

Sources:

(1) Briggs, D. Forest Products Measurements and Conversion Factors. College of Forest Resources University of Washington. Available as of 9/29/2008 at: http://www.ruraltech.org/projects/conversions/briggs_conversions/briggs_book.asp

(2) Pennsylvania Department of Conservation and Natural Resources. Guidance on Harvesting Woody Biomass for Energy in Pennsylvania. September, 2007. Available as of 9-29-08 at: http://www.dcnr.state.pa.us/PA_Biomass_guidance_final.pdf

Section: Appendix A
Number of Trees per Acre and per Hectare by Various Tree Spacing Combinations

Spacing (feet) =	Trees per Acre =	Spacing (meters)=	Trees per Hectare[a]
1 x 1	43,560	0.3 x 0 .3	107,637
2 x 2	10,890	0.6 x 0.6	26,909
2 x 4	5,445	0.6 x 1.2	13,455
3 x 3	4,840	0.9 x 0.9	11,960
4 x 4	2,722	1.2x 1.2	6,726
4 x 5	2,178	1.2 x 1.5	5,382
4 x 6	1,815	1.2 x 1.8	4,485
4 x 7	1,556	1.2 x 2.1	3,845
4 x 8	1,361	1.2 x 2.4	3,363
4 x 9	1,210	1.2 x 2.7	2,990
4 x 10	1,089	1.2 x 3.0	2,691
5 x 5	1,742	1.5 x 1.5	4,304
5 x 6	1,452	1.5 x 1.8	3,588
5 x 7	1,245	1.5 x 2.1	3,076
5 x 8	1,089	1.5 x 2.4	2,691
5 x 9	968	1.5 x 2.7	2,392
5 x 10	871	1.5 x 3.0	2,152
6 x 6	1,210	1.8 x 1.8	2,990
6 x 7	1,037	1.8 x 2.1	2,562
6 x 8	908	1.8 x 2.4	2,244
6 x 9	807	1.8 x 2.7	1,994
6 x 10	726	1.8 x 3.0	1,794
6 x 12	605	1.8 x 3.7	1,495
7 x 7	889	2.1 x 2.1	2,197
7 x 8	778	2.1 x 2.4	1,922
7 x 9	691	2.1 x 2.7	1,707
7 x 10	622	2.1 x 3.0	1,537
7 x 12	519	3.1 x 3.7	1,282
8 x 8	681	2.4 x 2.4	1,683
8 x 9	605	2.4 x 2.7	1,495
8 x 10	544	2.4 x 3.0	1,344
8 x 12	454	2.4 x 3.7	1,122
9 x 9	538	2.7 x 2.7	1,329
9 x 10	484	2.7 x 3.0	1,196
9 x 12	403	2.7 x 3.7	996
10 x 10	436	3.0 x 3.0	1,077
10 x 12	363	3.0 x 3.7	897
10 x 15	290	3.0 x 4.5	717
12 x 12	302	3.7 x 3.7	746
12 x 15	242	3.7 x4.6	598

Spacing (meters)=	Trees per Hectare	Spacing (ft and in) =	Trees per Acre[b]
0.1 x 0.1	1,000,000	4" x 4 "	405,000
0.23 x 0.23	189,035	9" x 9 "	76,559
0.3 x 0.3	107,593	1' x 1'	43,575
0.5 x 0.5	40,000	1'8" x 1'8"	16,200
0.5 x 1.0	20,000	1'8" x 3'3"	8,100
0.5 x 2.0	10,000	1'8" x 6'7"	4,050
0.75 x 0.75	17,778	2'6" x 2'6"	7,200
0.75 x 1.0	13,333	2'6" x 3'3"	5,400
0.75 x 1.5	8,889	2'5" x 4'11"	3,600
1.0 x 1.0	10,000	3'3" x 3'3"	4,050
1.0 x 1.5	6,667	3'3" x 4'11"	2,700
1.0 x 2.0	5,000	3'3" x 6'6"	2,025
1.0 x 3.0	3,333	3'3" x 9'10"	1,350
1.5 x 1.5	4,444	4'11"x4'11"	1,800
1.5 x 2.0	3,333	4'11"x 6'6"	1,350
1.5 x 3.0	2,222	4'11"x9'10"	900
2.0 x 2.0	2,500	6'6" x 6'6"	1,013
2.0 x 2.5	2,000	6'6" x 8'2"	810
2.0 x 3.0	1,667	6'6" x 9'10"	675
2.0 x 4.0	1,250	6'6" x 13'1"	506
2.5 x 2.5	1,600	8'2" x 8'2"	648
2.5 x 3.0	1,333	8'2" x 9'10"	540
3.0 x 3.0	1,111	9'10"x9'10"	450
3.0 x 4.0	833	9'10"x13'1"	337
3.0 x 5.0	666	9'10"x13'1"	270
4.0 x 4.0	625	13'1" x 13'1'	253
5.0 x 5.0	400	16'5" x 16'5'	162

[a] The spacing is approximated to nearest centimeter but trees per hectare = trees per acre x 2.471

[b] The spacing is approximated to nearest inch but trees per acre = trees per hectare x 0.405

The conversions in this table are only suitable for converting volume units of harvested roundwood or processed sawtimber to approximate alternative volume units, but not for estimating standing volume of biomass.

Section: Appendix A
Wood and Log Volume to Volume Conversion Factors

	TO						
FROM	**standard cord**	**solid cord**	**cunit**	**board foot**	**1,000 board feet**	**cubic foot average**	**cubic meters average**
standard cord	1	1.6	1.28	1,536	1.536	128	3.6246
solid cord	0.625	1	0.8	960	0.96	80[a]	2.2653
cunit	0.7813	1.25	1	1,200	1.2	100	2.832
board foot	0.00065	0.00104	0.00083	1	0.001	0.0833	0.0024
1,000 board feet	0.651	1.0416	0.8333	1,000	1	83.33	2.3598
cubic foot	0.0078	0.0125	0.01	12	0.012	1	0.0283
cubic meters	0.2759	0.4414	0.3531	423.77	0.4238	35.3146	1

Source:
http://www.unitconversion.org/
(Verified with several other sources.)

Brief Definitions of the Forestry Measures
A standard cord is 4 ft x 4 ft x 8 ft stack of roundwood including bark and air
A solid cord is the net volume of roundwood in a standard cord stack
A cunit is 100 cubic feet of solid wood
1 board foot (bf) is a plank of lumbar measuring 1 inch x 1 foot x 1 foot (1/12 ft^3)
1000 board feet (MBF) is a standard measure used to buy and sell lumber
1 cubic foot of lumber or roundwood is a 1 ft x 1 ft x 1 ft cube
1 cubic meter of lumber or roundwood is a 1 m x 1 m x 1 m cube

[a] The estimate of 80 cubic feet (or 2.26 cubic meters) in a solid cord is an average value for stacked lumber and also for hardwood roundwood with bark. Values for all roundwood wood types with and without bark can range from 60 to 95 cubic feet or (1.69 to 2.69 cubic meters) depending on wood species, moisture content and other factors.

To use these conversion factors, first decide the mill type, which is based on equipment; then determine the average scaling diameter of the logs. If the equipment indicates a mill type B and the average scaling diameter is 13 inches, then look under Mill Type B, line 2. This line shows that for every thousand board feet of softwood lumber sawed, 0.42 tons of bark, 1.18 tons of chippable material, and 0.92 tons of fines are produced, green weight. Equivalent hard hardwood and soft hardwood data are also given. Converting factors for shavings are omitted as they are zero for sawmills.

Section: Appendix A
Estimating Tons of Wood Residue Per Thousand Board Feet of Lumber Produced by Sawmills, by Species and Type of Residue

		Softwood[c]						Hard hardwood[c]						Soft hardwood[c]					
		Bark		Chippable		Fine[f]		Bark		Chipable		Fine		Bark		Chipable		Fine	
Mill Type[a]	Small end diameter[b]	G[d]	OD[e]	G	OD	G	OD	G	OD	G	OD	G	OD	G	OD	G	OD	G	OD
A, B, C, H, and I	1	0.46	0.31	1.57	0.78	0.98	0.48	0.84	0.59	1.84	1.04	1.26	0.71	0.58	0.41	1.27	0.72	0.86	0.49
	2	0.42	0.29	1.18	0.58	0.92	0.45	0.72	0.51	1.53	0.87	1.34	0.76	0.50	0.35	1.06	0.60	0.91	0.52
	3	0.41	0.28	1.07	0.53	1.00	0.49	0.56	0.39	1.17	0.66	1.08	0.61	0.39	0.27	0.81	0.46	0.74	0.42
	4	0.31	0.21	0.88	0.43	0.91	0.45	0.49	0.35	1.03	0.58	1.05	0.60	0.34	0.24	0.72	0.41	0.72	0.41
D and E	1	0.29	0.20	1.57	0.78	0.90	0.45	0.84	0.59	1.84	1.04	0.92	0.52	0.58	0.41	1.27	0.72	0.63	0.36
	2	0.29	0.20	1.18	0.58	0.76	0.38	0.72	0.51	1.53	0.87	0.84	0.48	0.50	0.35	1.06	0.60	0.58	0.33
	3	0.29	0.20	1.07	0.53	0.71	0.35	0.56	0.39	1.17	0.66	0.84	0.48	0.39	0.27	0.81	0.46	0.58	0.33
	4	0.29	0.20	0.88	0.43	0.64	0.32	0.49	0.35	1.03	0.58	0.80	0.45	0.34	0.24	0.72	0.41	0.55	0.31
	1	0.29	0.20	1.57	0.78	0.98	0.48	0.84	0.59	1.84	1.04	1.26	0.71	0.58	0.41	1.27	0.72	0.86	0.49
	2	0.29	0.20	1.18	0.58	0.92	0.45	0.72	0.51	1.53	0.87	1.34	0.76	0.50	0.35	1.06	0.60	0.91	0.52
	3	0.29	0.20	1.07	0.53	1.00	0.49	0.56	0.39	1.17	0.66	1.08	0.61	0.39	0.27	0.81	0.46	0.74	0.42
F	4	0.29	0.20	0.88	0.43	0.91	0.45	0.49	0.35	1.03	0.58	1.05	0.60	0.34	0.24	0.72	0.41	0.72	0.41
G	1	0.29	0.20	1.90	0.94	0.57	0.28	0.84	0.59	2.23	1.28	0.53	0.28	0.58	0.41	1.54	0.88	0.36	0.20
	2	0.29	0.20	1.34	0.66	0.60	0.30	0.72	0.51	1.72	0.98	0.65	0.37	0.50	0.35	1.19	0.68	0.45	0.25
	3	0.29	0.20	1.17	0.58	0.61	0.30	0.56	0.39	1.29	0.73	0.72	0.41	0.39	0.27	0.89	0.51	0.50	0.28
	4	0.29	0.20	0.98	0.48	0.54	0.28	0.49	0.35	1.15	0.65	0.68	0.38	0.34	0.24	0.80	0.46	0.47	0.26

Source:
Ellis, Bridgette K. and Janice A. Brown, Tennessee Valley Authority. "Production and Use of Industrial Wood and Bark Residues in the Tennessee Valley Region," August 1984.

[a] Mill Type
- A. Circular headsaw with or without trim saw
- B. Circular headsaw with edger and trim saw.
- C. Circular headsaw with vertical band resaw, edger, trim saw.
- D. Band headsaw with edger, trim saw.
- E. Band headsaw with horizontal band resaw, edger, trim saw.
- F. Band headsaw with cant gangsaw, edger, trim saw.
- G. Chipping head rig.
- H. Round log mill.
- I. Scragg mill.

[b] Average small-end log (scaling) diameter classes.
1. 5-10 inches.
2. 11-13 inches.
3. 14-16 inches.
4. 17 inches and over

[c] See Appendix A for species classification, i.e., softwood, hard hardwood, and soft hardwood.

[d] G = green weight, or initial condition, with the moisture content of the wood as processed

[e] OD = Oven Dry. It is the weight at zero percent moisture.

[f] Fine is sawdust and other similar size material.

Section: Appendix A
Estimating Tons of Wood Residue Per Thousand Board Feet of Wood Used for Selected Products

Type of Plant	Bark	% MC	Chipable[b]	% MC	Shavings	% MC	Fine[c]	%MC
				Softwood[a]				
Planing mill	-	-	0.05	19	0.42	19	-	-
Wood chip mill[d]	0.60	50	-	-	-	-	-	-
Wooden furniture frames	-	-	0.22	12	0.25	12	0.05	12
Shingles & cooperage stock	0.42	50	1.29	100	-	-	1.01	100
Plywood	-	-	0.13	9	-	-	0.21	9
Veneer	0.42	50	1.77	100	-	-	-	-
Pallets and skids	-	-	0.42	60	0.21	60	0.07	60
Log homes	-	-	0.17	80	-	-	0.05	80
Untreated posts, poles, and pilings	0.46	50	0.40	100	-	-	0.05	100
Particleboard	0.60	60	-	-	-	-	0.21	6
Pulp, paper, and paperboard	0.60	70	-	-	-	-	-	-
				Hard hardwood[a]				
	Bark	% MC	Chipable[b]	% MC	Shavings	% MC	Fine[c]	%MC
Planing mill	-	-	0.06	19	0.54	19	-	-
Wood chip mill	0.90	60	-	-	-	-	-	-
Hardwood flooring	-	-	0.12	6	0.57	6	-	-
Wooden furniture frames	-	-	0.31	9	0.36	9	0.07	9
Shingles & cooperage stock	0.56	60	1.66	70	-	-	1.47	70
Plywood	-	-	0.16	9	-	-	0.26	9
Veneer	0.72	60	2.70	70	-	-	-	-
Pallets and skids	-	-	0.50	60	0.25	60	0.08	60
Pulp, paper, and paperboard	0.90	60	-	-	-	-	-	-
				Soft hardwood[a]				
	Bark	% MC	Chipable[b]	% MC	Shavings	% MC	Fine[c]	%MC
Planing mill	-	-	0.04	19	0.40	19	-	-
Wood chip mill	0.62	88	-	-	-	-	-	-
Wooden furniture frames	-	-	0.22	9	0.26	9	0.05	9
Plywood	-	-	0.13	9	-	-	0.21	9
Veneer	0.50	88	2.13	95	-	-	-	-
Pallets and skids	-	-	0.34	60	0.17	60	0.06	60
Particleboard	0.60	60	-	-	-	-	0.21	6
Pulp, paper, and paperboard	0.62	88	-	-	-	-	-	-

Source:
Ellis, Bridgette K. and Janice A. Brown, Tennessee Valley Authority. "Production and Use of Industrial Wood and Bark Residues in the Tennessee Valley Region", August 1984.

Notes:
For shingles and cooperage stock the table indicates that for every thousand board feet of softwood logs used, 1.29 tons of chippable material could be expected, with an average moisture content (MC) of 100%, based on oven dry weight. If the Average MC of the wood used is greater or less than 100%, proportionally greater or lesser weight of material could be expected.

---

[a] For definitions of species, see next page

[b] Chippable is material large enough to warrant size reduction before being used by the paper, particleboard, or metallurgical industries.

[c] Fines are considered to be sawdust or sanderdust.

[d] For chipping mills with debarkers only

Section: Appendix A
Area and Length Conversions

Area

Multiply	by	To Obtain
acres (ac)[a]	0.4047	hectares
hectares (ha)	2.4710	acres
hectares (ha)	0.0039	square miles
hectares (ha)	10000	square meters
square kilometer (km^2)	247.10	acres
square kilometer (km^2)	0.3861	square miles
square kilometer (km^2)	100	hectares
square mile (mi^2)	258.9990	hectares
square mile (mi^2)	2.5900	square kilometers
square mile (mi^2)	640	acres
square yards (yd^2)	0.8361	square meters
square meters (m^2)	1.1960	square yards
square foot (ft^2)	0.0929	square meters
square meters (m^2)	10.7639	square feet
square inchs (in^2)	6.4516	square centimeters (exactly)
square decimeter (dm^2)	15.5000	square inches
square centimeters (cm^2)	0.1550	square inches
square millimeter (mm^2)	0.0020	square inches
square feet (ft^2)	929.03	square centimeters
square rods (rd^2), sq pole, or sq perch	25.2930	square meters

Length

Multiply	by	To Obtain
miles (mi)	1.6093	kilometers
miles (mi)	1,609.34	meters
miles (mi)	1,760.00	yards
miles (mi)	5,280.00	feet
kilometers (km)	0.6214	miles
kilometers (km)	1,000.00	meters
kilometers (km)	1,093.60	yards
kilometers (km)	3,281.00	feet
feet (ft)	0.3048	meters
meters (m)	3.2808	feet
yard (yd)	0.9144	meters
meters (m)	1.0936	yards
inches (in)	2.54	centimeters
centimeters (cm)	0.3937	inches

Source:
National Institute of Standards and Technology, General Tables of Units and Measurements
http://ts.nist.gov/WeightsAndMeasures/Publications/upload/h4402_appenc.pdf

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

Section: Appendix A
Mass Units and Mass per Unit Area Conversions

Mass

Multiply	by	To Obtain
ounces (oz)	28.3495	grams
grams (gm)	0.0353	ounces
pounds (lbs)	0.4536	kilograms
pounds (lbs)	453.6	grams
kilograms (kg)	2.2046	pounds
kilograms (kg)	0.0011	U.S. or short tons
metric tons or tonne (t)[a]	1	megagram (Mg)
metric tons or tonne (t)	2205	pounds
metric tons or tonne (t)	1000	kilograms
metric tons or tonne (t)	1.102	short tons
metric tons or tonne (t)	0.9842	long tons
U.S. or short tons, (ts)	2000	pounds
U.S. or short tons, (ts)	907.2	kilograms
U.S. or short tons, (ts)	0.9072	megagrams
U.S. or short tons, (ts)	0.8929	Imperial or long tons
Imperial or long tons (tl)	2240	pounds
Imperial or long tons (tl)	1.12	short tons
Imperial or long tons (tl)	1016	kilograms
Imperial or long tons (tl)	1.016	megagrams

Mass per Unit Area

Multiply	by	To Obtain
megagram per hectare (Mg ha^{-1})	0.4461	short tons per acre
kilograms per square meter (kg m-1)	4.461	short tons per acre
tons (short US) per acre (t ac^{-1})	2.2417	megagram per hectare
tons (short US) per acre (t ac^{-1})	0.2241	kilograms per square meter
kilograms per square meter (kg m-1)	0.2048	pounds per square foot
pounds per square foot (lb ft^2)	4.8824	kilogram per square meter
kilograms per square meter (kg m-1)	21.78	short tons per acre
kilogram per hectare (kg ha^{-1})	0.892	pounds per acre
pounds per acre (lb ac^{-1})	1.12	kilogram per hectare

Sources:
www.gordonengland.co.uk/conversion and
http://www.convert-me.com/en/convert/weight
and the Family Farm Series Publication, "Vegetable Crop Production" at
http://sfp.ucdavis.edu/pubs/Family_Farm_Series/Veg/Fertilizing/appendix.html

[a] The proper SI unit for a metric ton or tonne is megagram (MG) however "t" is commonly used in practice as in dt ha^{-1} for dry ton per hectare. Writers in the US also normally use "t" for short ton as in dt ac^{-1} for dry ton per acre, so noting the context in the interpretation of "t" is important.

Section: Appendix A
Distance and Velocity Conversions

1 inch (in)	= 0.0833 ft	1 centimeter (cm)	= 0.3937 in
	= 0.0278 yd		= 0.0328 ft
	= 2.54 cm		= 0.0109 yd
	= 0.0254 m		= 0.01 m
1 foot (ft)	= 12.0 in	1 meter (m)	= 39.3700 in
	= 0.3333 yd		= 3.2808 ft
	= 30.48 cm		= 1.0936 yd
	= 0.3048 m		= 100 cm
1 mile (mi)	= 63360 in	1 kilometer (km)	= 39370 in
	= 5280 ft		= 3281 ft
	= 1760 yd		= 1093.6 yd
	= 1609 m		= 0.6214 mile
	= 1.609 km		= 1000 m

1 in/hr = 2.54 cm/hr
1cm/hr = 0.3937 in/hr
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

Source:
Davis, S.C., S.W. Diegel and R.G. Boundy. 2008, *Transportation Energy Data Book: Edition 27* , ORNL-6981, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Section: Appendix A
Capacity, Volume and Specific Volume Conversions[a]

Capacity and Volume

1 U.S. gallon (gal)	=	3.785	liters (L)	1 liter (L)	=	0.2642	US gal
	=	4	US quarts (qt)		=	0.22	UK gal
	=	0.8327	UK gallon (gal)		=	1.056	US qt
	=	0.0238	barrels oil (bbl)		=	0.00629	bbl (oil)
	=	0.0039	cubic meters (m^3)		=	61.02	in^3
	=	0.1337	cubic feet (ft^3)		=	0.03531	ft^3
	=	231	cubic inches (in^3)		=	0.001	m^3
1 imperial (UK) gallon (gal)	=	4.546	liters	1 barrel (bbl) oil	=	158.97	L
	=	4.803	US qt		=	168	US qt
	=	1.201	US gal		=	42	US gal
	=	0.0286	bbl (oil)		=	34.97	UK gal
	=	0.0045	m^3		=	0.15897	m^3
	=	0.1605	ft^3		=	5.615	ft^3
	=	277.4	in^3			9702	in^3
1 cubic meter (m^3)	=	264.172	US gal	1 cubic foot (ft^3)	=	7.4805	US gal
	=	1000	L			28.3168	L
	=	1056	US qt			29.9221	US qt
	=	6.2898	bbl (oil)			0.1781	bbl (oil)
	=	35.3145	ft^3			0.0283	m^3
		1.3079	yd^3			0.037	yd^3
1 cubic centimeter (cm^3)	=	0.061	in^3	1 cubic inches (in^3)	=	16.3872	cm^3
1 Liter (L) dry volume	=	1.8161	US pint (pt)	1 US bushel	=	64	US pt
	=	0.908	US qt		=	32	US qt
	=	0.1135	US peck (pk)		=	35.239	L
	=	0.1099	UK pk		=	4	US pk
	=	0.0284	US bushel (bu)		=	3.8757	UK pk
	=	0.0275	UK bu		=	0.9700	UK bu
	=	0.0086	US bbl dry		=	0.3947	US bbl dry
1 barrel (dry)	=	13.1248	US pk	1 barrel (dry)	=	12.7172	UK pk
	=	3.2812	US bu		=	3.1793	UK bu

Specific Volume

1 US gallon per pound	=	0.8326	UK gal/lb	1 liter per kilogram	=	0.0997	UK gal/lb
(gal/lb)	=	0.1337	ft^3/lb	(L/kg)	=	0.1118	US gal/lb
	=	8.3454	L/kg		=	0.016	ft^3/lb
	=	0.0083	L/g		=	0.0353	ft^3/kg
	=	0.0083	m^3/kg		=	1	m^3/kg
	=	8.3451	cm^3/g		=	1000	cm^3/g

Sources:
Websites www.gordonengland.co.uk/conversion/power.html and www.unitconversion.org were used to make or check conversions.

[a] Forestry unit relationships are provided in table A.9.

Section: Appendix A
Power Unit Conversions

Per second basis

FROM	TO: hp	hp-metric	kW	kJ s^{-1}	Btu_{IT} s^{-1}	$kcal_{IT}$ s^{-1}
Horsepower	1	1.014	0.746	0.746	0.707	0.1780
Metric horsepower	0.986	1	0.736	0.736	0.697	0.1757
Kilowatt	1.341	1.360	1	1	0.948	0.2388
kilojoule per sec	1.341	1.359	1	1	0.948	0.2388
Btu_{IT} per sec	1.415	1.434	1.055	1.055	1	0.2520
Kilocalories $_{IT}$ per sec	5.615	5.692	4.187	4.187	3.968	1

Per hour basis

FROM	TO: hp	hp- metric	kW	J hr^{-1}	Btu_{IT} hr^{-1}	$kcal_{IT}$ hr^{-1}
Horsepower	1	1.014	0.746	268.5×10^4	2544	641.19
Metric horsepower	0.986	1	0.736	265.8×10^4	2510	632.42
kilowatt	1.341	1.360	1	360×10^4	3412	859.85
Joule per hr	3.73×10^{-7}	3.78×10^{-7}	2.78×10^{-7}	1	9.48×10^{-4}	2.39×10^{-4}
Btu_{IT} per hr	3.93×10^{-4}	3.98×10^{-4}	2.93×10^{-4}	1055	1	0.2520
Kilocalories $_{IT}$ per hr	1.56×10^{-3}	1.58×10^{-3}	1.163×10^{-3}	4187	3.968	1

Sources:
www/unitconversion.org/unit_converter/power.html and
www.gordonengland.co.uk/conversion/power.html were used to make conversions

Note: The subscript "IT" stands for International Table values, which are only slightly different from thermal values normally subscripted "th". The "IT" values are most commonly used in current tables and generally are not subscripted, but conversion calculators ususally include both.

Section: Appendix A

Small and Large Energy Units and Energy per Unit Weight Conversions

Energy Units

	TO:				
FROM:	MJ	J	k W h	Btu_{IT}	cal_{IT}
megajoule (MJ)	1	1×10^{6}	0.278	947.8	238845
joule (J)[a]	1×10^{-6}	1	0.278×10^{-6}	9.478×10^{-4}	0.239
Kilowatt hours (k W h)	3.6	3.6×10^{6}	1	3412	859845
Btu_{IT}	1.055×10^{-3}	1055.055	2.93×10^{-4}	1	251.996
$calorie_{IT}$ (cal_{IT})		4.186	1.163×10^{-6}	3.97×10^{-3}	1

Energy per Unit Weight

	TO:			
FROM:	$J\ kg^{-1}$	kJ kg-1	$cal_{IT}\ g^{-1}$	$Btu_{IT}\ lb^{-1}$
joule per kilogram ($J\ kg^{-1}$)	1	0.001	2.39×10^{-4}	4.299×10^{-4}
kilojoules per kilogram($kJ\ kg^{-1}$)	1000	1	0.2388	0.4299
calorieth per gram ($cal_{IT}\ g^{-1}$)	4186.8	4.1868	1	1.8
BtuIT per pound ($Btu_{IT}\ lb^{-1}$)	2326	2.326	0.5555	1

Large Energy Unit 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	2.52×10^{-8}	1	2.931×10^{-4}
Gigawatthours	3.6	860	8.6×10^{-5}	3412	1

Sources:

www.gordonengland.co.uk/conversion/power.html and www.convert-me.com/en/convert/power and www.unitconversion.org/unit_converter/fuel-efficiency-mass were used to make or check conversions

Davis, S.C., S.W. Diegel and R.G. Boundy. 2008. *Transportation Energy Data Book: Edition 27,* Appendix B.7. ORNL-6981, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Note:

The subscript "IT" stands for International Table values, which are only slightly different from thermal values normally subscripted "th". The "IT" values are most commonly used in current tables and generally are not subscripted, but conversion calculators ususally include both.

[a] One Joule is the exact equivalent of one Newton meter (Nm) and one Watt second.

Section: Appendix A
Most Commonly Used Biomass Conversion Factors

1 Quadrillion Btu's (Quad) = 1 x 10^{15} Btu = 1.055 Exajoules (EJ) = 1.055 x 10^{18} Joules (J)

1 Million Btu's (MMbtu) = 1 x 10^{6} Btu = 1.055 Gigajoules (GJ) = 1.055 x 10^{9} J

1000 Btu per pound x 2000 lbs per ton = 2 MMbtu per ton = 2.326 GJ per Megagram (Mg)

8500 Btu per pound (average heating value of wood) = 17 MMbtu per ton = 19.8 GJ per Mg

Section: Appendix A
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)

Source:
Davis, S.C., S.W. Diegel and R.G. Boundy. 2008. *Transportation Energy Data Book: Edition 27*, Appendix B.9. ORNL-6981, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Section: Appendix A
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

Source:

Davis, S.C., S.W. Diegel and R.G. Boundy. 2008. *Transportation Energy Data Book: Edition 27* , Appendix B.13. ORNL-6981, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Note: MPG = Miles per Gallon. L = Liters.

Section: Appendix A
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

Source:
Davis, S.C., S.W. Diegel and R.G. Boundy. 2008. Transportation Energy Data Book: Edition 27, Appendix B.14. ORNL-6981, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

[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.

Section: Appendix A
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

Source:
Davis, S.C., S.W. Diegel and R.G. Boundy. 2008. *Transportation Energy Data Book: Edition 27*, Appendix B.15. ORNL-6981, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Section: Appendix A
Cost per Unit Conversions

Multiply	by	To Obtain
$/ton	1.1023	$/Mg
$/Mg	0.9072	$/ton
$/Mbtu	0.9407	$/GJ
$/GJ	1.0559	$/Mbtu

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; 8600-12900 Btu/lb). However, nearly all kinds of biomass feedstocks destined for combustion fall in the range 15-19 GJ/tonne (6450-8200 Btu/lb). For most agricultural residues, the heating values are even more uniform – about 15-17 GJ/tonne (6450-7300 Btu/lb); the values for most woody materials are 18-19 GJ/tonne (7750-8200 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 2-30%. However, the bulk density (and hence energy density) of most biomass feedstocks is generally low, even after densification – between about 10 and 40% of the bulk density of most fossil fuels – although liquid biofuels have comparable bulk densities.

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 herbaceous 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 tables on the following 3 pages show some "typical" values or a range of values for selected compositional, chemical and physical properties of biomass feedstocks and liquid biofuels. Figures for fossil fuels are provided for comparison.

Sources for further information:

US DOE Biomass Feedstock Composition and Property Database.
http://www1.eere.energy.gov/biomass/feedstock_databases.html

PHYLLIS - database on composition of biomass and waste.
http://www.ecn.nl/phyllis/

Nordin, A. (1994) Chemical elemental characteristics of biomass fuels. Biomass and Bioenergy 6, 339-347.

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

Section: Appendix B
Characteristics of Selected Feedstocks and Fuels

		Cellulose (Percent)	Hemi-cellulose (Percent)	Lignin (Percent)	Extractives (Percent)
Bioenergy Feedstocks	Corn stover[a]	30 - 38	19 - 25	17 - 21	3.3 - 11.9
	Sweet sorghum	27	25	11	
	Sugarcane bagasse[a]	32 - 43	19 - 25	23 - 28	1.5 - 5.5
	Sugarcane leaves	b	b	b	
	Hardwood	45	30	20	
	Softwood	42	21	26	
	Hybrid poplar[a]	39 - 46	17 - 23	21 - 8	1.6 - 6.9
	Bamboo	41-49	24-28	24-26	
	Switchgrass[a]	31 - 34	24 - 29	17 - 22	4.9 - 24.0
	Miscanthus	44	24	17	
	Giant Reed	31	30	21	
Liquid Biofuels	Bioethanol	N/A	N/A	N/A	N/A
	Biodiesel	N/A	N/A	N/A	N/A
Fossil Fuels	Coal (low rank; lignite/sub-bituminous)	N/A	N/A	N/A	N/A
	Coal (high rank bituminous/anthracite)	N/A	N/A	N/A	N/A
	Oil (typical distillate)	N/A	N/A	N/A	N/A

Source:
Oak Ridge National Laboratory, Bioenergy Feedstock Development Program. P.O. Box 2008, Oak Ridge, TN 37831-6407 (compiled by Jonathon Scurlock in 2002, updated by Lynn Wright in 2008).

Notes:
N/A = Not Applicable.
[a]Updated using http://www1.eere.energy.gov/biomass/feedstock_databases.html
[b] Data not available.

Characteristics of Selected Feedstocks and Fuels (Continued)

		Ash %	Sulfur (Percent)	Potassium (Percent)	Ash melting temperature [some ash sintering observed] (C)
Bioenergy Feedstocks	Corn stover[a]	9.8 - 13 5	0.06 - 0.1	b	b
	Sweet sorghum	5.5	b	b	b
	Sugarcane bagasse[a]	2.8 - 9.4	0.02 - 0.03	0.73-0.97	b
	Sugarcane leaves	7.7	b	b	b
	Hardwood	0.45	0.009	0.04	[900]
	Softwood	0.3	0.01	b	b
	Hybrid poplar[a]	0.4 - 2.4	0.02 - 0.03	0.3	1,350
	Bamboo	0.8 - 2.5	0.03 - 0.05	0.15 - 0.50	b
	Switchgrass[a]	2.8 - 7.5	0.07 - 0.11	b	1,016
	Miscanthus	1.5 - 4.5	0.1	0.37 - 1.12	1,090 [600]
	Giant reed	5 - 6	0.07	b	b
Liquid Biofuels	Bioethanol	b	<0.01	b	N/A
	Biodiesel	<0.02	<0.05	<0.0001	N/A
Fossil Fuels	Coal (low rank; lignite/sub-bituminous)	5 - 20	1.0 - 3.0	0.02 - 0.3	~1,300
	Coal (high rank bituminous/anthracite)	1 - 10	0.5 - 1.5	0.06 - 0.15	~1,300
	Oil (typical distillate)	0.5 - 1.5	0.2 - 1.2	b	N/A

Source:

Oak Ridge National Laboratory, Bioenergy Feedstock Development Program. P.O. Box 2008, Oak Ridge, TN 37831-6407 (compiled by Jonathon Scurlock in 2002, updated by Lynn Wright in 2008).

Notes:

N/A = Not Applicable.

[a]Updated using http://www1.eere.energy.gov/biomass/feedstock_databases.html

[b] Data not available.

Characteristics of Selected Feedstocks and Fuels (Continued)

		Cellulose fiber length (mm)	Chopped density at harvest (kg/m^3)	Baled density [compacted bales] (kg/m^3)
Bioenergy Feedstocks	Corn stover[a]	1.5	b	b
	Sweet sorghum	b	b	b
	Sugarcane bagasse[a]	1.7	50 - 75	b
	Sugarcane leaves	b	25 - 40	b
	Hardwood	1.2	b	b
	Softwood	b	b	b
	Hybrid poplar[a]	1 - 1.4	150 (chips)	b
	Bamboo	1.5 - 3.2	b	b
	Switchgrass[a]	b	108	105 - 133
	Miscanthus	b	70 - 100	130 - 150 [300]
	Giant reed	1.2	b	b
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:

Oak Ridge National Laboratory, Bioenergy Feedstock Development Program. P.O. Box 2008, Oak Ridge, TN 37831-6407 (compiled by Jonathon Scurlock in 2002, updated by Lynn Wright in 2008).

Notes:

N/A = Not Applicable.

[a]Updated using http://www1.eere.energy.gov/biomass/feedstock_databases.html

[b] Data not available.

GLOSSARY

Agricultural Residue - Agricultural crop residues are the plant parts, primarily stalks and leaves, not removed from the fields with the primary food or fiber product. Examples include corn stover (stalks, leaves, husks, and cobs); wheat straw; and rice straw. With approximately 80 million acres of corn planted annually, corn stover is expected to become a major biomass resource for bioenergy applications.

Air dry - The state of dryness at equilibrium with the water content in the surrounding atmosphere. The actual water content will depend upon the relative humidity and temperature of the surrounding atmosphere.

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.

Alkaline metals - Potassium and sodium oxides (K2O + NaO2) that are the main chemicals in biomass solid fuels that cause slagging and fouling in combustion chambers and boilers.

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.

Avoided costs - An investment guideline describing the value of a conservation or generation resource investment by the cost of more expensive resources that a utility would otherwise have to acquire.

Baghouse - A chamber containing fabric filter bags that remove particles from furnace stack exhaust gases. Used to eliminate particles greater than 20 microns in diameter.

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).

Basal Area - The area of the cross section of a tree stem, including the bark, measured at breast height (4.5 feet above the ground).

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.

Biological oxygen demand (BOD) - An indirect measure of the concentration of biologically degradable material present in organic wastes. It usually reflects the amount of oxygen consumed in five days by biological processes breaking down organic waste.

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.

Biogasification or biomethanization - The process of decomposing biomass with anaerobic bacteria to produce biogas.

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.

Biomass processing residues - Byproducts from processing all forms of biomass that have significant energy potential. For example, making solid wood products and pulp from logs produces bark, shavings and sawdust, and spent pulping liquors. Because these residues are already collected at the point of processing, they can be convenient and relatively inexpensive sources of biomass for energy.

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.

Bound nitrogen - Some fuels contain about 0.1-5 % of organic bound nitrogen which typically is in forms of aromatic rings like pyridine or pyrrole.

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).

BTL - Biomass-to-Liquids.

Bulk density - Weight per unit of volume, usually specified in pounds per cubic foot.

Bunker - A storage tank.

Buyback Rate - The price a utility pays to purchase electricity from an independent generator.

By-product - Material, other than the principal product, generated as a consequence of an industrial process or as a breakdown product in a living system.

Capacity factor - The amount of energy that a power plant actually generates compared to its maxumum rated output, expressed as a percentage.

Carbonization - The conversion of organic material into carbon or a carbon-containing residue through pyrolysis.

Carbon Cycle - The carbon cycle includes the uptake of carbon dioxide by plants through photosynthesis, its ingestion by animals and its release to the atmosphere through respiration and decay of organic materials. Human activities like the burning of fossil fuels contribute to the release of carbon dioxide in the atmosphere.

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.

Catalyst - A substance that increases the rate of a chemical reaction, without being consumed or produced by the reaction. Enzymes are catalysts for many biochemical reactions.

Cellulose - The main carbohydrate in living plants. Cellulose forms the skeletal structure of the plant cell wall.

Chemical oxygen demand (COD) - The amount of dissolved oxygen required to combine with chemicals in wastewater. A measure of the oxygen equivalent of that portion of organic matter that is susceptible to oxidation by a strong chemical oxidizing agent.

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.

Cloud point - The temperature at which a fuel, when cooled, begins to congeal and take on a cloudy appearance due to bonding of paraffins.

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

Combustion turbine - A type of generating unit normally fired by oil or natural gas. The combustion of the fuel produces expanding gases, which are forced through a turbine, which produces electricity by spinning a generator.

Commercial species - Tree species suitable for industrial wood products.

Condensing turbine - A turbine used for electrical power generation from a minimum amount of steam. To increase plant efficiency, these units can have multiple uncontrolled extraction openings for feed-water heating.

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).

Construction and Demolition (C&D) Debris - Building materials and solid waste from construction, deconstruction, remodeling, repair, cleanup or demolition operations.

Coppicing - A traditional method of woodland management, by which young tree stems are cut down to a low level, or sometimes right down to the ground. In subsequent growth years, many new shoots will grow up, and after a number of years the cycle begins again and the coppiced tree or stool is ready to be harvested again. Typically a coppice woodland is harvested in sections, on a rotation. In this way each year a crop is available.

Cord - A stack of wood comprising 128 cubic feet (3.62 m3); standard dimensions are 4 x 4 x 8 feet, including air space and bark. One cord contains approximately 1.2 U.S. tons (oven-dry) = 2400 pounds = 1089 kg.

Corn Distillers Dried Grains (DDG) - Obtained after the removal of ethanol by distillation from the yeast fermentation of a grain or a grain mixture by separating the resultant coarse grain fraction of the whole stillage and drying it by methods employed in the grain distilling industry.

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 (dbh) 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.)

dbh - The diameter measured at approximately breast high from the ground.

Deck - (also known as "landing", "ramp", "set-out") An area designated on a logging job for the temporary storage, collection, handling, sorting and/or loading of trees or logs.

Denatured - In the context of alcohol, it refers to making alcohol unfit for drinking without impairing its usefulness for other purposes.

Deoxygenation - A chemical reaction involving the removal of molecular oxygen (O2) from a reaction mixture or solvent.

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

Dimethyl ether - Also known as methoxymethane, methyl ether, wood ether, and DME, is a colorless, gaseous ether with with an ethereal smell. Dimethyl ether gas is water soluble and has the formula CH3OCH3. Dimethyl ether is used as an aerosol spray propellant. Dimethyl ether is also a clean-burning alternative to liquified petroleum gas, liquified natural gas, diesel and gasoline. It can be made from natural gas, coal, or biomass.

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

Distillers Dried Grains (DDG) - The dried grain byproduct of the grain fermentation process, which may be used as a high-protein animal feed.

Distillers Wet Grains (DWG) - is the product obtained after the removal of ethyl alcohol by distillation from the yeast fermentation of corn.

Distributed generation - The Generation of electricity from many small on-site energy sources. It has also been called also called dispersed generation, embedded generation or decentralized generation.

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 types of 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.

Enzyme - A protein or protein-based molecule that speeds up chemical reactions occurring in living things. Enzymes act as catalysts for a single reaction, converting a specific set of reactants into specific products.

Ethanol (CH5OH) - 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 (E10 – 10% ethanol by volume).

Exotic species - Introduced species not native or endemic to the area in question.

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.

Farmgate price - A basic feedstock price that includes cultivation (or acquisition), harvest, and delivery of biomass to the field edge or roadside. It excludes on-road transport, storage, and delivery to an end user. For grasses and residues this price includes baling. For forest residues and woody crops this includes minimal comminution (e.g. chipping).

Fast pyrolysis - Thermal conversion of biomass by rapid heating to between 450 and 600 degrees Celsius in the absence of oxygen.

Fatty acids - A group of chemical compounds characterized by a chain made up of carbon and hydrogen atoms and having a carboxylic acid (COOH) group on one end of the molecule. They differ from each other in the number of carbon atoms and the number and location of double bonds in the chain. When they exist unattached to the other compounds, they are called free fatty acids.

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.

Fischer-Tropsch Fuels - Liquid hydrocarbon fuels produced by a process that combines carbon monoxide and hydrogen. The process is used to convert coal, natural gas and low-value refinery products into a high-value diesel substitute fuel.

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.

Flash pyrolysis - See fast pyrolysis.

Flash vacuum pyrolysis (FVP) - Thermal reaction of a molecule by exposing it to a short thermal shock at high temperature, usually in the gas phase.

Flow control - A legal or economic means by which waste is directed to particular destinations. For example, an ordinance requiring that certain waste be sent to a landfill is waste flow control.

Flow rate - The amount of fluid that moves through an area (usually pipe) in a given period of time.

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.

Forestry residues - Includes tops, limbs, and other woody material not removed in forest harvesting operations in commercial hardwood and softwood stands, as well as woody 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.

Forwarder - A self-propelled vehicle to transport harvested material from the stump area to the landing. Trees, logs, or bolts are carried off the ground on a stake-bunk, or are held by hydraulic jaws of a clam-bunk. Chips are hauled in a dumpable or open-top bin or chip-box.

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.

Fouling - The coating of heat transfer surfaces in heat exchangers such as boiler tubes caused by deposition of ash particles.

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.

Global Climate Change - Global climate change could result in sea level rises, changes to patterns of precipitation, increased variability in the weather, and a variety of other consequences. These changes threaten our health, agriculture, water resources, forests, wildlife, and coastal areas.

Global warming - A term used to describe the increase in average global temperatures due to the greenhouse effect.

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.

Green Power - Electricity that is generated from renewable energy sources is often referred to as "green power." Green power products can include electricity generated exclusively from renewable resources or, more frequently, electricity produced from a combination of fossil and renewable resources. Also known as "blended" products, these products typically have lower prices than 100 percent renewable products. Customers who take advantage of these options usually pay a premium for having some or all of their electricity produced from renewable resources.

Green Power Purchasing/Aggregation Policies - Municipalities, state governments, businesses, and other non-residential customers can play a critical role in supporting renewable energy technologies by buying electricity from renewable resources. At the local level, green power purchasing can mean buying green power for municipal facilities, streetlights, water pumping stations and other public infrastructure. Several states require that a certain percentage of electricity purchased for state government buildings come from renewable resources. A few states allow local governments to aggregate the electricity loads of the entire community to purchase green power and even to join with other communities to form an even larger green power purchasing block. This is often referred to as "Community Choice." Green power purchasing can be achieved via utility green pricing programs, green power marketers (in states with retail competition), special contracts, or community aggregation.

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.

Hammermill - A device consisting of a rotating head with free-swinging hammers which reduce chips or wood fuel to a predetermined particle size through a perforated screen.

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.

Hemicellulose — Hemicellulose consists of short, highly branched chains of sugars. In contrast to cellulose, which is a polymer of only glucose, a hemicellulose is a polymer of five different sugars. It contains five-carbon sugars (usually D-xylose and L-arabinose) and six-carbon sugars (D-galactose, D-glucose, and D-mannose) and uronic acid. The sugars are highly substituted with acetic acid. The branched nature of hemicellulose renders it amorphous and relatively easy to hydrolyze to its constituent sugars compared to cellulose. When hydrolyzed, the hemicellulose from hardwoods or grasses releases products high in xylose (a five-carbon sugar). The hemicellulose contained in softwoods, by contrast, yields more six-carbon sugars.

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 and grasses are typically in the 7,000 to 7,500 Btu/lb range.

Hog - A chipper or mill which grinds wood into an acceptable form to be used for boiler fuel.

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.

Hydrolysis - A process of breaking chemical bonds of a compound by adding water to the bonds.

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.

Invasive species - A species that has moved into an area and reproduced so aggressively that it threatens or has replaced some of the original species.

Iodine number - A measure of the ability of activated carbon to adsorb substances with low molecular weights. It is the milligrams of iodine that can be adsorbed on one gram of activated carbon.

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.

Landing - A cleared working area on or near a timber harvest site at which processing steps are carried out.

Legume - Any plant belonging to the leguminous family. Characterized by pods as fruits and root nodules enabling the storage of nitrogen.

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 dbh 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.

Lower heating value (LHV) - The potential energy in a fuel if the water vapor from combustion of hydrogen is not condensed.

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

Merchantable - Logs from which at least some of the volume can be converted into sound grades of lumber ("standard and better" framing lumber).

Methanol - A Methyl alcohol having the chemical formula CH30H. Also known as wood alcohol, methanol is usually produced by chemical conversion at high temperatures and pressures. Although usually produced from natural gas, methanol can be produced from gasified biomass (syngas).

Mill/kWh - A common method of pricing electricity in the U.S. 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.

Municipal solid waste (MSW) - Garbage. Refuse offering the potential for energy recovery; includes residential, commercial, and institutional wastes.

National Environmental Policy Act (NEPA) - A federal law enacted in 1969 that requires all federal agencies to consider and analyze the environmental impacts of any proposed action. NEPA requires an environmental impact statement for major federal actions significantly affecting the quality of the environment. NEPA requires federal agencies to inform and involve the public in the agency´s decision making process and to consider the environmental impacts of the agency´s decision.

Net Metering - For those consumers who have their own electricity generating units, net metering allows for the flow of electricity both to and from the customer through a single, bi-directional meter. With net metering, during times when the customer's generation exceeds his or her use, electricity from the customer to the utility offsets electricity consumed at another time. In effect, the customer is using the excess generation to offset electricity that would have been purchased at the retail rate. Under most state rules, residential, commercial, and industrial customers are eligible for net metering, but some states restrict eligibility to particular customer classes.

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) - Gases consisting of one molecule of nitrogen and varying numbers of oxygen molecules. Nitrogen oxides are produced from the burning of fossil fuels. In the atmosphere, nitrogen oxides can contribute to the formation of photochemical ozone (smog), can impair visibility, and have health consequences; they are thus considered pollutants.

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.

Oilseed crops - Primarily soybeans, sunflower seed, canola, rapeseed, safflower, flaxseed, mustard seed, peanuts and cottonseed, used for the production of cooking oils, protein meals for livestock, and industrial uses.

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 and 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.

Pour point - The minimum temperature at which a liquid, particularly a lubricant, will flow.

Prescribed fire - Any fire ignited by management actions to meet specific objectives. Prior to ignition, a written, approved prescribed fire plan must exist, and National Environmental Protection Act requirements must be met.

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.

Proximate analysis - An analysis which reports volatile matter, fixed carbon, moisture content, and ash present in a fuel as a percentage of dry fuel weight.

Public power - The term used for not-for-profit utilities that are owned and operated by a municipality, state or the federal government.

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.

Pulp chips - Timber or residues processed into small pieces of wood of more or less uniform dimensions with minimal amounts of bark.

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 (1015 Btu) = 1.055 exajoules (EJ), or approximately 172 million barrels of oil equivalent.

Reburning - Reburning entails the injection of natural gas, biomass fuels, or other fuels into a coal-fired boiler above the primary combustion zone—representing 15 to 20 percent of the total fuel mix—can produce NOx reductions in the 50 to 70 percent range and SO2 reductions in the 20 to 25 percent range. Reburning is an effective and economic means of reducing NOx emissions from all types of industrial and electric utility boilers. Reburning may be used in coal or oil boilers, and it is even effective in cyclone and wet-bottom boilers, for which other forms of NOx control are either not available or very expensive.

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.

Renewable diesel - Defined in the Internal Revenue Code (IRC) as fuel produced from biological material using a process called "thermal depolymerization" that meets the fuel specification requirements of ASTM D975 (petroleum diesel fuel) or ASTM D396 (home heating oil). Produced in free-standing facilities.

Renewable Fuel Standards - Under the Energy Policy Act of 2005, EPA is responsible for promulgating regulations to ensure that gasoline sold in the United States contains a minimum volume of renewable fuel. A national Renewable Fuel Program (also known as the Renewable Fuel Standard Program, or RFS Program) will increase the volume of renewable fuel required to be blended into gasoline, starting with 4.0 billion gallons in calendar year 2006 and nearly doubling to 7.5 billion gallons by 2012. The RFS program was developed in collaboration with refiners, renewable fuel producers, and many other stakeholders.

Renewables Portfolio Standards/Set Asides - Renewables Portfolio Standards (RPS) require that a certain percentage of a utility's overall or new generating capacity or energy sales must be derived from renewable resources, i.e., 1% of electric sales must be from renewable energy in the year 200x. Portfolio Standards most commonly refer to electric sales measured in megawatt-hours (MWh), as opposed to electric capacity measured in megawatts (MW). The term "set asides" is frequently used to refer to programs where a utility is required to include a certain amount of renewables capacity in new installations.

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.

Saccharification - The process of breaking down a complex carbohydrate, such as starch or cellulose, into its monosaccharide components.

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.

Slagging - The coating of internal surfaces of fireboxes and in boilers from deposition of ash particles.

Softwood - Generally, one of the botanical groups of trees that in most cases have needle-like or scale-like leaves; the conifers; also the wood produced by such trees. The term has no reference to the actual hardness of the wood. The botanical name for softwoods is gymnosperms.

Sound dead - The net volume in salvable dead trees.

Species - A group of organisms that differ from all other groups of organisms and that are capable of breeding and producing fertile offspring. This is the smallest unit of classification for plants and animals.

spp. - This notation means that many species within a genus are included but not all.

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.

Stand density - The number or mass of trees occupying a site. It is usually measured in terms of stand density index or basal area per acre.

Starch - A naturally abundant nutrient carbohydrate, found chiefly in the seeds, fruits, tubers, roots, and stem pith of plants, notably in corn, potatoes, wheat, and rice, and varying widely in appearance according to source but commonly prepared as a white amorphous tasteless powder.

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.

Stover - The dried stalks and leaves of a crop remaining after the grain has been harvested.

Sulfur Dioxide (SO2) - Formed by combustion of fuels containing sulfur, primarily coal and oil. Major health effects associated with SO2 include asthma, respiratory illness, and aggravation of existing cardiovascular disease. SO2 combines with water and oxygen in the atmosphere to form acid rain, which raises the acid levels of lakes and streams, affecting the ability of fish and some amphibians to survive. It also damages sensitive forests and ecosystems, particularly in the eastern part of the US. It also accelerates the decay of buildings. Making electricity is responsible for two-thirds of all Sulfur Dioxide.

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.

Switchgrass - Panicum virgatum, is a native grass species of the North American Praries that has high potential as an herbaceous energy crop. The relatively low water and nutrient requirements of switchgrass make it well suited to marginal land and it has long-term, high yield productivity over a wide range of environments.

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

Systems benefit charge - A small surcharge collected through consumer electric bills that are designated to fund certain "public benefits" that are placed at risk in a more competitive industry. Systems benefit charges typically help to fund renewable energy, research and development, and energy efficiency.

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

Thermal NOx - Nitrous Oxide (NOx) emissions formed at high temperature by the reaction of nitrogen present in combustion air. cf. fuel NOx.

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.

Total Solids - The amount of solids remaining after all volatile matter has been removed from a biomass sample by heating at 105°C to constant weight.

Transesterification - A chemical process which reacts an alcohol with the triglycerides contained in vegetable oils and animal fats to produce biodiesel and glycerin.

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.

Trommel screen - A revolving cylindrical sieve used for screening or sizing compost, mulch, and solid biomass fuels such as wood chips.

Tub grinder - A shredder used primarily for woody, vegetative debris. A tub grinder consists of a hammermill, the top half of which extends up through the stationary floor of a tub. As the hammers encounter material, they rip and tear large pieces into smaller pieces, pulling the material down below the tub floor and ultimately forcing it through openings in a set of grates below the mill. Various sized openings in the removable grates are used to determine the size of the end product.

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.

Ultimate analysis - A description of a fuel´s elemental composition as a percentage of the dry fuel weight.

Unmerchantable wood - Material which is unsuitable for conversion to wood products due to poor size, form, or quality.

Urban wood waste - Woody biomass generated from tree and yard trimmings, the commercial tree care industry, utility line thinning to reduce wildfire risk or to improve forrest health, and greenspace maintenance.

Volatile matter - Those products, exclusive of moisture, given off by a material as a gas or vapor, determined by definite prescribed methods that may vary according to the nature of the material. One definition of volatile matter is part of the proximate analysis group usually determined as described in ASTM D 3175.

Volatile organic compounds (VOC) - Non-methane hydrocarbon gases, released during combustion or evaporation of fuel.

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 chips - Wood chips produced by chipping whole trees, usually in the forest. Thus the chips contain both bark and wood. They are frequently produced from the low-quality trees or from tops, limbs, and other logging residues.

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.